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EMBODIED NAVIGATION OF COMPLEX PIANO NOTATION:
RETHINKING MUSICAL INTERACTION FROM A PERFORMER'S PERSPECTIVE

(«NAVIGATION INCARNÉE » DE LA NOTATION COMPLEXE POUR PIANO :

REPENSER L'INTERACTION MUSICALE SELON LA PERSPECTIVE DE L'INTERPRÈTE)

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στούς γονείς μου, Ευανθία και Παρασκευά / to my parents, Evanthía & Paraskevá

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Abstract

This thesis proposes a

a) *performer-specific paradigm* of
b) *embodied interaction with complex piano notation* from
c) an *expert user perspective*.

This paradigm, which I term *embodied navigation,* complements, extends and confronts the traditional composer-oriented paradigm of piano interpretation. At a second stage, the proposed paradigm serves as the basis for the development of methodologies and customized tools, dedicated to a range of applications for piano performance. Those applications include performance analysis, embodied interactive learning, contemporary composition, free improvisation, piano pedagogy and score-following.

The central dichotomy of a "performer-specific" in lieu of a "composer-oriented" paradigm; the notion of "embodied interaction" instead of "interpretation"; the term "complex notation" and the term "expert user", will be defined at length in the first part of this dissertation, in relation to developments in music composition and musicology after 1945.

In what follows, we provide some provisional opening definitions of the above-mentioned terms, to be developed later at length:

The PARADIGM is summarized under the rubric *embodied navigation of complex notation* and is informed by developments in Contemporary Performance Practice, Embodied Cognition, Human-Computer Interaction (HCI) and New Interfaces for Musical Expression (NIMEs, *nouvelles lutheries*).

The TOOLS include gesture capture, gesture analysis & gesture following tools, as well as interactive notation platforms, combined in the customized system called *GesTCom (Gesture Cutting through Textual Complexity).*

The PERFORMANCE ANALYSIS refers crucially to the whole learning trajectory, ranging from the first approach to a new piano work up to learning strategies and varied interpretations of the piece in future performances.

COMPLEX NOTATION is viewed in both historical and systematic ways, including not only intrinsic notational complexity, but also its opening-up to the electronic medium and to digitally extended notations and interactions: *intra-notational* and *interactive complexity*.

PERFORMER-SPECIFICITY refers crucially to methods of performative self-reflexivity. In the Anglo-Saxon world, those methods are often referred to as *practice-led* or *artistic* or *auto-ethnographic* research[1]. In the field of embodied music cognition, they would be identified with the notion of *first-person descriptions.* In the field of interaction they would correspond to *expert-user* studies. The subjective character of this research is counter-balanced by the use of OBJECTIVE DATA and EMPIRICAL METHODS in the form of *third-person descriptions*[2].

Let us now elaborate a bit more on the notions above.

PARADIGM: Interaction versus Interpretation; TUI versus UTI

This thesis proposes a performer-specific paradigm of embodied interaction with complex piano notation. This paradigm, which I term *embodied navigation,* extends and even confronts the traditional paradigm of textual interpretation. The latter assumes a linear and hierarchical process, whereby internalized understanding of the musical text is considered a prerequisite of instrumental technique towards

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[1] Term by Nicholas Cook to describe what in the Anglo-Saxon world is often termed "performance-led research" and in continental Europe "artistic research".

[2] After Marc Leman's definition in his *Embodied Music Cognition and Mediation Technology*, the MIT Press, Cambridge Massachusetts, 2008, p. 79.

personal interpretation. I call this classical paradigm *UTI: Understanding-Technique-Interpretation*. In lieu of that, I advocate for a dynamic, non-linear, embodied and external processing of music notation, even without the need for mental representations on the part of the performer, in the radical version of the model[3]. Music notation is theorized as a *state-space*[4] of *affordances*[5], to be navigated by the performer during a diachronic learning trajectory, ranging from the moment of first contact until on-stage interpretation. The pianist manipulates and processes notation through physical movement, as if it were an extension of her instrument. To take the metaphor even further, the pianist *touches notation* as much as she touches the instrument, and this action constitutes cognition. I term this conception of notation *TUI*: *a Tangible User Interface*[6], which is integral part of the instrument, enabling a composer-performer-listener communication based on *corporeal articulations*[7].

TOOLS: Gesture capture, Interactive notation

At a second stage, the proposed paradigm serves as the basis for the development of methodologies and customized tools for a range of applications, including: performance analysis, embodied interactive learning, contemporary composition, free improvisation, piano pedagogy and score-following. The tools in question include gesture capture, gesture analysis, gesture following and gesture interaction systems developed at IRCAM by the team *Interaction-Son-Musique-Mouvement*[8] (*MuBu for MAX*[9], *motionfollower*); the system of capacitive sensing *TouchKeys*[10] developed at Queen Mary University*;* as well as interactive notation platforms developed at

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[3] As will be several times underlined, such definition does not do away with mental representations altogether (for example, in softer versions of the model), but does consider them as *contingent* rather than *necessary* to the performance of complex music.

[4] Term in dynamic systems theory, indicating all the possible states of a dynamic system, that is a system changing in time.

[5] Term introduced by James Jerome Gibson in his ecological theory of visual perception, indicating the possibilities for action given the abilities of an organism in a given environment.

[6] The use of the term *Tangible User Interface* here is metaphorical. The original term, referring to real interfaces which enable tangible interactions, is employed in the field of Human Computer Interaction.

[7] Similarly, term by Marc Leman, Embodied Music Cognition, p. 77

[8] http://ismm.ircam.fr/ accessed 30.03.2018

[9] http://forumnet.ircam.fr/product/mubu-en/ accessed 13.04.2018

[10] http://www.eecs.qmul.ac.uk/~andrewm/touchkeys.html accessed 13.04.2018

GRAME, Lyon (*INScore*[11]). These systems are combined in a sensor-based environment for the processing of complex music called *GesTCom (Gesture Cutting through Textual Complexity).*

METHODOLOGY

The methodology consists in practice-led research, theoretical and empirical, informed by the performative and embodied turns in both composition and musicology, by the general field of embodied cognition, by Human-Computer Interaction (HCI) and by research around New Interfaces for Musical Expression (NIMEs, nouvelles lutheries[12]) and other related communities (MOCO[13], TENOR[14] and others).

The concept of *embodied navigation* emerges out of my personal, expert-user perspective and practice as a professional pianist for new music. Thus, it falls into the category of practice-led research and often features subjective, first-person descriptions. At the same time, this research is interdisciplinary. It is informed by a variety of theoretical tools, empirical methodologies and objective data, captured during my praxis at the custom-built studio for gesture capture of LabEx GREAM and at IRCAM. In that way, it reaches towards third-person descriptions.

STRUCTURE: Why, what, how and case studies

The thesis is articulated in four parts.

The **first part** addresses the following research question: *If and why does complex piano music necessitate an embodied interactive paradigm, which is different from the traditional interpretation paradigm.* I attempt to answer the question by looking at developments in both music creation and musicology. As far as music creation is concerned, I explore a wide range of postwar repertoire along three overlapping axes of complexity: intrinsic notational complexity; complex interactions with electronic

[11] http://inscore.sourceforge.net/ accessed 13.04.2018

[12] after the homonymous conferences and community: http://www.nime.org/ accessed 31.03.2018

[13] MOvement and COmputing: http://moco.ircam.fr/videos/ accessed 31.03.2018

[14] TEchnologies for music NOtation and Representation: http://tenor-conference.org/ accessed 31.03.2018

media; and the theatrical investment of the performative body in intermedia constellations[15]. I examine discourses by composers and performers under the light of theories and works by (indicatively): Martin Zenck ("corporeal subtext"), Harry Lehmann (*The digital revolution of new music*), Erika Fischer-Lichte (*Aesthetics of the performative*) and Stefan Drees (*Body-Media-Music*). In this way, notational complexity is defined as *intra-* and *inter-complexity*, pointing at different types of notational interactions with the body and the media. As far as musicology is concerned, I am looking at the performative turn in the English- (Cook/*Beyond the Score*), French- (Lalitte/*Analysis of 20th century music interpretation*) and German-speaking (Hiekel/*Musical embodiments*) academia. I identify a central aporia, namely the problematic ontological status of the musical score in performance-oriented methodologies. I am also looking at the embodied cognitive turn in systematic musicology, as epitomized by Marc Leman. I eventually suggest that the UTI ("Understanding-Technique-Interpretation") model is inadequate for these repertoires and results in the aporias witnessed in the performative turn.

The **second part** addresses the research question: *What could be the alternative to the UTI paradigm.* I show how developments in cognitive psychology resonate with the unseating of the UTI paradigm and I introduce my embodied and technology-mediated alternative under the name "embodied navigation of complex notation". This alternative is featuring a TUI (*Tangible User Interface*) conception of notation. I am drawing from both the general field of embodied cognition (Gibson's *ecological psychology*, Rowlands' *4E cognition*, Chemero's *radical embodied cognitive science* and Lakoff's *metaphor theory*), tending towards a radical anti-representationalist dynamic stance; as well as from the field of music embodied cognition, notably

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[15] We prefer the mid-1960s term "intermedia", introduced by the Fluxus artist Dick Higgins to describe various interdisciplinary art activities and convergence of genres, in lieu of the most commonly used "multimedia" and "mixed media". The reason is, that the latter is indissolubly associated today with technologically advanced media, while our research adopts a wider definition of technology, considering for example ancient forms of paper music notation as an equal interactive part of ancient media constellations (such as instruments and human bodies), while remaining obviously open to the highest degree of technological advancement of the media in question. Dick Higgins, Hannah Higgins, *Leonardo*, Volume 34, Number 1, February 2001, MIT Press, pp. 49-54

Leman's *mediation theory* and Godøy's notions of *co-articulation* and *sound-action chunks*, as well as other studies on musical gesture (for example, Guerino Mazzola's notion of *hypergestures*).

The **third part** addresses the research question: *How could the embodied navigation paradigm contribute to the development of interactive tools for the recording, analysis and integration of physical movement in augmented dynamic notational representations.* I introduce technological implementations of notation as gesturally controlled interface, by investigating: gesture modeling conducted at IRCAM by the ISMM (*Interaction-Son-Musique-Mouvement*) team; as well as the predecessor of the current *GesTCom* (*Gesture Cutting through Textual Complexity*) project, the *augmented violin project* (Kimura & Bevilacqua); interactive notations featured in the TENOR (*Technologies for Music Notation and Representation*) communities; new interfaces as presented by the NIME (*New Interfaces for Musical Expression*) community; and wider perspectives on movement modeling from the MOCO (*Movement and Computing*) community. Ideas and concepts from the history of HCI (*Human Computer Interaction*) will further frame the argument for a radical revision of the role of notation as extension of the instrument.

Eventually, the **fourth part** will put at work the concept of embodied navigation and the corresponding tools, in the form of case studies. A wide range of complex piano music, pertaining to all three axes of embodied interactive complexity will be examined: works by Iannis Xenakis and Brian Ferneyhough, which encapsulate the usual meaning of intra-notational complexity; post-complexity in the work of the French-German composer Mark Andre; action notation with theatrical consequences, in the work of the German-British composer Wieland Hoban; mixed music and live electronics, with a case study by the Greek composer Nicolas Tzortzis. This chapter will show hands-on examples of how the theoretical framework of embodied navigation and the prototype system called *GesTCom* (*Gesture Cutting through Textual Complexity*) may be used for the performance analysis, embodied interactive learning and composition of complex piano scores.

Résumé en français

« NAVIGATION INCARNÉE » DE LA NOTATION COMPLEXE POUR PIANO:

REPENSER L'INTERACTION MUSICALE SELON LA PERSPECTIVE DE L'INTERPRÈTE

Ce projet de recherche interdisciplinaire soutenu par le Labex GREAM de l'Université de Strasbourg et l'IRCAM porte sur l'interprétation de la notation musicale complexe pour piano selon une perspective « incarnée » et «située »[16] de l'interprète. Ses objectifs sont :

1) la modélisation d'un nouveau paradigme de l'analyse et de la représentation de la performance
2) la contribution au développement de systèmes interactifs pour l'apprentissage musical et la performance.

Cela inclut les champs de :

a) la pratique musicale et des esthétiques compositionnelles après 1945
b) la cognition musicale « incarnée » et « située »
c) des technologies de l'interaction multimodale.

Ce projet de recherche est motivé par mes compétences et activités de pianiste de musique contemporaine. Il introduit la notion de « navigation incarnée » dans le domaine de l'interprétation musicale, et il a déjà abouti à une application technologique en collaboration avec l'IRCAM (équipe Interaction-Son-Musique Mouvement – ISMM).

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[16] La traduction de « embodied » ici provient des textes français de référence dans le domaine des sciences cognitives et de la philosophie, notamment le domaine appelé « embodied and extended cognition ».

CONCEPT: Interaction versus Interprétation ;
TUI (*Tangible User Interface*)[17] versus UTI (*Understanding-Technique-Interpretation*)[18]

La thèse propose un paradigme d'interaction avec la notation musicale complexe pour piano selon une perspective « incarnée » et «située » de l'interprète. Ce paradigme, que je nomme *navigation incarnée*, s'oppose au paradigme traditionnel d'interprétation textuelle. Le paradigme traditionnel considère un processus de lecture linéaire et hiérarchique, selon lequel la compréhension et l'internalisation du texte musical sont les conditions préalables pour l'application de la technique instrumentale, permettant par la suite une interprétation personnelle. Je décris ce paradigme classique comme *UTI*, un acronyme désignant « Understanding – Technique – Interpretation » (« Compréhension – Technique – Interprétation »). À la place de ce paradigme, je propose de traiter la notation musicale comme un élément dynamique, non linéaire, et à la fois incarné et externalisé. La notation musicale est théorisée comme un espace d'états et de potentialités physiques (intitulées « affordances » dans la psychologie écologique de Gibson). Le pianiste manipule et traite la notation musicale par le mouvement physique, comme si elle faisait partie de l'instrument ou si elle en était une extension. En poursuivant cette métaphore, on peut considérer que le ou la pianiste *touche* la notation comme on touche l'instrument, et que cette action fait partie de la cognition. J'associe cette conception aux travaux des interfaces tangibles TUI[19] (en anglais pour « Tangible User Interface ») : la notation comme « interface utilisateur tangible » permet de reformuler les relations entre compositeur, interprète et auditeur comme relations fondées sur des articulations corporelles – une approche d'interaction incarnée proposée par Marc Leman.

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[17] Acronyme en anglais pour « Interface utilisateur tangible »

[18] Acronyme en anglais pour « Compréhension – Technique – Interprétation »

[19] L'emploi du terme « TUI » ici est métaphorique. Le terme original dans le domaine de l'interaction homme-machine signifie des interfaces réelles, qui permettent des interactions tangibles.

OUTILS : Captation du geste, Notation musicale interactive

Dans une deuxième phase, le paradigme proposé devient la base du développement d'outils adaptés au projet de la navigation incarnée et de diverses applications, incluant l'analyse de la performance, l'apprentissage incarné et interactif, la composition musicale et l'improvisation. Durant ce travail de thèse, des outils existants ont été intégrés sous la forme d'un système intitulé *GesTCom* (*Gesture Cutting through Textual Complexity*) – acronyme en anglais pour « Geste qui traverse la complexité textuelle ». Les divers éléments en question comprennent des outils pour l'interaction gestuelle, développés à l'IRCAM (*MuBu for Max*, *motionfollower*, *Modular Musical Objects*) ; le système de captation sur les touches du piano (*TouchKeys – A. McPherson*) ; le logiciel pour le codage des notations augmentées et interactives (*INScore - GRAME*) .

METHODOLOGIE : Recherche fondée sur la pratique[20], recherche théorique et empirique, informée par la musicologie de la performance, la *cognition incarnée* et l'interaction homme-machine.

Le concept de la *navigation incarnée* émerge de ma pratique personnelle en tant que pianiste professionnel et spécialiste de la musique contemporaine. Cette recherche peut être labélisée de recherche fondée sur la pratique (« practice-led research »). Elle est initiée par des expériences subjectives et des descriptions à la première personne, cependant, cette recherche, fortement pluridisciplinaire, est informée par des cadres théoriques et des méthodologies expérimentales. En particulier, elle est informée par la dimension désormais performative et incarnée de la musicologie, et plus généralement par le domaine identifié sous le terme de *cognition incarnée* dans les sciences cognitives, ainsi que par certains développements dans les domaines *de l'Interaction homme-machine* et des *nouvelles lutheries* (présentes dans la communauté *NIME*[21]*)*. Cette recherche est appuyée par des données expérimentales, captées lors mes séances d'enregistrement dans le studio du LabEx

[20] Traduction du terme anglais « practice-led research »

[21] *New Interfaces for Musical Expression*

Gream et à l'IRCAM. Les analyses objectives des données multimodales (gestuelles et sonores) font partie de cette recherche.

STRUCTURE : Pourquoi, quoi, comment ? Cas d'étude.

La thèse est articulée en quatre parties.

La première partie pose la question de savoir si le répertoire du piano contemporain complexe nécessite de considérer un paradigme d'interprétation incarné et interactif, qui serait différent du paradigme d'interprétation classique, et pourquoi. J'essaie de répondre à cette question en considérant la création musicale et la musicologie contemporaine après la Seconde Guerre mondiale. Concernant la création musicale, j'ai exploré trois axes de complexité : la complexité intrinsèque de la notation musicale (intitulée « intra-complexité ») et son « inter-complexité » dans les interactions complexes avec de nouveaux médias électroniques, ainsi que dans l'investissement théâtral du corps performatif sous la forme d'*intermedia*[22]*.* J'examine les réflexions des compositeurs et des interprètes dans le contexte des théories proposées notamment par Martin Zenck (« sous-texte corporel »), Harry Lehmann (*La révolution numérique de la musique*), Erika Fischer-Lichte (*Esthétique de la performance*) et Stefan Drees (*Corps-média-musique*). De cette façon, la complexité de la notation est définie en tant qu' *intra- et inter-complexité*, afin de décrire des interactions différentes entre le corps et les médias, en incluant la notation comme faisant partie des médias. Concernant la musicologie, je m'inspire de la partie performative de la recherche anglo-saxonne (Nicholas Cook, *Au-delà de la partition*), française (Philippe Lalitte, *Analyser l'interprétation de la musique du XXe siècle*) et allemande (Jörn Peter Hiekel, *Incarnations musicales*), et aussi de la partie dite « incarnée » de la musicologie systématique (Marc Leman, *La cognition incarnée de la musique*). Je me concentre sur une aporie centrale dans ces recherches, notamment l'ontologie problématique du texte musical dans les

[22] Terme anglais de Dick Higgins qui indique la convergence des plusieurs médias, qui ne sont pas nécessairement avancés technologiquement. Le terme est plus souvent remplacé par le terme « multimédia » ou « mixed media », qui porte cependant un accent technologique pas toujours désirable, par exemple dans le cas de la notation traditionnelle.

méthodologies orientées vers la performance. Finalement, je soutiens que le modèle classique d'interprétation n'est pas suffisant pour ces répertoires musicaux et que les apories des recherches sur la performance sont le résultat de ce paradigme.

Dans la deuxième partie je m'intéresse aux alternatives possibles au paradigme « Understanding – Technique – Interpretation ». Je soutiens que les développements dans les sciences cognitives sont parallèles aux apories de ce modèle et j'introduis une alternative incarnée et située sous le titre « navigation incarnée de la notation complexe », présentant ainsi une conception de la notation comme « Interface utilisateur tangible ». J'ai pris en compte les théories de la cognition incarnée, par exemple la « psychologie écologique » de James Gibson, la « Cognition 4 E » de Mark Rowlands, la « science cognitive incarnée radicale » de Anthony Chemero, et la « théorie des métaphores » de George Lakoff. Ma thèse s'inspire fortement de la direction la plus radicale et non-représentationnelle fondée sur la théorie des systèmes dynamiques, sans en exclure des variantes plus modérées. Je m'appuie aussi sur des théories issues de la cognition incarnée musicale, notamment la « théorie de la médiation » de Marc Leman, les concepts de « coarticulation » et « sound-action chunks » de Rolf Inge Godøy, ou d'autres concepts comme celui des « hypergestures » de Guerino Mazzola.

La troisième partie se concentre sur la réalisation du paradigme de la navigation incarnée par le développement d'outils interactifs pour l'enregistrement, l'analyse et l'intégration du geste dans des représentations musicales augmentées et dynamiques. J'ai introduit divers prototypes technologiques pour traiter la notation en tant qu'interface contrôlée par le geste. En particulier plusieurs éléments ont été utilisés provenant des travaux de la modélisation du geste conduite à l'IRCAM par l'équipe « Interaction-son-musique-mouvement » ; des systèmes de notations interactives présentées dans le cadre du colloque TENOR (Technologies for Music Notation and Representation); des nouvelles lutheries numériques comme celles présentées dans la communauté NIME. Enfin, mes travaux reposent sur certaines propositions issues de travaux dans le champ de l'interaction homme – machine, qui alimentent l'argumentation vers une réflexion du rôle de la notation comme extension de l'instrument.

Finalement, la quatrième partie met en œuvre le concept et les outils pour la navigation incarnée sous la forme de cas d'études. Un spectre du répertoire correspondant aux trois axes de complexité est analysé : l'intra-complexité de l'écriture par rapport aux œuvres de Iannis Xenakis, Brian Ferneyhough et Mark Andre ; notation des actions et théâtralité par rapport à l'œuvre du compositeur Wieland Hoban ; musique mixte par rapport à l'œuvre de Nicolas Tzortzis ; et création entre composition et improvisation dans une œuvre collective initiée par Panos Ghikas et Pavlos Antoniadis. Cette partie montrera des exemples pratiques sur la façon dont le paradigme de la *navigation incarnée* et les outils *GesTCom* peuvent être employés pour l'analyse, l'apprentissage et la création de la musique contemporaine pour piano.

PREMIÈRE PARTIE: LA COMPLEXITÉ ET SON INCARNATION PERFORMATIVE DANS LA MUSIQUE ET LA MUSICOLOGIE APRÈS 1945

1. Structure

La première partie pose la question de savoir si le répertoire du piano contemporain complexe nécessite de considérer un autre paradigme d'interprétation, *incarné* et *interactif,* qui serait différent du paradigme d'interprétation classique, et pourquoi.

La réponse à cette question est articulée en deux chapitres :

Dans le premier, on examine certains développements qui posent de nouvelles questions concernant la relation entre le corps musical et l'écriture complexe dans la création contemporaine. Dans le deuxième, on résume le tournant de la musicologie vers l'étude de l'interprétation (*performative turn* en anglais), et on présente quelques correspondances actuelles entre la musicologie systématique et les sciences cognitives.

La problématique de la création contemporaine par rapport à son interprétation est introduite par une étude du livre de Philippe Lalitte *Analyser l'interprétation de la* *musique du XX siècle*. Dans les deux premiers chapitres (*L'interprète face aux innovations de la création, L'interprète acteur de la création*), Lalitte résume les nouveaux rôles et défis performatifs et expose des thèmes centraux de ma thèse, par exemple la dialectique entre liberté et exactitude dans les notations hyper-détaillées.

Après cet aperçu général, la notation complexe est repensée selon trois axes de sa corrélation à l'incarnation de la performance, vers une définition multiple de la « complexité ».

Le premier axe se concentre sur les innovations de la création pour des instruments classiques. Il est fait référence ici aux propos de certains compositeurs sur les œuvres : Pierre Boulez, John Cage, Iannis Xenakis, Luciano Berio, Brian Ferneyhough, Helmut Lachenmann et Klaus Karl Hübler, et surtout aux réponses des interprètes comme David Tudor, Claude Helffer, Lori Freedman ou Franklin Cox. Les propos cités soulignent un rôle déterminant de l'incarnation pour la conception et la perception de l'écriture complexe.

Le deuxième axe se concentre sur les innovations par rapport à la musique électronique et les nouveaux médias dans la culture numérique. Des questions se posent sur une «esthétique désincarnée » autour de la musique acousmatique, la présence de l'interprète dans la musique mixte et les innovations dans les domaines de *nouvelles lutheries* et *interaction homme-machine*.

Le troisième axe concerne la considération du corps dans le théâtre musical et autres *intermedia*, où la création musicale se mélange à d'autres formes artistiques. Autrement dit, la musicologie et la création s'ouvrent vers les arts visuels, le théâtre, et affirment le caractère multimodal de la musique. Des correspondances entre la philosophie, la sociologie, l'anthropologie sont discutées, ainsi que les nouvelles significations du corps humain dans la pratique musicale.

La complexité de la notation musicale peut être définie en prenant compte des différents points suivants:

1) Elle est la règle principale d'évolution historique de l'écriture, en tant qu'abstraction d'actions performatives sous la forme d'une langue symbolique et « métonymique » (Philippe Manoury) en restant toujours incomplète sans la performance.
2) Elle est une caractéristique essentielle de la musique après la deuxième Guerre Mondiale, présente dans plusieurs styles contemporains. Par exemple : La musique sérielle et postsérielle, l'école « stochastique » autour de Xenakis, la musique spectrale, la 'musique concrète instrumentale' de Lachenmann, la musique mixte après Nono, et le « complexisme » (*Komplexismus*) comme défini par le compositeur allemand Claus-Steffen Mahnkopf et les compositeurs et compositrices de la « New Complexity ».
3) Elle est, encore plus particulièrement, l'idéologie de *Komplexismus* selon Claus-Steffen Mahnkopf, comme exprimée dans le mouvement de la « New Complexity ».
4) Chaque notation, complexe ou non, fait partie d'un système dynamique complexe de la performance. L'écriture est un médium et la notation n'est pas uniquement le véhicule privilégié d'une conception abstraite, mais elle participe dynamiquement à plusieurs formes d'interactions notamment avec l'interprète et l'instrument..
5) Cette dernière définition s'étend aux interactions avec des medias numériques, multimédia, et systèmes interactifs multimodaux. Les partitions dynamiques, le « retour augmenté » (*augmented feedback*) el le suivi de la partition sont des applications qui sont rattachées à cette définition de la « notation complexe ».

2. La complexité incarnée selon trois axes

Trois axes de complexité sont spécifiés par rapport aux différents rôles nouveaux du corps humain dans la musique contemporaine, notamment

1) Dans le dispositif traditionnel (acoustique)
2) Dans la musique électronique et la numérisation de la culture
3) Dans les supports intermedia.

a. Le dispositif traditionnel

Les innovations dans le « dispositif traditionnel », cette-à-dire le dispositif de la musique classique comme transféré vers la musique contemporaine, sont vues positivement par Philippe Lalitte dans son ouvrage *Analyser l'interprétation de la musique du XX siècle* et, par contre, comme en état de crise par le philosophe allemand Harry Lehmann dans son ouvrage *La révolution numérique de la musique* (*Die Digitale Revolution der Musik*). Selon Lehmann, la persistance de la musique contemporaine à reproduire les tropes de la musique classique, par exemple la notion de la musique absolue ou les instruments acoustiques et les notations traditionnelles, est signe de conservatisme et d'isolation dans un monde numérisé. Pour Lehmann, c'est uniquement la base technologique des outils numériques et l'esthétique multimodale, qui pourraient rafraîchir le paradigme de la musique contemporaine.

Une autre approche concernant le dispositif traditionnel est offerte par le musicologue allemand Martin Zenck. Selon Zenck, la performativité de la musique contemporaine et les innovations citées par Lalitte proviennent d'un phénomène plus profond et diachronique, également présent dans la musique classique. Il s'agit d'une inscription du corps musical dans le texte *avant l'acte* lui-même, c'est-à-dire un « sous-texte corporel ». L'acte de la création de la partition est dès lors ontologiquement « entouré » par des pratiques incarnées. De cette manière, Zenck montre comment la musique occidentale a toujours été relationnelle, multimodale, incarnée et interactive, par rapport au sous-texte corporel.

b. Premier axe : Intra-complexité

Le premier axe de la complexité incarnée est consacré à l'*intra-complexité*, cette-à-dire la complexité intrinsèque de la notation. Cette complexité dissimule le sous-texte corporel et invite des réponses interprétatives distinctes par rapport à la notation ancienne. L'intra-complexité est examinée dans une séquence de discours compositionnels et performatifs. Plus particulièrement, on examine les points suivants :

- L'idéologie de « désincarnation » et du cognitivisme présente dans l'article "Temps, notation et code" de Pierre Boulez, mais aussi les éléments d'une approche déconstructiviste par rapport au codage d'impossibilités pour la performance. Ce discours est central pour les développements ultérieurs de la « New Complexity ».
- La réponse intuitive et idiosyncratique du pianiste David Tudor pendant sa préparation de la *Deuxième sonate* pour piano de Boulez. Dans cette approche, on trace les premiers signes d'une pensée hors du dualisme code-performance. Cette pensée est reliée a l'esthétique d'Antonin Artaud dans son « théâtre de la cruauté ».
- Les applications de cette nouvelle approche performative dans *Music of Changes* de John Cage, où Tudor exprime pour la première fois la notion d'un « espace performatif » généré par la partition.
- Le sens de l'incarnation de la performance dans l'œuvre de Iannis Xenakis, soit comme défi, soit comme transparence, par des interprètes qui restent enfermés dans un discours dominé par le compositeur. Une exception est proposée par la clarinettiste Lori Freedman, qui approche l'œuvre de Xenakis comme une chance d'exploration primordiale du corps et d'instrument hors-temps.
- L'investissement esthétique de la notion de navigation dans la *Troisième Sonate* de Pierre Boulez, œuvre centrale pour la *forme ouverte*.
- La *virtuosité* par rapport à sa théâtralité et sa notation, liberté et exactitude, dans les *Sequenze* de Luciano Berio.
- L'analyse approfondie de la pratique de la performance dans la musique complexe par le violoncelliste et compositeur américain Franklin Cox. Celui-ci propose une approche globale concernant les limites de cette liberté interprétative dans la musique complexe et affirme le rôle du corps humain en s'appuyant sur les techniques de « découplage paramétrique » du compositeur allemand Klaus K. Hübler.

- Le texte de Hübler sur la stratification du corps humain au moyen de ces techniques de découplage instrumental et la notation en forme de tablature, originellement dans sa musique pour instruments à cordes.
- Une proposition théorique d'« intelligence somatique » évoquée dans la création du compositeur Brian Ferneyhough, malgré ses prédilections pour une approche cérébrale de l'interprète. Ce point est relié à ses textes sur la notation (« Aspects of notational and compositional practice »), la matérialité de la perception temporelle (« The tactility of time ») et la distinction entre la « figure » et le geste, où la figure assume un rôle d'énergie incarnée diffusée dans l'acte de la composition (« Il tempo de la figura »).
- Le rôle primordial de l'instrument dans l'esthétique d'une 'musique concrète instrumentale' de Helmut Lachenmann, ou la reconstruction négative de l'instrument en tant que champ d'expérience existentielle (« Existentielle Erfahrung ») qui a bien défini le développement des nouvelles techniques instrumentales et des notations de tablature.

c. Deuxième axe : Inter-complexité / Le médium électronique

Le deuxième axe est consacré à l'introduction du medium électronique dans la musique contemporaine et de ses conséquences pour la performance. Ces conséquences nécessitent une nouvelle approche des interactions entre l'écriture, le corps et les médias.

Les thèmes suivants sont abordés ici :

- L'histoire de la musique électronique. Ces histoires sont plutôt liées à des questions de composition mais pas d'interprétation. L'interprétation apparaît avec des innovations concernant les interfaces et la musique interactive, à partir des années 1990.
- La révolution numérique de Harry Lehmann et sa critique du dispositif traditionnel dans la musique contemporaine. Il propose que les instruments, les notations et l'esthétique soient repensés en une esthétique multimodale et

relationnelle, aussi par rapport au mouvement de *Neuer Konzeptualismus* en Allemagne.

- La problématique de désincarnation dans la musique acousmatique et dans la musique mixte, où l'interaction humain-machine introduit des problèmes de contrôle et de représentation du corps.
- La contribution à la notion de « partitions virtuelles » par Philippe Manoury, qui propose que les problèmes de la notation de la musique électronique soient en fait une extension des problèmes déjà posés par l'écriture traditionnelle, notamment le problème de la nature « métonymique » de la partition.

d. Troisième axe : Inter-complexité / Performativité

Le troisième axe autour de la complexité incarnée est consacré à la *performativité*. La performativité signifie la théâtralisation de la pratique musicale et l' objectivisation du corps humain dans des supports *intermedia*. Ces pratiques correspondent à l'extension de la musique et la musicologie vers des formes de convergence entre plusieurs genres artistiques. Ces considérations sont à en mettre en parallèle avec le concept de *sous-texte corporel* chez Martin Zenck ou avec les stratégies de visualisation, théâtralisation et sémantisation vers une esthétique relationnelle, mentionnées par Lehmann.

Ce chapitre aborde les conceptions du corps dans plusieurs autres domaines comme l'anthropologie, la sociologie et le théâtre. Dans l'anthropologie, par exemple, Courtine résume l'histoire des discours sur le corps au XX^{ème} siècle par cette phrase: "Where once we had subjects without bodies, now we find bodies without subjects", « Alors que nous avions des sujets sans corps, nous avons désormais des corps dépersonnalisés[23] »

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[23] In Courtine, Jean-Jacques, „The Body", in *The Columbia History of Twentieth-Century French Thought* , L. D. Kritzman (eds.), New York 2006, 166

Dans le champ de la sociologie, Fraser et Greco identifient huit domaines pour les conceptions du corps, qui sont plus ou moins parallèles aux considérations du corps dans la musique actuelle: ontologie de l'incarnation, corps et dispositifs de pouvoir, corps et identité, corps et normalité, extension du corps par la technologie, corps et éthique, corps et consumérisme.

Dans une "esthétique de la présence, et non de la représentation, de l'émergence, et non des apparences", Erika Fischer-Lichte donne une définition de la présence en tant que diffusion de l'image du corps: pour elle la présence radicale du corps est une forme d'énergie qui circule entre les spectateurs, plutôt qu'une abstraction visuelle du corps. Dans ce sens, plusieurs formes d'objectivisation du corps dans les musiques contemporaines sont moins incarnées que les formes de la musique ancienne. Ces formes investissent à une incarnation anti-visuelle et énergétique ; une transfiguration du corps dans le son.

Stefan Drees résume dans son livre *Corps-média-musique* les idées suivantes : il décrit l'évolution des discours sur le corps comme l'objectivisation à mettre en relation avec les sujets sociologiques et anthropologiques, tout en identifiant le corps avec son image. Il aborde la pratique vocale contemporaine comme une libération du corps, le théâtre musical de Mauricio Kagel et Dieter Schnebel, ou encore la création chez Nam Jun Paik ou Stellarc, où le corps devient un medium par lui même. Dès lors, il affirme la direction d'une externalisation et la médiatisation de l'incarnation musicale.

3. Musicologie de la performance et musicologie systématique incarnée

a. Musicologie de la performance

Depuis les années 1990, l'étude de la performance par rapport à la musique contemporaine devient centrale dans la musicologie historique et systématique. Dans la musicologie historique on parle d'un « *performative turn* », résumé par Philippe Lalitte, Eric Clarke et Ian Pace.

Je me suis intéressé aux apories de ce tournant vers la performance et, plus exactement, à la crise de la représentation dans les textes et les méthodes d'étude de l'interprétation. J'approche ces apories en comparant trois ouvrages représentatifs des musicologies anglo-saxonne, française et allemande, à savoir : *Beyond the Score. Music as Performance* (2013) de Nicholas Cook, *Analyser l'interprétation de la musique du XXe siècle* (2015) de Philippe Lalitte et *Verkörperungen der Musik. Interdisziplinäre Betrachtungen* (2014) de Jörn Peter Hiekel & Wolfgang Lessing.

Ces trois ouvrages expriment des points de vue critiques sur le rôle du texte musical dans la musicologie de la performance. J'ai tracé des dichotomies pertinentes (méthodes qualitatives versus quantitatives, données versus signification, technique versus culture, historique versus systématique, corps versus descripteurs et formation versus pratique) et j'ai proposé les réponses suivantes aux apories :

a) L'objectif n'est pas d'abolir la partition ou de l'étendre, mais plutôt de réintroduire la partition comme une partie dynamique dans un réseau d'interactions multimodales. Les formes des représentations d'aujourd'hui devraient devenir dynamiques et interactives, afin de projeter la fragilité et plasticité de l'acte musical.
b) Le concept de la partition est celui d'un *palimpseste* qui accumule de nouvelles couches d'information.
c) L'image du corps n'est pas suffisante pour comprendre les processus de *body schema* (Gallagher).
d) Il est nécessaire d'étudier longitudinalement l'évolution de la performance pendant les phases d'apprentissage et sur la scène.

b. Vers un paradigme incarné dans la musicologie systématique

Dans son livre *Embodied Music Cognition*, Marc Leman présente le développement d'un paradigme cognitif vers un paradigme incarné de la musicologie systématique.

Leman étudie les distinctions entre cognitivisme et cognition incarnée dans les fondations de la recherche musicale en Grèce classique, notamment les différences entre le paradigme cognitif de Pythagore, le paradigme d'Aristoxene orienté vers la perception et un paradigme d'interaction fondé sur la notion de *mimesis* chez Aristote et Platon.

Leman fait l'association entre le pythagorisme dans la musique et la recherche cognitiviste moderne, comme la recherche acoustique de Helmholz, les recherches autour des *Gestalts*, les applications de la théorie de l'information dans la musique, le concept d' *objet sonore* de Pierre Schaeffer etc.

La transition entre la modélisation computationnelle et la modélisation empirique est importante car elle permet d'aller vers une approche d'apprentissage machine plutôt que des modèles préfabriqués. Cependant, l'évolution vers une musicologie incarnée arrive avec des recherches autour du geste musical et en relation avec les technologies pour l'interaction, par exemple les capteurs qui se sont démocratisés à partir des années 2000.

4. Vers un paradigme d'interaction incarnée pour la notation complexe du piano

Les visions multiples du corps dans la musique complexe (et notation), ainsi que les apories concernant l'ontologie de la partition dans la performance ont alimenté notre approche vers un modèle interactif et incarné de la notation complexe.

Ma réponse a cette aporie est double : d'une part, la formalisation d'un paradigme d'*interaction* au lieu d'un paradigme d'*interprétation* ; et d'autre part le développement des outils qui intègrent la performance dans la partition et transforment la partition en une tablature malléable, dynamique et multimodale.

J'ai formalisé cette évolution comme le transfert d'un modèle appelé UTI (« Compréhension-Technique-Interprétation ») vers le paradigme TUI (« Interface Utilisateur Tangible »).

Dans les chapitres suivants, je vais a) fonder ce paradigme dans le domaine élargi de la cognition incarnée b) décrire les outils développés pour l'animation de la partition par la performance c) examiner des cas d'étude autour des trois axes de complexité incarnée.

DEUXIÈME PARTIE: LA COGNITION INCARNÉE COMME BASE D'UN MODÈLE DE NAVIGATION INCARNÉE DE LA NOTATION COMPLEXE

La recherche d'un paradigme incarné de la notation complexe est contextualisée dans le domaine des sciences cognitives. En particulier, je propose de substituer l'interprétation textuelle par l'interaction incarnée. Le texte musical est considéré comme un codage compositionnel qui conduit l'expérience incarnée, mais ce texte est également transformé lui même par la performance. Selon le paradigme d'interprétation textuelle, cette transformation est considérée comme mentale et les annotations du texte sont considérées comme des éléments externes. J'ai alors proposé d'étendre ces notions d'élements externes à un autre niveau, à l'aide d'outils d''enregistrement et de représentation de la performance pianistique et de l'apprentissage. Je décris ce processus comme une *navigation incarnée de la notation complexe*. Dans cette première phase, la navigation incarnée se manifeste par des tablatures multi-dimensionnelles, qui sont produites en jouant la partition originale. Dans la troisième partie, ce concept de navigation incarnée est développé expérimentalement sous la forme d'une plateforme interactive résumée par l' acronyme *GesTCom* (geste qui traverse la complexité textuelle – en anglais « gesture cutting through textual complexity »).

a. Structure de la deuxième partie

La deuxième partie est articulée comme suit :

Premièrement, je décris l'élaboration de mon modèle à travers mon travail de pianiste, en distinguant trois phases distinctes : a) une phase d'internalisation b) une phase de perception directe et d'annotation de la partition c) une phase d'utilisation des systèmes interactifs. Chaque phase est comparée au passage de l'internalisation à l'externalisation, ainsi qu'au changement de paradigme d'un cerveau *« calculatoire »* à une approche *incarnée* des sciences cognitives.

Deuxièmement, ces deux approches générales, l'internalisation et l' externalisation, sont identifiées dans deux textes classiques sur la technique et l'interprétation pianistique de Karl Leimer & Walter Gieseking et de György Sándor Sándor.

Troisièmement, je traite certains thèmes du domaine de la cognition incarnée, notamment la distinction entre les notions de *constitution*, *conceptualisation, remplacement* et les influences de la Théorie des Systèmes Dynamiques. Ces théories offrent des concepts et des outils fertiles pour élaborer mon concept de la navigation incarnée de la notation complexe.

Quatrièmement, la navigation incarnée de la notation complexe est décrite en trois versions :

Dans une version « douce », la performance nécessite l'intériorisation préalable de la notation complexe sous la forme de représentations mentales et elle est ergonomiquement facilitée par le corps, l'instrument et la partition en tant que structures extérieures.

Dans la version « dure », le texte musical est transformé par l'expérience incarnée de l'interprète et par des annotations externalisées, qui soutiennent le développement de représentations *orientées vers l'action* pendant l'apprentissage et la performance.

Dans la version « radicale », l'interaction avec le texte peut être expliquée et effectuée même sans représentations mentales de la notation, en tant que « danse dynamique » entre les éléments constitutifs du système : *corps -instrument-notation-systèmes interactifs*. Cette version n'invalide pas la représentabilité du processus, mais elle propose que, d'un point de vue épistémologique, les représentations mentales soient *contingentes* et pas nécessaires pour l'interaction dynamique.

Cinquièmement, la navigation incarnée de la notation complexe est présentée de façon très pratique à travers deux extraits de *Mists* pour piano seul de Iannis Xenakis, où certaines notions de la cognition incarnée, comme l'*affordance*, sont clarifiées. Les affordances sont visualisées en tant que tablatures multidimensionnelles pour la musique complexe.

Sixièmement, on établit des relations entre la navigation incarnée et certaines perspectives musicologiques sur le geste musicale et le mouvement.

Septièmement, l'aporie liée aux difficultés de représenter le paradigme dynamique, est résolue comme un passage possible des tablatures multidimensionnelles à des systèmes interactifs. Ce passage est mis en relation avec les distinctions entre des descriptions aux première, deuxième et troisième personnes, proposées par Marc Leman.

Les références générales dans le domaine de la cognition incarnée incluent la psychologie écologique de James Jerome Gibson's, la notion de *cognition 4-E* chez Mark Rowlands (d'après Shaun Gallagher), le fonctionnalisme d'Andy Clark et ses récentes idées sur le traitement prédictif du cerveau (*predictive processing*), les trois sujets de l'incarnation chez Lawrence Shapiro ("three themes of embodiment"), la *Science cognitive incarnée radicale* d'Anthony Chemero (*Radical embodied cognitive science*), qui fait référence à l'application de la théorie des systèmes dynamiques dans la cognition, et la théorie des métaphores conceptuelles de Lakoff et Johnson / Lakoff et Nuñez, dans la linguistique cognitive.

Je retiens certains éléments de ces théories pour la navigation incarnée de la notation complexe :

a) Une proposition pragmatique vers l'efficacité de l'apprentissage, qui simplifie la complexité textuelle au moyen des mouvements corporels.
b) Des notions concernant la modélisation dynamique du système de la performance selon la théorie des systèmes dynamiques.

c) Des notions concernant la conceptualisation linguistique du système, sous la forme du développement d'un discours *par* et *pour* l'interprète. Cette conceptualisation est fondée sur la théorie des *métaphores conceptuelles*.
d) Des notions concernant la fondation écologique de ces interactions par rapport aux concepts centraux de James Gibson, notamment la *perception directe*, le *couplage entre action et perception* ("action-perception coupling"), et *les affordances*.

En plus de ces références générales dans le domaine de la cognition incarnée, j'ai mis à profit plusieurs théories dans le domaine émergent de la musicologie systématique incarnée, et plus particulièrement la *théorie de médiation* fondée sur des *articulations corporelles* de Marc Leman et ses recherches actuelles sur les *interactions expressives* ; la théorie de coarticulation de Rolf Inge Godøy ; et la théorie mathématique des *hypergestures* proposée par Guerino Mazzola et Maria Mannone. Il faut également noter les recherches importantes de la communauté NIME sur la relation entre le geste et les nouvelles lutheries, et celles sur la modélisation probabiliste du geste conduites par l'équipe *Interaction-son-musique-mouvement* à l'IRCAM. Ces approches sont présentes dans la troisième partie de la thèse, à propos des systèmes interactifs.

Le modèle de la navigation incarnée de la notation complexe peut être considéré comme une extension des modèles de communication entre l'interprète et l'auditeur dans la relation entre le compositeur et l'interprète. Cette extension est inspirée par la théorie de la médiation de Marc Leman, mais avec une formulation utilisant les théories radicales et anti-représentatives d'Anthony Chemero.

b. *Internalisme* et *externalisme* dans la philosophie et les sciences cognitives

La distinction centrale à la base de la cognition incarnée est de différencier *internalisme* et *externalisme*. Après les années 1960, cette distinction s'est manifestée comme la différence entre des théories informatiques de la cognition et des théories incarnées, situées et dynamiques.

Selon le philosophe Marc Rowlands (2003, 2010), l'externalisme est un rejet double de la dichotomie cartésienne entre le corps et l'esprit : d'une part le rejet d'une substance d'esprit immatérielle, et d'autre part le rejet d'une localisation d'esprit dans le corps. Cette deuxième proposition forme la base de la cognition incarnée, opposée aux sciences cognitives classiques, où la dichotomie cartésienne entre le corps et l'esprit est reformulée comme dichotomie entre le corps et le cerveau.

Selon les sciences cognitives classiques, l'esprit est identifiable aux processus neuronaux. Ces processus sont décrits comme des processus « calculatoires » sur des représentations mentales, mettant en oeuvre des algorithmes spécifiques, d'où la métaphore du cerveau comme matériel informatique et de l'esprit comme logiciel qui effectue le traitement. Cette conception de l'esprit est développée par Hilary Putnam, Jerry Fodor and John Searle.

Au contraire, l'externalisme perçoit la cognition comme un phénomène non seulement localisé dans le cerveau, mais distribué entre le cerveau, le corps et l'environnement. Les processus mentaux sont en partie orientés vers l'action (*enactive*), situés (*embedded*), incarnés (*embodied*) et étendus (*extended*), d'où l'acronyme *4 E* de Mark Rowlands d'après Shaun Gallagher. Si on voulait décrire le cerveau selon un modèle informatique, il faudrait alors faire référence à la robotique plutôt qu'à des programmes informatiques.

Retournant dans le domaine de l'interprétation pianistique, je souligne la manifestation de cette dichotomie entre l'internalisme et l'externalisme dans deux œuvres centrales pour la pédagogie et l'interprétation : la *Technique du piano* de Karl Leimer et Walter Gieseking et *Sur le jeu du piano* par György Sándor. Les deux livres sont orientés vers une conception de la performance pianistique moderne et rationaliste. Cependant, je montre que le paradigme cognitif de Leimer-Gieseking est internaliste, tandis que le paradigme du Sándor est externaliste. Dans mon analyse je décris les conceptions de Leimer-Gieseking concernant la mémorisation et la technique pianistique selon les théories de Rowlands sur l'externalisation des processus mentaux. De même, je considère les propositions de Sándor sur l'interprétation pianistique comme une philosophie externaliste du piano, qui est décrite comme un système dynamique, incluant la gravité, le corps, l'instrument et la partition.

Dans un chapitre dédié, je résume des typologies et directions issues de la cognition incarnée selon les trois axes proposés par Lawrence Shapiro. Le premier axe fait l'hypothèse de la *constitution* des processus mentaux par des structures externes. Dans cet axe, j'inclus les distinctions de la cognition 4 E de Rowlands / Gallagher et les formes de fonctionnalisme d'Andy Clark. Le deuxième axe aborde le sujet de la *conceptualisation*, c'est à dire que les concepts et le language sont fondés sur l'expérience incarnée. L'information symbolique est considérée comme de l'*information présente dans l'environnement* (Rowlands) et comme des *métaphores conceptuelles*, selon Lakoff et Johnson. Cela est mise en relation avec la *fondation des symboles sur l'expérience* de Barsalou, et avec les avancées des neurosciences cognitives concernant le *couplage entre action et perception*, et les *neurones miroirs et canoniques*. Le troisième axe fait l'hypothèse du *remplacement*, cette-à-dire que les représentations mentales sont totalement remplaçables par des processus externes, comme une danse dynamique des éléments en faisant référence à la théorie des systèmes dynamiques. Je me réfère aux contributions de Thelen, Van Gelder, Beer, Brooks, et Chemero, et je propose des transferts de la méthodologie des systèmes dynamiques vers la performance pianistique de l'écriture complexe sous la forme de quatre propositions :

a) Par rapport à Rowlands, je soutiens l'externalisation de certains processus mentaux vers le corps, l'environnement, l'instrument et la partition, soit une façon plus efficace de gérer des informations denses dans la musique complexe.
b) Par rapport à la conceptualisation, j'avance l'argument que la notation complexe pourrait être considérée comme une structure externe de traitement des informations et que cela pourrait contribuer au développement d'un discours réellement fondé sur l'expérience des interprètes, complémentaire à celui des compositeurs.
c) Par rapport au remplacement, j'ai proposé que les concepts d'*émergence*, d'*auto-organisation* et de *dynamisme sans représentations* soient transférables au jeu du piano.

d) Par rapport à la psychologie écologique, j'ai adopté les trois principes d'*action directe*, *couplage perception-action* et d'*affordances* dans le modèle de la navigation incarnée.

c. Navigation incarnée

Dans ce chapitre 4, je présente le modèle de la navigation incarnée sous la forme de cinq propositions et de deux paradigmes en relation avec le cas d'étude central de la thèse, *Mists* pour piano seul par Iannis Xenakis.

Les propositions sont les suivantes :

a. L'interprétation d'une partition est définie comme une navigation incarnée dans un espace non-linéaire d'états et d'affordances notationnelles.

b. Les affordances sont localisées dans la partition comme des notations et des annotations.

c. L'extension de la notation comme partie d'instrument, ou leur amalgame, justifie la métaphore, selon laquelle l'interprète « touche la notation » de manière similaire au fait qu'il touche l'instrument, d'où la conception de la notation en tant qu'Interface Utilisateur Tangible (TUI) au lieu du paradigme UTI.

d. Ce paradigme est utilisé comme un processus de médiation entre la signification symbolique de la notation, les descripteurs de l'action et l'énergie physique de la performance.

e. Le geste pianistique est conçu comme une interface pour le traitement de la notation complexe, faisant partie d'un système dynamique incluant l'instrument.

Dans le chapitre 4, je aussi présente un cas d'étude, *Mists* de Xenakis, en considérant notamment le traitement de la distribution stochastique des mesures 45-46.

L'idée centrale est que pour un tel passage, l'internalisation ou la mémorisation lors de l'apprentissage ne se réalise pas, mais qu'il s'agit plutôt d'une externalisation sous la forme de couches d'informations correspondant aux articulations corporelles. Ces couches révèlent des affordances incarnées de la notation et sont représentées par différentes formes notationnelles. L'ensemble de ces traitements de la notation forme une tablature multidimensionnelle, dans laquelle on « navigue » pendant l'apprentissage. Les couches en question sont relatives aux mouvements des doigts, des poignets et des bras.

Dans une seconde phase, ces articulations, premièrement définies par les variations des hauteurs, sont couplées aux autres éléments, notamment les éléments rythmiques complexes, par les techniques de médiation (Cox 2002). Le couplage entre ces paramètres (hauteurs, rythmes) peut être représenté par des réseaux de connexions, et par une représentation des *nœuds d'intentionnalité* (*intentionality nodes*).

La caractéristique centrale de ces couches est qu'elles se situent *entre* la notation et l'action, représentant à la fois des contraintes physiques et symboliques, ainsi que des possibilités et des capacités pour l'action, caractérisées en tant qu'*affordances*.

Dans le chapitre 4, j'analyse aussi la différence entre ce concept de couches incarnées et des concepts classiques de la technique pianistique, ainsi que des concepts récents comme celui de la coarticulation dans la musicologie systématique, avec entre autres le concept de « sound-action chunks » de Rolf Inge Godøy.

La modélisation mathématique du modèle de navigation incarnée pourrait mettre à profit la théorie des *hypergestures* (*hyper-gestes*) de Guerino Mazzola et Maria Mannone. Quelques idées concernant cette traduction des coarticulations en *hyper-gestes* dans un espace topologique ont été énoncées par Maria Mannone.

L'ontogenèse d'une performance pourrait alors être défini comme la navigation dans cet espace des états, des affordances, suivant les lignes de continuité et de discontinuité selon quatre dimensions :

a) La *vue d'assemblage*, correspondant au premier passage dans cet espace notationnel. Il s'agit d'un assemblage spontané de mouvements et de positions produisant un premier modèle gestuel
b) La *stratification*, comme établissement des lignes de continuité dans ce modèle primordial, vers la continuité et la fluidité de la performance
c) La *résistance à la fluidité*, comme déchiffrage et projection des discontinuités du modèle
d) La *ligne de fuite*, comme passage en temps réel entre ces dimensions formées pendant l'apprentissage.

Donc, la navigation incarnée est considérée comme l'extension du mouvement corporel, elle-même un mouvement physique de haut-niveau, dans un espace d'états multidimensionnels. Elle correspond aux allers et retours entre des structures incarnées dans la partition fixe, qui produit un espace renouvelé et malléable. Il s'agit donc d'un mouvement entre l'apprentissage et la performance, entre des aspects détaillés et globaux et entre la fluidité de la performance et la résistance du déchiffrage. Les caractéristiques de cette navigation, comme la direction, la vitesse, la viscosité etc. conditionnent le résultat sonore d'une image notationnelle inintelligible. L'Interprétation peut être conçue comme ce « mouvement » plutôt que la reproduction d'une image fixe.

La méthodologie de la navigation incarnée reste cependant ouverte aux typologies de mouvement autres que celles des couches incarnées que j'ai proposées, comme par exemple, les méthodologies de technique pianistique proposée par G. Sándor ou le concept des *sound-action chunks* par Godoy. En fait, on peut étendre ce concept à des typologies extrêmement personnalisées et définies par le / la pianiste.

Dans le dernier chapitre , j'examine le paradigme de la navigation incarnée par rapport aux modèles de prédiction sensorimotrice proposés par Lehmann ; par rapports aux typologies du geste proposées par Jensenious et Gallagher ; et par rapport aux articulations corporelles comme modèles d'une communication entre compositeur et *performer*, faisant référence au modèle de Leman concernant la communication entre l'interprète et l'auditeur.

TROISIÈME PARTIE: SYSTÈMES INTERACTIFS POUR LA NAVIGATION INCARNÉE DE LA NOTATION COMPLEXE

a. Introduction

La troisième partie aborde des éléments théoriques du domaine de l'*interaction homme-machine (HCI)* dans la musique, et aussi du domaine plus large de l'interaction musicale. Dans un second temps ce chapitre examine le développement du système *GesTCom* (acronyme pour « Gesture Cutting through Textual Complexity ») pour le traitement et le contrôle de la notation complexe en temps-réel.

Deux apories sont centrales pour le passage des tablatures multidimensionnelles aux systèmes interactifs : la nature statique des tablatures, qui devraient être dynamiques afin de représenter un paradigme de navigation interactif; et l'introduction d'une représentation objective au lieu d'une représentation subjective ou intersubjective. Ce passage est également motivé par la disparition de frontières nettes entre les partitions et les instruments dans la communauté du domaine des *nouvelles lutheries* (NIME, *New Interfaces for Musical Expression*).

Sur la question de la fusion entre l'instrument et la partition, je présente de nouvelles interfaces, partitions graphiques, théories compositionnelles (Lachenmann, Hübler), modèles théoriques d'évolution (*ratchet effect*-Leman) et critères d'instrumentalité partagés par instruments, notations et logiciels (Veitl). Je rappelle également les définitions de l'instrument par Tanaka et le traitement de l'information par Rasmussen, ce qui permet d'opérer un changement de point de vue sur la notation.

b. Le système *GesTCom*

Le système *GesTCom* est conçu comme une évolution de systèmes existants. Il fut développé pendant une résidence de recherche musicale à l'IRCAM par Pavlos Antoniadis, Frédéric Bevilacqua (IRCAM, Equipe *interaction-son-musique-mouvement*), et Dominique Fober (GRAME, Lyon). Il inclut des systèmes pour la captation, l’analyse et le contrôle du geste pianistique en temps réel, aussi bien que des systèmes pour le traitement de la notation.

D’une part j’utilise la collection d’objets Max/MSP *MuBu* (multi-buffer) pour la synchronisation et l’analyse du son et du mouvement, et pour l’enregistrement et la reproduction des données multimodales ; un patch de suivi du geste en temps réel (*motionfollower*); et des patches pour l’intégration des données du système *TouchKeys* dans notre recherche.

D’autre part, la notation est représentée par le système *INScore*, qui permet la combinaison des objets graphiques, dont des signaux gestuels et sonores dans une représentation augmentée et interactive.

La méthodologie du système *GesTCom* repose sur quatre étapes :

a) L’enregistrement et la reproduction des données multimodales
b) L’analyse qualitative des données
c) Le traitement de notation hors ligne selon les données multimodales
d) Les applications en temps réel : intégration des représentations complexes au moyen d’*INScore* ; navigation de *nœuds d’intentionnalité* avec le *motionfollower* ; et contrôle des performances variables au moyen d’une tablature multimodale et interactive.

Enregistrements

Les enregistrements ont eu lieu à l’IRCAM pendant la résidence musicale et dans un studio que j’ai arrangé spécialement pour la captation du geste, dans le cadre du LabEx GREAM à l’Université de Strasbourg. J’ai enregistré un corpus de répertoire complexe, détaillé dans les annexes.

Le matériel pour les enregistrements multimodaux inclut :

- Un Disklavier E3 pour l’enregistrement des données MIDI.
- Un capteur *Xbox 360 Kinect* pour l’enregistrement de la vidéo.

- Deux microphones à condensateur *DPA ST 2011C,* reliés à une carte-son *RME Fireface UFX.*
- Deux capteurs de mouvement inertiels sans fil, réalisés par Emmanuel Fléty (IRCAM), qui mesurent trois dimensions d'accélération et trois axes de rotation (accéléromètres et gyroscopes). Les capteurs sont portés sur les poignets au moyen de bandes élastiques et ne sont pas invasifs pour la performance.
- Des capteurs capacitifs *TouchKeys* sur les touches du piano, pour la mesure de la position exacte des doigts sur les touches.

Le logiciel d'enregistrement des données et de synchronisation sont réalisés avec des modules Max / MSP adaptés pour le projet, en utilisant la collection d'objets *MuBu*.

Pendant les enregistrements, je me suis focalisé sur le processus général plutôt que sur le résultat de l'apprentissage. J'ai développé plusieurs scénarios d'interaction avec la musique complexe. Le premier scénario est appelé « déchiffrer » (sight-reading). Il s'agit d'un enregistrement qui produit le « modèle gestuel », à partir duquel sont fondées toutes les phases suivantes de la méthodologie. Les autres scénarios correspondent aux autres dimensions d'apprentissage (« scanning » pour l'assemblage, « stratification », « résistance » et « ligne de fuite » pour la performance).

Analyse qualitative des données

L'analyse qualitative des données est réalisée en deux étapes: la comparaison empirique des données gestuelles avec les données sonores et visuelles, et la comparaison avec les annotations implicites de l'interprète, afin de révéler des corrélations entre les descriptions à la deuxième et celles à la troisième personne. Le résultat de cette analyse est a) une syntaxe basique du geste pianistique, sous la forme d'une enveloppe *Préparation-Attaque-Déplacement-Extinction*, (inspirée du modèle de Jules Françoise); b) une extraction des « primitives gestuelles », qui correspondent aux couches incarnées (d'après Caramiaux).

Le patch pour la reproduction des données multimodales est équipé de plusieurs fonctions d'analyse et d'interaction. Il est possible de synchroniser les données, de les visualiser de plusieurs façons différentes, d'interagir avec des GUIs (interaction utilisateur graphique), et enfin d'appliquer des techniques d'apprentissage machine.

J'ai développé cette méthodologie autour d'un cas d'étude, l'œuvre *Lemma-Icon-Epigram* de Brian Ferneyhough. J'ai choisi spécifiquement cette pièce grâce à la proposition d'une approche d'apprentissage « descendante » ("top-down") émise par Ferneyhough lui-même. Il propose que l'apprentissage de cette pièce, particulièrement difficile, se fasse sur la base d'un « modèle gestuel » global, avant de se concentrer sur des détails. Mon hypothèse est que cet approche peut être rendue visible par les données gestuelles. L'apprentissage proposé par Ferneyhough (global-détails-global) pourrait être donc modélisé sur la base des données multimodales.

Traitement de la notation complexe sur la base des données multimodales

J'ai poursuivi trois directions :

1) simplification de la notation par rapport aux hauteurs
2) simplification de la notation par rapport au rythme
3) augmentation de la notation avec des objets graphiques et vidéos.

1) La simplification au niveau des hauteurs est effectuée au moyen des outils en forme de lignes de commande développés par Dominique Fober, utilisant le *Guido Engine*, une plateforme pour la génération algorithmique de notation musicale.

À partir d'un fichier MIDI d'une performance donnée, on peut produire une notation *réduite et proportionnelle* en quatre systèmes.

Cette notation permet de réduire les informations présentes dans les quatre étapes correspondant aux couches incarnées visibles dans les données. Chaque couche correspond à une élimination des notes qui ne sont pas nécessaires pour le mouvement. Dans la première étape, on organise le fichier en tant que poignets, dans une deuxième étape on supprime tous les notes sauf les notes jouées par les doigts 1 et 5 ; dans une troisième étape on garde uniquement une de ces deux notes, selon la direction du mouvement ; dans la quatrième étape, on élimine encore des notes entre les maxima et le minima de la trajectoire du bras.

La notation finale est réduite d'environ 80 % par rapport à la quantité de notes initiale. L'analyse de ce modèle gestuel permet de déduire une syntaxe, par rapport à la relation homodirectionnelle ou hétérodirectionnelle des mains (comme dans le contrepoint).

2) La simplification du rythme suit le même processus. J'ai en particulier mis en évidence des corrélations entre les couches incarnées et des structures rythmiques, par exemple il y a une correspondance entre la couche des poignets et la pulsation, la couche des bras et les mesures, la couche des doigts et les rythmes des subdivisions complexes. Selon cette corrélation, on peut simplifier les rythmes en un modèle métrique qui correspond au modèle gestuel. De plus, on peut créer une piste rythmique sur ce modèle gestuel.

3) L'augmentation multimodale de la notation est effectué au moyen du système *INScore* (Dominique Fober, GRAME). *INScore* est une plateforme de codage des partitions portantes plusieurs objets graphiques. La synchronisation avec la partition présuppose une relation (*mapping*) explicite entre le temps musical et l'espace graphique.

Toutes les représentations sont incarnées: elles sont produites par des actions performatives, elles représentent des données multimodales et sont contrôlables par le geste.

Interaction : *motionfollower*

L'étape suivante correspond à la mise en place d'applications interactives permettant d'aller au-delà de la représentation.

Le *motionfollower* permet de comparer, sur la base d'un modèle probabiliste, des mouvements en temps-réel. Dans une phase d'apprentissage du système on enregistre un geste, qui est utilisé en tant que modèle pour la comparaison d'un autre geste capté en temps-réel. Le système calcule la probabilité de ce geste à être similaire au geste enregistré. Cette similarité peut être visualisée par la progression d'un curseur qui se superpose au signal enregistré en temps réel.

J'ai inclut le *motionfollower* en utilisant le modèle gestuel issu de la notation: le modèle enregistré est comparé à des performances avec des variations de vitesse, d'articulation, ainsi que d'autres distorsions. Le système fonctionne si la segmentation originelle est définie de manière pertinente.

Interaction : tablature multimodale

Le système *GesTCom* permet également d'utilser le *motionfollower* pour contrôler *INScore*, donc produire une tablature multimodale contrôlée par le geste. Dans une première phase, l'interprète suit le curseur sur la tablature et se synchronise avec plusieurs éléments graphiques. Dans une deuxième phase, l'utilisateur peut reproduire ce mouvement avec des variations et distorsions, en gardant le modèle original gestuel.

Voici un résumé des contributions de la plateforme GesTCom par rapport au modèle de navigation incarnée:

Dans le domaine de la représentation musicale :

1) Enregistrement de plusieurs modalités (son, image, signaux gestuels, MIDI, données capacitives sur les touches).
2) Supervision de l'apprentissage.

3) Archivage et documentation de la trajectoire d'apprentissage longitudinale.
4) Représentabilité dynamique du paradigme de navigation au-delà des tablatures statiques.
5) Interaction en temps réel avec la notation complexe et sa transformation dans une interface.
6) Externalisation des processus mentaux internes pendant l'apprentissage.
7) Extension des pratiques de l'annotation traditionnelle.
8) Reproductibilité et communicabilité des processus d'apprentissage, qui pourrait s'intégrer à l'avenir dans des plateformes en ligne pour l'apprentissage collaboratif.

Dans le domaine de l'interaction:

1) Simplification de la notation complexe sur la base des données de la performance.
2) Proposition de multiples représentations et intégration du retour multimodal enrichi.
3) Contrôle gestuel de la notation symbolique et multimodal en temps réel.
4) Approche intégrative de la notation et de l'instrument dans une nouvelle interface.
5) Réalisation du paradigme radical de navigation incarnée, sans avoir recours à des représentations mentales.
6) Perception directe de la notation en tant que signal.
7) Entraînement, alignement et apprentissage sensorimoteurs réalisés lors d'interactions avec les informations symboliques.

QUATRIÈME PARTIE: CAS D'ÉTUDES

Dans les cas d'études suivants, j'explore les trois axes de complexité décrits dans la première partie : l' intra-complexité de la notation par rapport à *Mists* de Iannis Xenakis ; la complexité comme interaction entre des médias dans l'œuvre de Nicholas Tzortzis ; et la complexité par rapport aux actes théâtrales dans le cas de Wieland Hoban. Je présente aussi un cas d'étude de la musique post-complexe, *Contrapunctus* par Mark Andre.

Xenakis : *Mists*

Mists de Iannis Xenakis, une œuvre composée en 1980, expose les théories centrales du compositeur et offre un cas d'étude pertinent pour mettre en évidence des corrélations entre les structures algorithmiques profondes et leur incarnation dans la performance. J'ai structuré le chapitre comme suit :

a) Présentation de la corrélation entre les structures basiques de la pièce "hors-temps" par rapport à la texture et ses manifestations performatives
b) Analyse entre divers types de navigation et structures profondes "en-temps"
c) Analyse par rapport à la navigation pendant l'apprentissage, selon quatre scénarios d'interaction différents.

Andre : *Contrapunctus*

J'ai proposé une corrélation entre la notion de *Zwischenräume* (« entre des espaces ») et la navigation incarnée, et une analyse de l'œuvre, locale et globale, fondée sur la notion des *nœuds d'intentionnalité* et sur le système *GesTCom*.

Hoban : *when the panting STARTS*

Hoban a développé des techniques instrumentales peu orthodoxes, qui génèrent un théâtre physique de la notation complexe. J'ai analysé les techniques par rapport au paradigme de la navigation incarnée et au moyen des systèmes multimodaux.

Tzortzis : *Incompatible(s) V*

Cet œuvre présente un cas d'interaction multidimensionnelle concernant les trois axes (intra-complexité, medias, théâtre). J'ai analysé quatre formes d'interaction (homme-machine, électronique-acoustique, son-image, corps performatif – écriture compositionnelle) par rapport au paradigme de la navigation incarnée et au moyen des systèmes multimodaux.

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List of Acronyms

4E Cognition (embodied, extended, embedded, enactive): Term by Shaun Gallagher for the overview of multiple strands of the field in cognitive science metonymically referred to as “embodied cognition”.

GesTCom (Gesture Cutting through Textual Complexity): A sensor-based environment for the analysis, processing and real-time gestural control of complex piano notation through multimodal recordings.

HCI (Human Computer Interaction, alternatively CHI): The design, refinement, evaluation, analysis and use of interactive systems that involve computer technology for any kind of activity, and in particular, scientific research on any aspect of this topic.

INScore (Interactive Score): An environment for the design of interactive, augmented, live music scores.

IRCAM (Institut de Recherche et Coordination Acoustique/Musique): Leading research and artistic center for digital music technology in Paris.

ISMM (Interaction-Son-Musique-Mouvement): Research team at IRCAM dealing with real-time interactions between sound and movement.

LabEx GREAM (Laboratoire d’Excellence, Groupe de Recherches Expérimentales sur l’Acte Musical): Laboratory of Excellence at the University of Strasbourg focusing on the study of musical performance.

MOCO (Movement and Computing): A relatively new community of researchers and practitioners that researches the computer-assisted modelization of physical movement and its implementation in interactive systems for a wide range of applications (music, dance, rehabilitation etc.)

MuBu (Multi-Buffer): Library of Max / MSP objects for multimodal analysis of sound and motion, interactive sound synthesis and machine learning

NIME (New Interfaces for Musical Expression): International community of new interface designers, performers and researchers, after the homonymous conferences and since 2001

TENOR (Technologies for Music Notation and Representation): A relatively new community of researchers and practitioners that focuses on technologically advanced forms of music notation and representation, including dynamic, interactive and augmented notations.

TUI (Tangible User Interface): The proposed paradigm of performer-specific embodied interaction with complex notation, an alternative to UTI. Instead of an algorithmic arrangement of *Understanding*, *Technique* and *Interpretation*, performers process notation in an embodied way, through active interaction with the score and the instrument. Understanding, technique and interpretation are shaped in a non-linear way by this interaction. Metaphorically speaking, performers touch notation and transform it into embodied structures which are dynamic, malleable, and interactive. The literal use of the term refers to a community in the wider field of Human Computer Interaction that designs and researches interfaces for tangible interaction.

UTI (Understanding-Technique-Interpretation): The hegemonic paradigm of interaction with a score. Interaction takes the form of an algorithm: First, the performer comprehends the notation and the composer's intentions (*Understanding*). Second, this comprehension enables the employment of instrumental (or vocal) technique for the physical execution of the notation (*Technique*). Third, the performer adds elements of personal expression, usually pertaining to timing, dynamics and articulation (*Interpretation*).

Introduction

Ὁ κόσμος νὰ γίνει εἰκόνα. Αὐτὴ θὰ εἶναι ἡ τελευταία ζωὴ τῶν ἀνθρώπων νὰ τοὺς σκεπάσει μιὰ εἰκὸνα[24].

[24] "The world turning into image. This shall be the last life of humans, to be covered by an image", Giorgos Cheimonàs, *I Chtistes* (*The Builders*), Athens: Ekdòsis Kastanioti, 2005, p. 345

Despite the astonishing heightening of technical standards in musical performance, its premises remain heavily attached to an interpretative model of the past. This model privileges compositional abstract thinking, which is represented as musical notation, to be further „sonified“ by the performer. Such hierarchy theorizes performance as a transparent channel between the sender-composer and the receiver-listener. This model of musical communication seems to ignore recent developments in aesthetics, cognitive science and computer music technology. Our interdisciplinary research attempts to integrate perspectives from those fields into a revision of interpretation today, focused on piano performance of the most complex repertoire. In particular, the emphasis on performativity and embodiment in modern aesthetics, the importance of action in cognition and the field of computer music interaction, form the background of this research.

Developments in contemporary composition have problematized notation as a transparent interface linking compositional intentionality to performative response. Paradigmatic in this respect is the work of Brian Ferneyhough, which programmatically employs complex notation for inviting multiple interpretational strategies and sonic results, as described in his *Collected Writings*[25]; or the work of Iannis Xenakis, whereby extremes of physicality function as a performer-specific perspectival point to complex notation, as shown in recent scholarship around Xenakis performance[26]. In such cases, the traditional performative paradigm seems to be sabotaged: *Understanding* the notation cannot anymore function as the

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[25] B. Ferneyhough: Aspects of Notational and Compositional Practice. In J. Boros & R. Toop (eds.) *Brian Ferneyhough-Collected Writings*, pages 2-13. Routledge, London and New York, 1995.

[26] Sharon Kanach (ed.), *Performing Xenakis*, The Iannis Xenakis Series vol. 2. Hillsdale, Pendragon Press, New York, 2010 ; Pavlos Antoniadis: Physicality as a performer-specific perspectival point to I. Xenakis's piano work. Case-study Mists. In: Proceedings of the I. Xenakis International Symposium 2011, Goldsmiths University, London. https://www.gold.ac.uk/media/documents-by-section/departments/music/07.3-Pavlos-Antoniadis.pdf accessed 11.05.2018

prerequisite of instrumental *technique* towards an expressive *interpretation*. Our research attempts to offer an embodied, technology-mediated and performer-specific alternative to this linear arrangement of *Understanding-Technique-Interpretation*. We refer to it as the UTI aporia[27].

The UTI aporia echoes a general performative turn in musicology, theatrology and cultural studies. A wholly new set of notions (*event* instead of *work*, *presence* instead of *representation*) and, more importantly, the notions of *embodiment* and *materiality,* become central for a new aesthetics of the performative, as in the work of Erika Fischer-Lichte[28].

Despite this performative turn and the move away from what Philippe Lalitte calls *graphocentrisme*[29], the musical praxis and musicological discourse alike still remain significantly oriented towards works and composers. Performative self-reflexivity remains muted and, even when it takes place in the context of practice-led research, it very often echoes a *paradigm* (in the sense of the philosopher Thomas Kuhn[30]) or *pre-theoretical picture* (in the sense of the philosopher Mark Rowlands[31], after Wittgenstein), which privileges the activity of the composer and its outcome, musical

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[27] "Aporia" denotes in philosophy a puzzle or state of puzzlement and in rhetorics a rhetorically useful expression of doubt. It will be used throughout the thesis with its current meaning in English: "a logical impasse or contradiction".

[28] E. Fischer-Lichte, *Ästhetik des Performativen*. Suhrkamp Verlag, Frankfurt am Main, 2004

[29] « Ce graphocentrisme a inhibé la capacité de l'analyse à conceptualiser la musique comme un art du son, un art du geste, un art de la scène, un art qui se nourrit d'interactions sociales, bref un art vivant », p. 9 in Philippe Lalitte, *Analyser l'Interprétation de la Musique du XXe Siècle. Une analyse d'interprétations enregistrées des Dix pièces pour quintette à vent de György Ligeti,* Hermann, Paris, 2015.

[30] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 3rd ed. Chicago, IL: University of Chicago Press, 1996 (original 1962).

[31] "The task of this book is to unseat not a particular philosophical or psychological theory, but a certain pre-theoretical conception or picture of the mind. This picture is prior to theory in that it is what guides theory construction and thus lends coherence and unity to the experimental practices and procedures judged relevant to the conformation or falsification of particular theories within its domain. The notion of a pre-theoretical picture, then, corresponds largely to what Kuhn (1970) has, famously, labeled a paradigm.", in Mark Rowlands,*The Body in Mind. Understanding Cognitive Processes*, Cambridge University Press, 2004, p. 8

works. Most indicative of this discrepancy is performers' inability to think through their bodies and articulate *performer-specific discourses*, which would thematize their main interface to musical works: their embodied interaction with instruments and scores alike.

The general objective of this dissertation is then to address issues of performative self-reflexivity in the under-represented and under-defined field of complex piano music. It is to offer a first-person perspective, while at the same time engaging with third-person media and techniques, in the form of multimodal recordings. It assumes that complexity constitutes a constant in the history of notation, with specific new meanings assigned to it in the post-war era through three overlapping developments: notational complexity in the music for classical instruments; the introduction of the electronic medium; and the multimodal and intermedia extensions of music into other art-forms. Those developments will constitute three axes for a brief history of embodiment in post-war music, through which the notion of complex notation will be considerably revised. Those developments problematize the interface of notation itself and pave the way to a different understanding of the role of the performer, in a revision of the classical UTI paradigm of interpretation. We will offer elements for an alternative model of communication based on embodied articulations, in a conception of notation under the rubric *TUI: notation as a Tangible User Interface*, through the concept of embodied navigation.

The case for a performer-specific theory and praxis finds further defense in the field of *embodied and extended cognition*. This interdisciplinary field has been embraced in recent years by music psychologists, who deal with embodiment, mediation, movement and gesture[32]. The underlying thesis of these studies is that (music) cognition is not reducible to its neural implementation, but is rather distributed among the brain, the body and the environment. This thesis ontologically upgrades gesture and movement into equal components of cognition, potentially resulting in genuine

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[32] Indicatively : M. Leman, *Embodied Music Cognition and Mediation Technology*. MIT Press, Cambridge, 2008 ; R. I. Godøy & M. Leman (eds.) *Musical Gestures: Sound, Movement and Meaning*. Routledge, New York, 2009 ; E. F. Clarke: *Ways of Listening: An Ecological Aproach to the Perception of Musical Meaning*. Oxford University Press, Oxford, 2005.

reflection on the UTI aporia. Some basic sources in the field, including James Jerome Gibson's "Urtext" *The Ecological Approach to Visual Perception*[33]. The enhanced role of action in music cognition, in combination with the increasing availability of low-cost sensors and interfaces in the turn of the 21st century, become the central parameters in the emerging field of computer music interaction, as documented, indicatively, in Jorge Sollis' and Kia Ng's *Musical Robots and Interactive Multimodal Systems*[34]. Gestural data can today effectively be captured, analyzed and mapped upon other modalities, paradigmatically sound, as the work of ISMM team at IRCAM demonstrates. This fact opens the way for novel interaction concepts and for the design of interactive multimodal systems and musical robots. The process can be closely tracked down in the context of the NIME (New Interfaces for Musical Expression) conferences since 2001. Those developments need to be democratized for the larger community of classically trained performers. Complementary to gesture and movement interaction, of special importance for this research is the field of computer music representation, in particular platforms for interactive augmented musical scores. Those platforms provide a link between computer music representation and interaction, to be further explored.

The concept of *embodied navigation* attempts to offer an embodied and mediated performer-specific alternative to the UTI paradigm. Instead of a strictly linear arrangement of its formants -understanding notation, then employing purposefully technique and then allowing, in the end, for expressive interpretation-, it proposes the conceptualization of learning and performance as embodied *navigation* in a non-linear notational space of *affordances*[35]: The performer moves inside the score in several dimensions and manipulates in real-time the elements of notation *as if* they were physical objects, with the very same gestures that s/he actually performs. This manipulation forms indispensable part of the cognitive processes involved in learning and performing and transforms the notation. This transformation can be represented as a multilayered tablature. In a nutshell, embodied navigation signifies the perpetual

[33] J. J. Gibson: *An Ecological Approach to Visual Perception.* Psychology Press, London, 1986.

[34] J. Solis & K. Ng (eds.): *Musical Robots and Interactive Multimodal Systems*. Springer-Verlag, Berlin Heidelberg, 2011.

[35] Both terms, *navigation* and *affordance*, are direct references to James J. Gibson's work.

movement in-between embodied representations of the immobile score-space. This movement produces a new and infinitely malleable space. The movement functions between learning and performance, between detailed and global aspects and between the continuity of performance and the resistance of decoding. The qualities of this navigation – its directionality, its speed, its viscosity etc. – define what can sound out of the initial notational image. Interpretation consists in this diachronic movement, rather than in the reproduction of a fixed sound-image.

The notion of embodied navigation draws from developments in the field of embodied and extended cognition, such as: the notion of the manipulation of *external information-bearing structures* (here notation), and of action in general, as constitutive of cognition[36]; the notion of self-organized systems and emergent behaviors (the system embodied mind, instrument, notation would be seen as such) from dynamic systems theory[37]; the notions of navigation and affordance from Gibson's ecological psychology as cited above; the notion of conceptualization based on embodied experience, from cognitive linguistics[38].

This concept's advantages over the UTI paradigm are the following: a) It is based on individual performative embodied experience, thus it might be a better metaphor for performers (performer-specificity); b) it directly involves notation in "dynamic visuo-gestural formations", unlike most studies of gesture which assume a static notation; c) it is not incompatible with analytical approaches and compositional intentions, which are fed as further dimensions and priorities into the system; d) it can account for the multivalent sound-images of postwar music, but could also be employed for earlier and simpler music as well. Complex post-1945 music serves merely as a point

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[36] As in : Mark Rowlands, *The New Science of the Mind: from extended mind to embodied phenomenology*, MIT Press, Massachusetts, 2010 ; Andy Clark, *Supersizing the Mind: Embodiment, Action, and Cognitive Extension*, Oxford University Press, New York, 2011 ; Lawrence Shapiro, *Embodied Cognition*, Routledge, London and New York, 2011.

[37] An overview of dynamic systems theory applications to cognition, from Rodney Brooks' subsumption architecture in robotics to the work of Esther Thelen, Tim van Gelder, Randal Beer and others, is offered in part two of this dissertation.

[38] Indicatively in: George Lakoff and Mark Johnson, Philosophy *in the Flesh: The Embodied Mind and its Challenge to Western Thought*, Basic Books, New York, 1999.

of departure, because of the explicit problematization of *understanding* and subsequently of *technique* and of *interpretation*.

PART ONE:
EMBODIMENT AND COMPLEXITY IN POST-1945 MUSIC AND MUSICOLOGY

1. Introduction

This chapter attempts to frame and respond to the research question:

If and why do we need a new performer-specific paradigm for complex music, which is self-reflective and based on both embodied interaction with instruments and on a renewed vision of notation as a medium or interface.

To this purpose, this section is looking at developments in both

A. Musical Creation (chapter 2) and

B. Musicology (chapter 3)

The chapter on *Musical Creation* offers an overview of the ways in which embodiment has become central in the innovations of Western Art Music (WAM) after 1950. Three partially overlapping, interdependent but also self-contained axes are to be investigated in this respect:

1) The first axis refers to compositional innovation and performative responses inside the traditional framework of contemporary classical music / Neue Musik / musique contemporaine[39]. Innovations in aesthetics and musical language, in notation, in the use of traditional instrumental resources and techniques and in modes of reception are explored through references to composers: Pierre Boulez, John Cage, Luciano Berio, Iannis Xenakis, Helmut Lachenmann, Klaus Karl Hübler and Brian Ferneyhough. This overview will set the scene for what could be termed an elevated or augmented role for performative embodiment in the second half of the twentieth century. No matter how radically different to each other, all these compositional languages still operate

[39] The terms “contemporary music” and “new music” (as translation of the German „Neue Musik“) will be used interchangeably throughout the dissertation.

at large under the category crystallized in the late 19th and early 20th century and known as “classical music”.

2) The second axis refers to the innovations brought about by the introduction of the electronic medium, along the line of the “aesthetics of disembodiment” of acousmatic music[40], the new challenges concerning embodied presence brought about by mixed music and live electronics and the new innovations in human-computer interaction. In other words, it refers to the extension and problematization of the traditional classical music system through technological means in a digitalized culture.

3) The third axis refers to the new significations of the human body in musical creation. These significations extend musical creation (and correspondingly musicology) into other art forms, while affirming the intrinsic multimodal character of music making. They correspond to developments in a number of related fields such as philosophy, sociology, and anthropology and more particularly with the *performative turn* in theatre (to be here differentiated from the performative turn in musicology, which will be the subject of section B of this first part).

Those three axes cover a rather extended range of musical phenomena after 1945 and after 1989[41] and offer a brief history of musical embodiment, which frames our subject matter, “complex piano notation”, as follows:

1) Complexity has been the main trope for the historical development of notation, as abstraction and symbolization of embodied actions into some form of symbolic language. This trope is not limited to WAM but refers to most sophisticated non-

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[40] This translation of “musique acousmatique” designates electroacoustic music without some form of controller or classical instruments, destined to be listened through speakers.

[41] At least two recent publications affirm the importance of 1989 for a renewed historiography: Tim Rutherford-Johnson, *Music After the Fall. Modern Composition and Culture since 1989*, University of California Press, 2017. And Seth Brodsky, *From 1989, or European Music and the Modernist Unconscious*, University of California Press, 2017.

western notational systems as well[42]. It reflects the impulse to abstraction and represents an increasing number of musical enactive features, while remaining always partial ("metonymic" according to Philippe Manoury[43]) and dependent on performance. We refer to it as *intra-complexity*.

2) Historically, intra-complexity is the defining stylistic feature of a large range of divergent musical languages in the post-war era[44].

3) This range of styles includes complexity as a specific school of composition by the name "New Complexity", including ideological overtones in the sense of the composer's Claus-Steffen Mahnkopf's notion of *Komplexismus*[45].

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[42] For an example, one might look at the historical evolution of neumes in two distinct traditions, the Byzantine and the Gregorian Plainchant, as codified in: Constantin Floros, *Einführung in die Neumenkunde*, Noetzel Verlag, 1980

[43] "En quelque sorte, la notation musicale est une sorte de métonymie du phénomène sonore: le tout est exprimé par une partie seulement", p. 64 in Philippe MANOURY, *La note et le son*. *Ecrits et entretiens. 1981-1998*. L' Harmattan, 1998.

[44] Indicatively : "1. the statistical / stochastic 'school' (Xenakis and his followers), aiming at complex musical masses ; 2. Spectralism (Murail, Grisey etc), employing complexly-structured sound spectra ; 3. Lachenmann's 'musique concrète instrumentale', with its broad spectrum of sounds – stretching from conventional to the most unconventional- derived not from the world, but rather from the 'sounding bodies' of the Classical instrumentarium ; 4. Live-electronic music (late Nono and the 'consequences') ; 5. complexism, with its radically and thoroughly polyphonized musical discursivity." (p.55). In Claus-Steffen Mahnkopf, "Complex music: an attempt at a definition", in Claus-Steffen Mahnkopf, Frank Cox, Wolfgang Shurig, *Polyphony & Complexity*, Wolke Verlag 2002, p. 54-64. And one should further include in this list the work of the early serialist pioneers of the '50s and '60s (Boulez, Stockhausen, Nono, Maderna etc), including some works by John Cage (for example, *Music of Changes* for solo piano).

[45] According to Mahnkopf, three qualities are characteristic of all forms of complexity: "1) large amount of information, both a) quantitative (mass of real 'empirical' sound events with great speed and density) and qualitative (as mass of subcutaneous relations exhibiting differing dimentions, semantic richness and great ability to form mutual contacts); 2) polyvalence of the meaning-bearing levels with all intracompositional, stylistic and historical implications: a polyvalence can take into account ambiguity, ambivalence and self-contradiction; 3) a high degree of binding energies between the individual (which is to say, contextualized but at the same time capable of consideration as individual) occurences in the music (the stringency, the bindingness and the authenticity of the relationships, whether particularized or super-contextualizing). In older terminology: between the parts and the

4) Complex notation is part of a *complex dynamic system* in performance, codifying but also interacting with the other parts of the system, namely: with the performer and with the instrument. Such definition can extend to almost any notation, considered as a medium among others in an intermedia constellation. We call this *inter-complexity*. In that sense, a graphically simple notation may generate a complex web of interactions and, vice versa, a high degree of notational intra-complexity could be simple in terms of interaction.

5) This last definition of complex notation can be extended to include interactions in technologically advanced constellations (multimedia) and interactive multimodal systems. Dynamic scores, augmented feedback, multimedia and score following would be some of the domains of application for such conception of "inter-

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whole, or, at different levels, the combining of parts into large units in relationship to the whole."(p. 54-55). As for the repertoire specifically belonging in the *complexist* genre, Mahnkopf identifies the following characteristics as indispensable to the compositional praxis (in different degrees of distinctness and combination): "density and rapidity of events; complexity of the rhythmic and pitch structures abundance of the morphology; (real/microparametric) polyphony in the sense of a high degree of dissociation in the discursivity; poly-processualization of formal directionalities; apperceptive surplus; diagonal mode of listening; immanentistic semantic; expressivist expression; multi-perspectivity and multidimensionality of the "empiricity" of the artwork, above all of musical time; deconstructionism of the work character and the performance situation; complexist complexity." (p.56)
In lieu of a short history of complexism, Mahnkopf writes: "After some already complex works starting with the late 1960s, Ferneyhough achieved a form of complexism with *La Terre est un Homme*, which he thereafter cultivated, established as a personal style and simultaneously protected against artistic competition. In the 1980s, the following composers of complex music appeared: the British composers Chris Dench, Michael Finnissy, Richard Barrett, Roger Redgate, James Erber and James Dillon, Ole Lützow-Holm (early works), Réné Wohlhauser, Klaus K. Hübler, Frank Cox and the present author. In the 1990s numerous more names appeared : Wolfram Schurig, Brice Pauset, Aaron Cassidy, Wieland Hoban, Simeon Pironkoff, Claude Lenners, Franck Christoph Yeznikian, Ian Willcock and Mark Andre. Some composers are involved with issues similar to those of complexism (such as Steven Kazuo Takasugi, Chaya Czernowin, Mario Garuti, Gerald Eckert, Liza Lim, Walter Feldmann, Klaus Ospald, James Clarke and Erik Ulman)" (p. 55, footnote nr. 3).
In Claus-Steffen Mahnkopf, "Complex music: an attempt at a definition", in Claus-Steffen Mahnkopf, Frank Cox, Wolfgang Shurig, *Polyphony & Complexity*, Wolke Verlag 2002, p. 54-64

complexity".

The above definitions are coupled neatly to the arrangement of this dissertation in four parts, namely: the first part dealing with the "repertoire" definition of complexity and exposing the context of our case studies; the second part exploring the interactive and embodied meanings of complexity through the field of embodied cognition and exposing the model of embodied navigation; the third part opening-up to the electronic medium and in particular to the field of interaction; eventually the fourth part, as a collection of case studies which put the different methodologies exposed before combined at work.

The current dissertation aspires to present a synthesis of the five definitions of complexity: It deals with intrinsically and interactively complex piano music, which is further re-inscribed into augmented, dynamic, interactive & multimodal musical scores.

One will be differentiating generally between two "complexities": the *intra-complexity*, referring exclusively to the traditional notion of a quantitative and qualitatively complex score; and the *inter-complexity*, for denoting complex interactions between the parts of a performing system, technologically advanced or not, including the musical score. In that sense, even a simple score in terms of intra-complexity may be generating complex interactions, and, vice versa, a score very complex in terms of deciphering might be part of a very simple network of interactions with the body, the instrument and other related parts of the performance system.

B. Musicology

The second chapter of the first part will deal with the so-called performative turn in musicology. The latter is being informed by the more general performative turns (John Langshaw Austin[46], Erika Fischer-Lichte[47], Kamper and Wulf[48]) and the so-

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[46] John Langshaw Austin, *How to Do Things with Words*, Harvard University Press, 1975

[47] Erika Fischer-Lichte, *Aesthetik des Performativen*, Suhrkamp, Franfurt am Main, 2004

called *body studies* (Fraser and Greco[49] in sociology) as investigated in the third axis of complexity embodied, but presents a very specific set of methods and tools which often relate to earlier repertoires.

This section is articulated in three parts:

1. A brief history of the *performative turn* in musicology, as well as a distinct *embodied turn* in relation to mediation technology.
2. Its state of the art, through the investigation of recent publications in English-speaking, French and German musicology.
3. The aporias of those performative turns and the need for a renewed, embodied model for interpretation as embodied interaction with the musical score, foreshadowed by the embodied cognitive turn in musicology.

C. Towards a model of embodied navigation

This section will summarize the reasons that necessitate the rethinking of the traditional model of interpretation in performer-specific terms, and in particular as "embodied navigation of complex notation", that is as a model of embodied interaction with complex notation.

At its heart lies the definition of the traditional model of interpretation, summarized in the acronym *UTI* which stands for "Understanding-Technique-Interpretation", and the alternative paradigm, which is going to be proposed in the second chapter of this dissertation as TUI, notation as a "Tangible User Interface" through a model of embodied navigation. This model summarizes complex notation's intrinsic interactive and embodied values and attempts to update them and materialize them through cutting edge methodologies and tools.

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[48] Dietmar Kamper & Christoph Wulf (eds.), *Die Wiedekehr des Körpers*, Suhrkamp, Franfurt am Main, 1982

[49] Mariam Fraser & Monica Greco (eds.), The Body: A Reader, Routledge, New York, 2005

2. Complexity Embodied: Three Axes In Musical Composition

In what follows, we present the embodiment of complexity in three axes of musical creation after 1945:

1) Composition for acoustic instruments
2) Electronic music and digitalization
3) The musical body as medium.

Our investigation will start with a positive evaluation of the contemporary classical music system, or *dispositif*[50], offered by Philippe Lalitte's *Analyser l'interprétation de la musique du XX siècle,* followed by a negative one, as offered by Harry Lehmann's *Die Digitale Revolution der Musik*. We will then trace the correlation of complexity and embodiment in selected composers' and performers' discourses, in the context of this classical *dispositif*.

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[50] Term used by Harry Lehmann 2012 after Michel Foucault, to denote the institutional organization of contemporary classical music as a branch of the classical music industry : „Nach Michel Foucault ist ein Dispositiv „ein entschieden heterogenes Ensemble, das Diskurse, Institutionen, architektonische Einrichtungen, reglementierende Entscheidungen, Gesetze, administrative Maßnahmen, wissenschaftliche Aussagen, philosophische, moralische oder philanthropische Lehrsätze, kurz: Gesagtes ebensowohl wie Ungesagtes umfasst. Soweit die Elemente des Dispositivs. Das Dispositiv ist das Netz, das zwischen diesen Elementen geknüpft ist.". In Harry LEHMANN, *Die digitale Revolution der Musik. Eine Musikphilosophie*, Schott, Mainz, 2012, p.10, originally in Michel Foucault, Dispositive der Macht. Über Sexualität, Wissen und Wahrheit, Berlin 1978, (New Edition 2000), p. 119f.

2.1 New Music, New Interpreter

In his latest book *Analyser l'interprétation de la musique du XX siècle*, Philippe Lalitte offers a neat overview of the interpretative challenges due to compositional innovations after 1945. It is already important to note, how the notion of "challenge" is a recurring motif in the scholarship around the performance of post-war music. This insistence constitutes an aporia, which I will later address as originating in the Cartesian *Body-Mind* and *Technique-Interpretation* dichotomies[51].

In two extended sections, titled "The interpreter faced with the innovations in composition" (« L'interprète face aux innovations de la création ») and "The interpreter as agent of composition" (or "co-creator", my translation) (« L'interprète acteur de la création »), Lalitte delineates the creative freedoms allowed to the performer, first by detailing the challenges posed to her by the composer, then by investigating the margin of creative agency that a performer can bring to the process. This very distinction naturally places Lalitte's meticulous study in a rather traditional frame, which is composer- and score-oriented, but offers at the same time an overview of the problems we will be dealing with.

The compositional innovations analyzed in the first of those section refer to well-documented characteristics, namely: The material innovations related to orchestration and extended techniques; questions around the medium of notation, which after all will also be most central in our reflections; the new concert practices, including an ever-increasing importance for the staging of musical performance; and the electronic medium. We will reserve the discussion pertaining to the electronic medium and new concert practices for the second and third axes of this brief history of embodiment respectively.

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[51] A range of important studies deals with twentieth-century Western art music after 1945. Amongst the most comprehensive are those by Paul Griffiths, Glenn Watkins, Arnold Whittall, Celéstin Dèliege and Hermann Danuser. Philippe Lalitte's book is selected due to its focus on performer-specific aspects of this repertoire, which remain rather sporadic or under-represented in the above-mentioned bibliography.

The second section of Lalitte's first chapter continues in the same spirit, accentuating the social roles of the performer as a messenger, educator, communicator, charged with the mission of enabling the mediation and diffusion of new music. Eventually, questions are raised on: the collaboration between performers and composers as source of innovation through experimentation; the special access to implicit performer knowledge; questions of interpretation in hyper-exact notations and modes of performance analysis.

A. The Material Base Of Novelty

Lalitte begins his account of 20th century innovations with the question of instruments and instrumental techniques. Lalitte's choice of such materialist base for innovation resonates with both the elevated role of the musical interface in our concept of embodied navigation and with Lehmann's analysis of the traditional *dispositif*.

After a dense introduction to the late 19th and early 20th century advancements in the art of orchestration, Lalitte summarizes the most important contributions after 1945, notably: the enhanced role of percussion instruments and musical objects of all kinds, *poly-instrumentality* as one of the renewed tasks of the new music performer, and the rise of extended techniques.

B. Towards A Seismographic Notation

The expansion of music's material base and its aesthetic innovations are reflected in the evolution of musical notation. One of its motors was the early 20th century shift to atonality. Given the absence of tonality's shaping power, the notation of nuances, articulations, phrasing and tempi became more important for the distinction of morphological entities. Edgard Varèse summarized the call for a notation that would inscribe physical energy into the symbolic fabric as a "notation sismographique"- *a seismographic notation* (Lalitte, p. 29).

After World War II, the proliferation of instructions concerning every parameter of performance becomes the norm rather than the exception. While leaving a minimum margin for interpretation in the romantic sense, this *hyper-exactitude* bears aspects of “psychologization” (Ferneyhough) or “manipulation” of the interpreter (Lalitte p. 37). Lalitte draws an interesting connection between an early lecture by Pierre Boulez on the role of notation[52] and Ferneyhough’s explicit “manipulative” strategies and performance rituals, seen from the side of both the composer and the flutist Pierre-Yves Artaud[53].

A defining parameter for interpretational possibilities despite the exactitude is the very ontological gap between the work as symbolic representation and the work’s realization in time and space[54]. The testimonies of performers, such as for example Claude Helffer, who have been faced with contradictory requests by composers, is telling:

“In his third sonata, Boulez indicates a tempo of eighty for the quarter-note. I work on this sonata in 1986, Boulez tells me: “No, there, it must go forward, it’s boring”. Ten years later, in preparation of a film dedicated to his work: “But it’s way too fast, it does not sound anymore”. -Well what do you want? -“There where it is written eighty, you do sixty”. Another day I play *Herma* by Xenakis on the radio. I had calculated the theoretical duration of the work as almost six minutes. Iannis calls: “it’s rather too fast what you do there”.-“Listen, I’ve taken the exact duration you have written there.”-“Make your minutes last longer”. He wished for more depth, more clarity. I’ve learned the lesson. Later it will be the same with Philippe Manoury. When I recorded his work a decade after he composed it, he asked me to slow down several passages”[55].

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[52] Pierre Boulez, “Time, notation and coding”, in Jean –Jacques Nattiez, *Orientations. Collected Writings. Pierre Boulez*, transl. by Martin Cooper, Faber and Faber, 1986, p. 84-89

[53] Pierre-Yves Artaud, « Unity Capsule, une explosion de quinze minutes », *Entretemps, No 3*, « Brian Ferneyhough », 1987, p. 198-109

[54] « Il existe une distance irréductible entre la représentation mentale de l’œuvre et sa réalisation effective dans l’espace et le temps avec tous les aléas que cela comporte », p. 74

[55] « Dans la Troisième sonate, Boulez indique une pulsation de quatre-vingt à la noire. Je travaille cette sonate en 1968, Boulez me dit : « Non, là, il faut que ça avance, on s’ennuie. » Dix ans plus tard, lorsque je tourne le film consacré à cette œuvre : « Mais c’est beaucoup trop vite, cela ne sonne pas. »-« Alors que veux-tu ? »-« Là où il est écrit quatre-vingt, tu mets soixante ». Un jour je jouais *Herma* de Xenakis à la radio. J’avais calculé la minutage théorique de l’œuvre, six minutes environ. Iannis me téléphone : « C’est beaucoup trop vite ton truc . » -« Ecoute, j’ai pris exactement le minutage que tu as donné . » -« Fais des secondes plus longues ! » Il avait envie d’avoir plus d’ampleur, plus de clarté. J’ai compris la leçon. Ce sera la même chose avec Philippe Manoury. Quand j’ai enregistré son œuvre une décennie après l’avoir créé, il m’a demandé de ralentir quantité

Another factor allowing for interpretative decision is the technical difficulties and extremities in themselves, which introduce a degree of indeterminacy in the fixed scripture. In the same line of thought, it is very often the necessary exploratory mode of an advancement “by trial and error”[56], as the harpist Frédérique Cambreling puts it, which allows for the interpretational malleability of the work.

In other cases, such as the music of Iannis Xenakis and Brian Ferneyhough, the writing beyond what is physically and mentally feasible is intentional and necessitates the performer’s “own discretion” (as John Cage puts it in his preface to his *Music of Changes*), the performer’s ability to manage paradoxes, make priorities and compromises.

Interpretative choices, such as the ones Helffer cites above, end up shaping the style and sound of highly individualistic performers, which should also be counted as one of the parameters of contemporary interpretation. Lalitte concludes by affirming the dialectics between the exploratory work of discovery “outside time” (“hors-temps”) and the interpretation “in action or in real-time” (“en-temps”) at the concert venue. We will return to this distinction, in the notion of Xenakis’ compositional aesthetics as transcribed in the performer’s navigation, in part four of the current.

On a critical note, foreshadowing some of the points in this thesis: In both Lalitte’s account and in the performers’ own discourses cited above, we note the absence of performative embodiment as a factor shaping interpretation, other than as a factor of material resistance or as a reservoir of technique, which allows for the negotiation of impossibilities. In what follows, we will attempt to reframe questions of both instrumental technique, material exploration, even the very distinction between

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de passages ». Lalitte p. 74, originally in Claude Helffer, *La musique au bout des doigts*, entretiens avec Bruno Serrou, s. l., Michel de Maule, 2005, p. 261-262.

[56] « Il faut beaucoup de temps, surtout dans des partitions complexes, pour faire les coix de doigtés, de jeux. La mise au point peut-être trop longue. Avec des références auditives, il est possible d’envisager la façon de travaille, alors qu’avec des œuvres nouvelles, on procède par tâtonnements ». Lalitte p. 75, originally in : Frédérique Cambreling, « Solo : Frédérique Cambreling », propos recueillis par Bruno Serrou, *Accents Le journal de l’Ensemble Intercontemporain*, no 6, 1998, p. 5.

learning “hors-temps” and performing “en-temps”, through the development of the model of embodied navigation.

On the antipode of strategically hyper-exact notations, Lalitte cites seminal texts by Stockhausen, Kagel and Ligeti[57], as attempts towards a “notational liberation”. One of the most celebrated techniques in this direction is the so-called *time-space* notation, an issue that we revisit in the reference to Luciano Berio, but also in the music of John Cage, Iannis Xenakis and others.

Other spaces of choice include *open form* (especially in the case of serialists such as Boulez *3ème sonate* or Karlheinz Stockhausen’s *Klavierstück XI*), action notation, the notation of instrumental music theatre, graphic scores with the New York School of John Cage and Earle Brown and verbal scores, quintessentially Howard Skempton and Cornelius Cardew, as well as the movement known as *Fluxus*. Today, Richard Barrett’s notation is distinguished for combining extreme complexity with “brackets” of free or controlled improvisation.

Lalitte cites the repartitioning of piano scores into more staves as another example of notational innovation. He brings up the notorious example of Xenakis’ piano concerto *Synaphaï*, notated in ten staves, one for each finger. The degree to which such visual arrangements of polyphony contribute to the clarity of the musical idea or rather to a challenging of primordial physical reflexes is debatable. The issue will be thoroughly discussed in relation to a case study, Wieland Hoban’s piano work *when the panting STARTS*, equally notated in ten staves for the fingers and three for the pedals. The issue is raised again in relation to works of *action notation* and *action decoupling* by Helmut Lachenmann and Klaus Karl Hübler. Such works re-introduce the ancient idea of *tablature* in contemporary music.

[57] Karlheinz Stockhausen, « Musik und Graphik », Darmstädter Beiträge zur Neuen Musik, Nr. 3, 1960; Mauricio Kagel, „Komposition-Notation-Interpretation“ , Darmstädter Beiträge zur Neuen Musik, Nr. 11, 1965; György Ligeti, „Nouvelle notation. Moyen de communication ou but en soi?“ , Darmstädter Beiträge zur Neuen Musik, Nr. 9, 1965**.**

Notations dedicated to *extended instrumental techniques*, including microtonality, are central in Lalitte's list of notational innovation, even though their standardization attempts have not been particularly successful[58]. The norm until today remains an explicit *legend* of techniques and corresponding symbols in the performance note of the musical score.

One of the most intensive aspects of contemporary music performance is the possibility of collaboration with (living) composers. This collaboration often exceeds the sheer clarification of the composer's intentions to the performer: It rather becomes a medium for compositional exploration of new materials. Such composer-performer interactions may shape the work in definitive ways, not only before but even after its creation, in the form of score modifications. Eventually, it is not unusual, long-term collaborations to be shaping the language of a composer for a given instrument, and here Lallitte cites important cases, such as John Cage and the pianist David Tudor or Iannis Xenakis and the percussionist Sylvio Gualda. (Lalitte, p. 67). This collaborative aspect puts performers in a condition different from the traditional interpreter's and "restores their initial function: the creation of new works" (Lalitte, p. 59)[59].

A recurring theme in Lalitte's account is the resistance of the classical music establishment against the production of contemporary music. This reluctance to open up to the new challenges has triggered a series of important mediational and infrastructural actions: The founding of new music ensembles and the curating of dedicated concert series by composers (Pierre Boulez with the foundation of some of the most important contemporary music institutions in France such as the *Ensemble Intercontemporain*, the *Domaine musical* and the *IRCAM* is here the obvious

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[58] Characteristic instances of such attempts may be found at : Erhard Karkoschka, *Das Schriftbild der neuen Musik*, Celle, Moeck, 1966 ; Gardner, Read *20th Century Microtonal Notation*, West Port, Greenwood Press, 1990 and *Pictographic Score Notation : A Compendium*, West Port, Greenwood Press 1998 ; Kurt Stone *Music Notation in the 20th Century*, New York, Norton and Company, 1980 ; as well as in Andreas Jaschinski's (ed.) *Notation*, Bärenreiter, Stuttgart, 2001.

[59] "Les changements esthétiques profonds qui révolutionnent la musique pendant la deuxième moitié du XXe siècle, font renouer l'interprète avec sa fonction initiale: la création de nouvelles œuvres." Lalitte p. 59

example); the overtaking of important educational actions by performers, such as the publication of treatises on extended techniques and the transmission of knowledge through short-term (master-classes and festivals) and long-term (through the institutions of higher education) pedagogical activities. Of course, it will be interesting to compare later Lalitte's account with Lehmann's polemic against what the contemporary music has become, that is the New Music establishment or *dispositif*.

One final word should be uttered concerning the sociopolitical conditions, which enable such infrastructures, namely policies that allow for state funding of these activities. After 1989, the hegemony of neoliberal policies has put state-driven policies at question and has triggered the emergence of entrepreneurial models of new music making, not only in the USA, where this was by default the case, but progressively also in Europe. For an overview of such developments, look at Rutherford-Johnson 2017.

C. Analysis As A Vehicle Of Performative Discovery

In the last section dedicated to the interpretation of 20th century music, Lalitte raises the question: To what extent does the learning phase necessitate in-depth analysis? While some sort of deeper understanding is deemed inevitable, Lalitte asserts that understanding should be different from the musicologist's, or tailored to the needs of performance, that is performer-specific. He goes on to introduce several analyses by renowned interpreters, which reveal different tropes of performer-specific thinking of post-war music.

The differences are telling: As far as pianists are concerned, Herbert Henck's analysis[60] of Stockhausen's *Klavierstück IX* combines the use of kinesthetic metaphors with in depth analysis of the serial structure of the piece; Claude Helffer's *15 analyses musicales*[61] offer meticulous insights into his technique of annotating scores, offering formal understanding and emphasizing the ties to the tradition, which makes his method apt for pedagogical use. Comparisons of different interpretative

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[60] Henck, Herbert, "Karlheinz Stockhausen's Klavierstück IX", Köln, Neuland Musikverlag, 1978.

[61] Helffer, Claude, *Quinze analyses musicales. De Bach à Manoury*, Genéve, Editions Contrechamps, 2000

analyses are illuminating different aspects of the works in question. Such is the case with Berio's *Sequenza VII* for oboe and the analyses of Libby Van Cleve[62] and Christopher Redgate[63]. Distinguished is Pierre Michel[64]'s analysis of *Sequenza VIIb* for saxophone, in that it comes in the form of a filmed demonstration of the analytical points in question, offering thus an empirical basis for the analysis. Finally, Lalitte makes mention to Tanja Orning's analysis[65] of Lachenmann's *Pression* for solo violoncello through the concept of *autopoietic feedback loop* by the German performance theorist Erika Fischer-Lichte, in the context of her *aesthetics of the performative* (*Ästhetik des Performativen*).

In the light of embodied interaction, the several styles of analytical intuition cited by Lalitte (with the notable exception of Orning) attest to our initial hypothesis: Performers employ a variety of means to handle challenges, usually in a rather idiosyncratic and eclectic way, which is not characterized by the consistency of strict musicological analysis. While the results of this type of analysis may be very creative, a point to be made concerns the ways performers express themselves on embodiment: Live embodied experience is overtaken by questions of instrumental technique, fingerings, impossibilities, the body as an obstacle rather as a medium for thought and action. This reduction of the dimension of embodiment is a historically constructed, disciplinary (in the sense of Mauss) *dispositif* (in the sense of Foucault). We will propose an alternative, in the form of performer-specific discourse and analysis based on primordial embodied experience and interaction.

D. Conclusion

Lalitte's overview maps a big range of new compositional materials and performers' responses, while making palpable the urgency of a performer-specific discourse. In what follows, we will propose three axes for an overview of those innovations from a

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[62] Van Cleve, Libby, "Suggestions for the performance of Berio's Sequenza VII", *The Double Reed, Journal of the International Double Reed Society*, vol. 13, nr. 3, 1991, p. 45-51

[63] Redgate, Chritopher, "Performing Sequenza VII", *Contemporary Music Review*, vol. 26, nr. 2, 2007, p. 219-230

[64] Michel, Pierre, "Sequenza VIIb by Luciano Berio: A performance point of view". *Musimédiane*, No 4, 2009, http://www.musimediane.com/4michel/ accessed 11.05.2018

[65] Orning, Tanja, "Pression – a performance study", *Music Performance Research*, vol. 5, 2012, p. 21

performer-specific perspective. This perspective focuses on *embodiment* and *interaction* rather than on compositional innovation. Those three axes, namely embodiment and composition, embodiment and electronics, embodiment and intermedia, are attempting to set the scene for a definition of complexity from an embodied and extended / media perspective. The axes very often overlap, so that, for example, Manoury's notion of virtual scores (*partitions virtuelles*) touches on both the first and second axes, or Stellarc's performances touch upon the second and third axes. It will also become clear, that while the focus of this dissertation will inevitably be on a much smaller portion of the repertoire presented here, all three axes will be informing and influencing the proposed approach to complexity: Composition through notation, electronics through interaction, embodiment through the focus on gesture and physical movement, intermedia through the gestural interactive control of notation via the *GesTCom*.

2.2 First Axis: Embodiment And Composition

In order to define the first axis of this short history of embodiment, namely *embodiment and composition*, it is necessary to review Martin Zenck' notion of the *corporeal subtext* and Harry Lehmann's appropriation of the term *dispositif* by Michel Foucault in his *Digitale Revolution der Musik* (the digital revolution of music). The latter will also be reviewed in full detail later, before the second axis referring to electronic music and digitalization.

Zenck's term originates in his "Luigi Nono-Marina Abramovic: Eingeschriebene bewegte und befreite Körper zwischen Aufführungspartitur, Live-Elektronik und freier Improvisation / Performance"[66] („Luigi Nono – Marina Abramovich: Inscribed, moved and liberated body between performance score, live electronics and free improvisation / performance art") and further developed in texts such as "Intermedialität von Performance, Improvisation und Choreographie im Neuen Musiktheater: Drei Modelle von Sasha Waltz: "Dido and Aeneas" – "Körper"-

[66] in Petra Maria Meyer (Hsgb.), *Performance in medialen Wandel*, Wilhelm Fink Verlag, München, 2006

"noBody"[67] ("Intermediality of performance, improvisation and choreography in new music theatre: three models by Sasha Waltz: "Dido and Aeneas – Körper-noBody") and "Vom Berühren der Klaviertasten und vom Berührtwerden von Musik. Mit einer Einleitung zum weit verbreiteten Anathema "Musik und Körper" in der Philosophie und in der Musikwissenschaft"[68] ("On touching the piano keys and being touched by music. With an introduction to the widespread anathema "music and body" in philosophy and musicology").

Zenck touches on the issue of the primordial origin of notation, by asserting that

"Music is performative, not primarily as sensory shaping during the performance and more generally in performance practice, as "performance art", but rather as having already achieved a performative inscription in the text of the notation; a second, so to speak, unwritten text inside the text, which I would like to designate as *corporeal subtext*. It is exactly this corporeal subtext under the notated text, which must emerge in the actual performance. Neither is the performance the result of a supposed mysterious deciphering of a score, nor is it the transformation of a signified into a signifier, of a meaningful mental sign into a horizontal or vertical sounding sign that is then articulated into a form-shaping process (performance)"[69].

Zenck's definition has far-reaching consequences. It implies that the development of Western music notation, along the line of an increased specificity of both the sound-image (descriptive function) and the performing instructions (prescriptive function) contained in a sacralized score, has radically affected the performer's primordial reflexes to the act of learning and performing. The very fact, that the score -a

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[67] In Marion Demuth / Jörn Peter Hiekel (Hsgb.), *Freiräume und Spannungsfelder. Reflexionen zur Musik heute*. Mainz:Schott, 2009

[68] In Jörn Peter Hiekel and Wolfgang Lessing, *Verkörperungen der Musik. Interdisziplinäre Betrachtungen.*Bielefeld: transcript, 2014

[69] „Performativ ist Musik also nicht erst in der sinnlichen Gestalt der Aufführung und Aufführungspraxis der „performing art", sondern vermöge einer performativen Einschreibung im Notentext; einem zweiten gleichsam ungeschriebenem Text im Text, den ich als corporalen subtext bezeichnen möchte. Genau dieser corporale Subtext unter dem Notierten „Text" ist es, der in der Aufführung in die Gegenwart zu ziehen ist. Weder verdankt sich die Aufführung einer angeblich mysteriösen Dechiffrierung eines Notentextes noch der Transformation eines signifié in ein signifiant, eines bedeutenden geistigen Zeichens in ein linear oder vertikal klingendes Zeichen, das sich dann im Form-Prozess artikuliert"

visuographic mode of representation- is the inevitable starting point of fixity for the whole learning trajectory, has privileged the eye and the mind as the performer's points of entry, in the expense of the ear and the performing body. But while the ear is at least implied through the signification of sound, the body, as the physical mediator between sign and sound, has been both a crucial *absence* in the notation and *the only performer-specific* field in the chain linking composers and listeners.

The problem almost remained muted through a centuries-long development of performative traditions and the linguistically structured tonal music material itself into a sort of *lingua franca*. Despite local deviations and distinct lineages in those traditions, the notational medium was rendered quasi-transparent through more or less commonly accepted stylistic rules applied to performance. After all, 19^{th} century saw the emergence of the star-performer who *becomes music* and the romantic ideals concerning talent, intuition, genius further mystified performance and disembodied notation. Of course, the development of virtuosity, very often inseparable from improvisation still active in those days, was a privileged field for experimentation with the performing body. Nevertheless, the fixation of the results in notation and the institutionalization of instrumentalist's education would ensure that "the unstable interface: performer/notation", a "deeply fragile and artificial" one, would remain "naively unquestioned"[70] as to its purely embodied aspects.

Zenck's notion of the "corporeal subtext" is key to reformulating the ways we think about notation and performance, in that it reverses the peculiar established hierarchy of a score preceding a performance, while rather the opposite has been the case: a score codifying something which is already performative. The consequence of such formulation is challenging established hierarchies: It illuminates differently the issues of creative collaboration between composers and performers as exposed by Lalitte, or issues of performance analysis. If performance is already there before the score, if the score is so to speak ontologically *wrapped in-between* performances which shape it, rather than it projecting or radiating a performance out of symbolic properties, then the whole composer-centered discourse must be reformulated.

[70] James Boros & Richard Toop (eds.), *Brian Ferneyhough: Collected Writings*, Routledge, London, 1995, p.5

Harry Lehmannn's term "Dispositiv" is appropriated from Michel Foucault, who defines it as "a heterogeneous ensemble of discourses, institutions, architectural structures, juridical decisions, laws, administrative measures, scientific truths, philosophical, moral and philanthropic preachings, briefly: It spans both the Said and the Unsaid. Those are the elements of a Dispositiv. The Dispositiv is the net, which binds those elements together"[71].

According to Lehmann, the "old *dispositif* of New Music" may explain the paradox, that

"Contemporary music has exhausted its original idea of material progress in the context of music for acoustic instruments, without having effectuated a rethinking or paradigm shift"[72].

To put it simply, Lehmann claims that the *dispositif* of New Music remains bound to the norms, instruments and institutions of classical music, crystallized in the late 19th and early 20th century, and this state equals a stagnation that can only be counteracted through the digital revolution taking place since the second half of the twentieth century.

One of Lehmann's main objections to the "Dispositiv Neue Musik" is the persistence of absolute music, which he sees as irrelevant in the digital era, as an anachronism, which perpetuates classical aesthetic ideals and means. A relational music, after Nicolas Bourriaud's *relational aesthetics*[73], is instead claimed to be the solution to the contemporary music's cul-de-sac.

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[71] Michel Foucault, *Dispositive der Macht. Über Sexualität, Wissen und Wahrheit*, Berlin 1978, (Neuaufl. 2000), S. 119f, in Harry Lehmann, *Die digitale Revolution der Musik. Eine Musikphilosophie*, Schott, Mainz, 2012, p. 10: „Nach Michel Foucault ist ein Dispositiv „ein eintschieden heterogenes Ensemble, das Diskurse, Institutionen, architektonische Einrichtungen, administrative Maßnahmen, wissenschaftliche Aussagen, philosophische, moralische oder philanthropische Lehrsätze, kurz: Gesagtes ebensowohl wie Ungesagtes umfasst. Soweit die Elemente des Dispositivs. Das Dispositiv ist das Netz, das zwischen diesen Elementen genküpft ist".

[72] (Neue Musik) sich Ihre ursprüngliche Leitidee des Materialfortschritts im Kontext der akustischen Musik erschöpft hat, ohne dass sich hier ein Umdenken oder gar ein Paradigmenwechsel vollzogen hätte", Lehmann, 2012, p. 9

[73] Nicolas Bourriaud, *relational aesthetics*, Bordeaux, 2002

A more thorough review of Lehmann's philosophy will follow in the introduction of the second axis of our short history of embodiment. For the moment, while accepting his main thesis, that digitalization offers paradigm-shifting possibilities which unseat the "Dispositiv Neue Musik", we will argue that, *already* in the context of the most absolute of the old "new music", the emergence of Zenck's "corporeal subtext" constitutes a movement towards a relational, multimodal, embodied and interactive aesthetics. We will also be critical as to some manifestations of relational music and claim that, very often, what is deemed as multimodal and embodied, actually equals a visualized abstraction of the musical body, which takes us back to the pitfall of "representationalism", usually addressed towards music notation.

We define thus the first axis of embodied and interactive notations towards a new embodied navigation paradigm as: *the emergence of the notation's corporeal subtext (Zenck) in the context of the old dispositif of New Music (Lehmann)*.

A. Disembodiment I: Pierre Boulez

A most characteristic document of structuralism in performance is to be found in Boulez's Darmstadt lecture "Temps, notation et code". This lecture was originally intended as the basis for an additional third chapter of his *Penser la musique aujourd'hui*[74], but was eventually published for the first time in his collected writings, in English under the title *Orientations*[75].

In the first part of his lecture, Boulez deals with music notation. As the title "Time, notation and coding" suggests, the text in question summarizes Boulez's early view of notation as

"the coding of structure, and it is in this form [as *coding of structure*] that it [notation] plays a role in the elaboration of local structure, and actually affects that structure. We must consider notation therefore as a means, and not as a principle, of creation. […] You cannot in any case take the actual coding as

[74] Boulez, Pierre, *Penser la musique aujourd'hui,* Paris, Gallimard, 1987

[75] Pierre Boulez, « Time, Notation and Coding », in *Orientations. Collected writings by Pierre Boulez*, ed. Jean –Jacques Nattiez, transl. Martin Cooper, London, Faver and Faber, 1986, pp. 84-90. Translation of Boulez, Pierre, *Point de repère I « Imaginer »*, Paris, Christian Bourgois Editeur, 1995.

the message that is to be transmitted, although the coding may be thought of as capable of influencing that message". (Boulez 1998, p. 89)

Boulez offers an evolutionary view of notation and its development up to its current (1960) state, which is characterized by the co-existence of two types of notation. He denotes them as "neumatic" and "structural", the latter termed also "mathematical", "proportional" or "symbolic". Despite making use of the same system of plane geometry co-ordinates, the two types co-exist in a clear historical and hierarchical relationship:

"Neumatic notation is a regression from symbolic notation, which consists of figures represented by a system of conventional symbols. Neumatic notation has no such coded and figured symbols, but consists simply of a line traced on the surface of the paper and referring implicitly to the space-time co-ordinates mentioned above". p. 84

The ancient neumatic notations, "an unsophisticated attempt to transcribe the musical phenomenon of singing" into a kind of ideogram, in which the vocalized syllable and the pitch or melisma are amalgamated, are *subsumed* by proportional notation, whereby "duration could be indicated *without the physical need of paper* (my italics)", p. 85.

Boulez's evolutionary view of graphic representations as inferior to purely symbolic ones, because of their reliance on *external information-bearing structures* (paper), is indicative of what will in part two be analyzed as *internalism* in cognitive science: The view that cognition is computation effected by the brain. In the same vein, he states that:

"psychologically and physiologically we should expect the eye to help the brain rather than the brain to be activated by the eye, the brain constituting a powerful agent of measurement whereas the eye is no more than a rough calculator. It is clear that here too any return from brain-measurement to eye-measurement represents a regression, with a corresponding increase in the element of approximations; and any such regression is essentially anti-historical". (p. 86)

The third reason Boulez gives for the superiority of structuralist notation is its fitness for the representation of what he calls "the true notion of musical time" (p. 86) and what he defines as a *pulsating* or *striated time*[76], as opposed to the *amorphous* or *smooth time*.

Summarizing, Boulez grounds the superiority of symbolic notation on:

a) abstraction as minimization of the need of external means of storage;
b) computability as a brain phenomenon;
c) representability of musical time.

In an interesting twist indicative of structuralist aporias, Boulez argues that he does not reject neumatic notations altogether. He comes to recognize that neumatic notation is more appropriate for the representation of *smooth time*, and since time cannot be either smooth or striated, but only capable of *reciprocal interaction*, so must be notation (p.86-87).

In the second part of his lecture, Boulez examines the role of notation not only as means of codification and composition, but also as a means of communication to the performer.

Boulez begins with an affirmation of "the discrepancy between notation and realization –i.e. use of this coded grid, in order to initiate an *interaction between the composer and the performer*, whether the performer is conscious of this or not" (p. 87, my italics).

The beginning of this interaction is algorithmically defined by Boulez as ciphering of an original structure in a grid, which is then decoded or deciphered and reconstituted by the performer, or:

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[76] For a detailed study of the contrast between smooth and striated time, look at *Penser la musique aujourd'hui*, p. 93-112. Also, concerning the influence of this distinction on post-structuralist thought, look at "1440: The Smooth and the Striated", in Deleuze, Gilles and Guattari Félix, *A Thousand Plateaus*. *Capitalism and Schizophrenia*, transl. Brian Massumi, University of Minnesota Press, 1987, p. 474-500, on Boulez in p. 477-478. Originally published as *Mille Plateaux*, vol. 2 of *Capitalisme et Schizophrénie*, Paris, Les Editions de Minuit, 1980.

A. Origination of a structure
B. Ciphering
C. Deciphering
D. Reconstitution of the structure

Concerning the third step of deciphering, Boulez differentiates between the coding of Stravinsky as representative of a modernist coding ("that it obliged the performer to reproduce the composer's message as exactly as it was originally communicated to him", p. 87) and the coding of the romantic era, which "was not designed to provide him with high-precision information, and the message was therefore reproduced with varying degrees of approximation", that is: interpreted.

And then follows another post-structuralist twist in Boulez's thought: the deliberate employment of compositional ambiguity in the coding system (p. 88).

Boulez differentiates between two varieties of ambiguity: Either a degree of complicity between performer and composer in "playing with the code", or the conscious employment by the composer of a deciphering beyond performative possibility, which will result in a defective reproduction of the message.

This deliberate deciphering beyond possibility is usually associated with the paradigm shift of *New Complexity*, for example in the text by Franklin Cox[77] to be reviewed shortly. Under the light of Boulez's lecture, maybe Ferneyhough's or Cox's writings are not as paradigm-shifting as they claim to be, but rather capitalizing on the consequences of a line of thought already present in early modernist work.

Back to the Boulez text, and specifically to the second case of deliberately ambiguous ciphering: The responsibility of the performer is defined as an as faithful as possible transmission of the message, despite of the actual impossibility of doing so. Moreover, Boulez defines this zero-sum game between composer and performer

[77] Franklin Cox (2002). "Notes Toward a Performance Practice for Complex Music" in Claus-Steffen Mahnkopf, Frank Cox and Wolfram Schurig, eds.: *Polyphony and Complexity, New Music and Aesthetics in the 21st Century,* i. Hofheim: Wolke Verlag, pp. 70-132.

as “beyond possibility”, but not as “impossible absurdity”, in the sense that “the composer has carefully considered the limits of the difficulty involved and knows that beyond a certain point he can only count on a performance that is only more or less approximate”(p. 88).

Interestingly enough, Boulez associates the impossibility of the ciphering not with some sort of interpretational ambiguity, but with “the sheer difficulty of performing extremely complicated rhythms or small and large intervals at the same set speed etc.” But the very fact that this deciphering is nothing else than *embodied interaction with the grid* does not become an object of Boulez’s analysis.

In order to make the distinction between absurdity and creative approximation palpable, Boulez gives an abstract example of a complex rhythmic task, with a surprising glimpse on the potential of embodiment for tackling difficult computational tasks. The task at hand involves the sequential performance of three irregular irrationals over three different durations. According to Boulez, the amount of mental operations if one were to perform the sequence as notated, that is if one were to “think three different temporal planes, subjacent temporal pulsations that are never expressed as such” (p. 88), makes the task at hand impossible. While the two first rhythms can be co-related as states and thus “thought”, the third becomes impossible to be correlated to the first and must therefore be mechanically reproduced by the fingers, without the need of a mental control mechanism: “The physical action of playing a certain number of notes being sufficient to establish the rhythm of the musical figure” (p. 88).

Boulez’s proposed solution is essentially a mediation technique known as *re-tempoing*: Each rhythm becomes representative of a different tempo, so that eventually performers only need to internalize a sequence of tempi.The urgent and instinctive question that arises here is: a) why then not have the composer notate this passage as the succession of three different tempi rather than three irregular irrationals and b) if the performative response following the first or second approach suggested by Boulez yields different sounding results.

While Boulez theorizes the above-mentioned challenges as challenges of brain computation, he does have an interesting comment on the actual realization, as an *Ersatz* of mental control. While Boulez does not elaborate on that, the implicit conclusion is that complex mental operations can partly be *outsourced* or *off-loaded* to the sheer physical action of playing, thus relieving the task at hand. The implicit solution to Boulez's problem is that actually both representations are possible through a *hybrid* of mental and embodied computations.

Summarizing: Boulez expresses stimulatingly contradictory views on notation and performance. Despite abstraction, notation integrates elements of potential *deconstruction* through a complicit accumulation of performative impossibilities and approximations. Despite the overall focus on computability and the brain, embodiment can assist with impossible mental operations. The platonic idea of music as structure encoded in symbols is affirmed, as is performance's interactive and deconstructive nature.

B. Embodiment As Discontinuity: David Tudor

Boulez's paradoxes as far as the relation of notation to performance is concerned - the structural clarity of the composer's ciphering versus the integrated failure of the performer's deciphering of non-absurd challenges that lie beyond possibility – seem to be echoed in David Tudor's accounts of his first United States performance of Boulez's notorious second piano sonata. The latter are to be found in Tudor's late interviews and become thematic in Holzaepfel's "Cage and Tudor", in the *Cambridge Companion* to John Cage[78].

According to Holzaepfel, Tudor was assigned at the very last moment the performance, originally intended by John Cage for his friend William Masselos. Despite his experience in dealing with scores of similar density, David Tudor found himself challenged in an unprecedented way. The reason of his trouble was not, as the Boulez "Time, notation, coding" lecture would have assumed, the complexity of specific tasks. It related to a more general category, which Tudor terms as "the

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[78] John Holzaepfel, (2002). "Cage and Tudor" in D. Nicholls (ed.),*The Cambridge Companion to John Cage.* Cambridge: CUP, pp. 169-85.

collapse of continuity" and the lack of musical directionality, as becomes evident from the following two passages:

"I'd always been well known for my ability to handle complex scores – it could be black as sin and I could still play it – but this time I found a sort of constant breakdown in the continuity . . . I became vitally concerned that it would be full of lapses and holes . . ." (Tudor 1972, p. 24)

"Boulez had written no counterpoints, no second voices, and you couldn't subordinate any voices at all, as there was nothing leading, nothing on which the music centered itself." (Tudor 1972[79], p. 24)

Rather than trying to discover some sort of thematic unity or directionality or ties to the tradition[80], David Tudor worked on the basis of *accepting* the radical discontinuity he sensed in Boulez's score as such. His decision and his means were at large influenced by the reading of Antonin Artaud's *Le Théâtre et son Double*[81], to which he arrived after a marginal reference of the revolutionary French writer, in an early Boulezian article by the title *Proposal* (1948)[82]:

"I think that music should be collective hysteria and magic, violently modern – along the lines of Antonin Artaud and not in the sense of a simple ethnographic reconstruction in the image of civilizations more or less remote from us. "(Boulez 1948, p. 54)

Most interestingly for our brief history of embodiment in the second half of the twentieth century, Artaud's *Theatre of Cruelty* evoked by Boulez promotes the violence of a disciplined but unreflective physical immediacy, which is to be grounded in the actor's unique embodied experience and breath, and not in the word of the written text. Crucially, it is this very somatic quality, termed "affective athleticism" by

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[79] Tudor, D. (1972). "From Piano to Electronics", interview quoted in Holzaepfel, 2002, p. 170.

[80] This approach is far from uncommon in Boulez's practice –one has but to read Claude Helffer's *Quinze Analyses Musicales* for a sample of pedagogical, some times even pedantic, but also fragmented clarity.

[81] Artaud, Antonin, *Le Théâtre et son Double,* Folio, 1985 (1938), translated in English by Tudor's partner Mary Caroline Richards as *The Theatre and Its Double*, Grove Press, New York, 1958.

[82] Boulez, Pierre 1948, "Propositions" ["Proposals"] in Boulez, Pierre 1991, *Stocktakings from an Apprenticeship*, ed. Paule Thévenin, trans. Stephen Walsh, Oxford

Artaud, which allows Tudor to experience the “lapses and holes” of the second sonata in a new way:

“All of a sudden I saw that there was a different way of looking at musical continuity, having to do with what Artaud called the *affective athleticism*. It has to do with the disciplines that an actor goes through. It was a real breakthrough for me, because my musical consciousness in the meantime had changed completely . . . I had to put my mind in a state of non-continuity – not remembering – so that each moment is alive. “(Tudor 1982[83])

The importance of this discovery for Tudor’s later development cannot be overstated:

“I recall this as a definite breaking point,” Tudor later said, “as the moment I became aware that another kind of musical continuity was possible, and from then on I began to see all other music in those terms” (Tudor 1982).

Tudor's confession communicates a performer-specific experience, namely the incomprehensibility of a complex score in the first phase of the learning process. What happens when the basis of understanding, and subsequently the one of technique, is in this way sabotaged? How is interpretation in the traditional sense still possible?

A later comment by Pierre Boulez does not shed much light in this aporia. In the booklet of a relatively new recording of his three piano sonatas, he states:

“Paavali Jumppanen [the pianist] has an understanding of the texts of these sonatas and the technical resources to play them [.] It's been interesting for me to see how someone who grew up in a different time conceives these pieces. For me they were steps in my development, a part of myself; for him they're an object he's found along his way, and he must deal with and make something of it.” (Boulez, 2005, p.7[84])

Not only does Boulez here explicitly refer to the traditional model of *understanding, technique and interpretation*, but he also foregrounds the model's basic aporia: The

[83] Tudor, D. (1982). Interview with Austin Clarkson, 4 October 1982, quoted in Holzaepfel, 2002, p. 171.

[84] Boulez, P. (2005) *The Three Piano Sonatas.* Paavali Jumppanen. Hamburg: Deutsche Grammophon GbmH. 00289 477 5328

allegedly objective and deterministic prerequisites of the notation (*understanding* and *technique*) still allow for the individual performer's subjective and indeterminate expressive space (*interpretation*). Paradoxically, this interpretative space seems to make no claims on Boulez's authenticity. The characterization of a work as a "found object" sounds quite extraordinary given Boulez's earlier predilections[85]. The inevitable question is: What exactly can the player really add beyond those objective prerequisites? What does interpretation mean in the context of a notation as fixed as Boulez's?

Boulez’s comment may well be read as a vivid indication of how traditional tropes of notation-based learning and performance remain mostly intact in contemporary performance practice, although postwar developments in composition clearly invite a shift of perspective.

C. The Performer’s Discretion: John Cage’s Music Of Changes

The notion of embodiment as discontinuity, independent from structural properties of the notation, would find its compositional fulfillment in Cage’s *Music of Changes* (1951), a work that according to Cage *was* David Tudor[86].

The combined use of rhythmic structures, charts and chance, through the ancient Chinese practice of the *I-Ching,* gave Cage the possibility to create a piece of equal, if not greater, complexity than Boulez’s Second Sonata. The correspondence[87] between Cage and Boulez is a testimony to the sort of fascination that the Second Sonata exerted in Cage’s decision to compose *Music of Changes*.

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[85] The performer is simply faced with the problem of this deciphering [of the compositional coding] and must try to transmit the message as faithfully as possible” (Boulez, 1986, p. 88)

[86] “As Cage suggested, “[a]t that time, [Tudor] was the Music of Changes” Cage, John and Daniel Charles (1981), For the Birds: John Cage in Conversation with Daniel Charles (London: Marion Boyars),p. 178. Cited in Iddon, Martin, *John Cage and David Tudor. Correspondence on Interpretation and Performance*, Cambridge University Press, 2013, p. 40

[87] Nattiez, Jean-Jacques, *The Boulez-Cage Correspondence*, Cambridge University Press, 1995

Another factor was definitely Tudor himself and what seemed to Cage as an infinite potential of realization.

One of the most troubling aspects of *Music of Changes* is not really the diversity and discontinuity of its materials, but rather its approach to time notation. The clash between time-space notation properties, formal time-structure and traditionally notated materials constituted a challenge, which urged Cage to leave the solution to the "performer's own discretion" (as asserted in the performance note of the piece). Tudor resorted to a series of preparatory computations, which would allow him to objectify musical time in the form of stopwatch indications.

The objectification of time in combination with the aesthetics of embodied discontinuity led Tudor to state in an interview:

"(in *Music of Changes*) I was watching time rather than experiencing it", while "in Boulez, the space seems to be in front of one, in one's line of aural vision, as it were; in your piece space is around one, that is present in a new dimension."[88]

Music of Changes, as much of Cage's later work for the piano, offers a unique example of composer-performer synergy: Tudor's initial insights as to discontinuity shaped Cage's musical language, which fed back into the pianist's elevated conception of *physical space* in performance.

D. Embodiment As Transcendence: Iannis Xenakis [89]

Embodied discontinuity as *affective athleticism* becomes the medium for Tudor's grasping of Boulez's *Second Piano Sonata.* In the work of Iannis Xenakis though,

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[88] 1951, quoted in Holzaepfel (2002)

[89] Some of the ideas presented here have been treated in my previous text Antoniadis, Pavlos (2011) 'Physicality as a performer-specific perspectival point to I. Xenakis's piano work. Case-study *Mists*'. Paper presented to the *I. Xenakis International Symposium 2011*, Goldsmiths University, London https://www.gold.ac.uk/media/documents-by-section/departments/music/07.3-Pavlos-Antoniadis.pdf accessed 06.05.2018

embodiment acquires a more literal sense of athleticism against a sheer physical challenge.

While the performance of Iannis Xenakis' work has today turned into an almost standardized rite of passage for many performers[90], it would be inaccurate to assume that the aura of Olympicism and achievement surrounding such undertaking has in any way diminished.

One of the most peculiar aspects of the Xenakian phenomenon is that notions of embodiment hardly seem to concern Xenakis himself. A reading of his *Formalized Music*[91] claims music as a purely cognitive phenomenon, a key to universal knowledge with important philosophical and spiritual connotations, whereby the question of human embodiment in general or performative embodiment in particular is hardly being treated. In the Preface of *Formalized Music,* we do read that the book's objective is to "consider sound and music as a vast potential reservoir in which a knowledge of the laws of thought and the structured creations of thought may find a completely new medium of materialization i.e. of communication" (p. ix). Music is, in other words, cognitive and of the mind.

In her panorama of testimonies of what she calls a "spiritual Confederacy of Xenakis Performers" (p. viii), Sharon Kanach[92] compiles exactly what only scarcely surfaces in Xenakis' own writings, that is consistent, detailed reports on the performance of his work. As far as Xenakis himself is concerned, testimonies of the performers who had the chance to work with him and selected excerpts from his interviews to Balint Varga[93] offer fragmented points of reference. Thus, such overview of a "practitioners' musicology" (p. ix) in Kanach's book becomes invaluable for the appreciation of the renewed position that embodiment assumes in Xenakis work.

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[90] Here comes to mind the percussion class of Stephen Schick at the University of California, San Diego, and the percussion group *red fish blue fish*: http://musicweb.ucsd.edu/about/about-pages.php?i=411 accessed 30.03.2018

[91] Xenakis, Iannis (1992). *Formalized Music*. Ed. S. Kanach. NY: Pendragon

[92] S. Kanach (ed.), *Performing Xenakis,* pp. 65-129, in *The Iannis Xenakis Series* vol. 2. Hillsdale, Pendragon Press, 2010

[93] Varga, Balint. *Conversations with Iannis Xenakis.* London:Faber and Faber, 1996

The notion of *self-surpassing* seems to be a constant in the testimonies of performers as well as in Xenakis's own biography: Anecdotal and official testimonies speak of a man who was a great athlete, always testing and challenging his endurance, measuring himself first against his own abilities before those of his competitors.

While Iannis Xenakis' references to performative physicality are far from common, the performer-specific language of interpreters who engage at all levels –mentally, physically, emotionally and in terms of live presence and interaction with his work- are far from scarce. One such prominent case is the contribution by the clarinetist Lori Freedman in Kanach's book[94].

Freedman's first person descriptions are excellent samples of what could be termed a *performer-specific language*. Her very first statement in the text clarifies what is the most salient characteristic of her interaction with Xenakis' music: *Visceral potency*. Rather than preparing in an 'outside time' domain[95] through analysis, contemplation and pre-meditation, Freedman asserts that the urgency of Xenakis' music requires more of what she terms "a primary construction: raw sound organized by time's most elemental feature, movement" (p. 3).

Freedman perceives embodiment rather as a site of liberation rather than a site of surpassing, as a vehicle for acquiring access to deeply ingrained somatic knowledge. Her points on the primordial essence of clarinet playing ("Big Breath"); the "construction" of one's physicality around the work; the extremity of the required tasks in terms of embouchure, strength and stamina, register leaps and sudden dynamic contrasts (the sort of challenges that Boulez had in mind when describing

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[94] Lori Freedman, "Potent", in S. Kanach (ed.), *Performing Xenakis,* pp. 65-129, in *The Iannis Xenakis Series* vol. 2. Hillsdale, Pendragon Press, 2010, p. 1-10

[95] Reference to the composer's famous distinction between 'inside time' and outside time', elaborated in several texts in his *Formalized Music.* For a concise overview of the concepts, refer to: Exarchos, Dimitris, "Temporality in Xenakis and Ferneyhough", *The Journal of Music and Meaning*, ISSN 1603-7170, http://musicandmeaning.net/articles/JMM13/DimitrisExarchosJMM13.pdf accessed 11.05.2018

his intentional impossibilities); and the various extended techniques, are all elements hardly transmissible from composer to performer or among performers themselves. They rather are the fruit of a highly individualistic ritual of exploration of the self.

One of Freedman's more original contributions is the *integration of improvisation* in her learning rituals. This practice binds her views on visceral potency and her proposal of an almost *materialist processing* of the musical score, its treatment as an interface rather than as the compositional idea *per se*. The fact comes as a surprise, if one takes into account Xenakis' dismissal of improvisation in his *Formalized Music*. For Freedman, improvisation becomes a medium for the exploration of a hidden, primordial musical idea, not however one which would lie in the platonic realm of physics or mathematics, but rather one which is deeply rooted to the performer's body: "the transcription of gestural mannerisms into my own clarinet language and vocabulary to serve as springboards from which to create momentum and flow in the resulting music: sound moving through time" (p. 8). This could be in itself a very apt description of Martin Zenck's notion of the "corporeal subtext" as cited previously.

Leaving for the moment aside Freedman's inspired and unique contribution, we would like to summarize the panorama of testimonies from Xenakis' renowned performers in Kanach's book. As often is the case with contemporary performance practice scholarship, I was struck by the position physicality holds in the keyboard performers' discourse: *Extreme physical effort*, as integral part of a "*philosophy of surpassing*" on the one hand, or a *mind-centered, disembodied approach*, which prioritizes an objective understanding of the Xenakian sonic image on the other, seem to predominate. The two poles, contradictory as they may seem, are actually complementary and reflect the traditional dichotomy between Technique and Interpretation (and its own aporias). A danger of further mystifications regarding physicality, through either quasi-athletic fetishization or through its sheer absence from the discourses, is here palpable. In the fourth part of this dissertation (case studies), I will attempt to elaborate in a different understanding of performative physicality, as the performers' *per se* mode of existence *inside* Xenakis' work, using *Mists* (1980) as my case study.

Association of physicality to extremities and effort forms an unquestioned consensus between scholars, performers, and more importantly the composer himself. In the context of his reference to what he calls the Xenakian "ecstatic gesture", Makis Solomos writes: “Xenakis aims at sheer physical pressure. [..] the performer is being asked to realize a feat”. And also: "With Xenakis, since it is impossible to tell the "wrong" notes, virtuosity is measured as pure consumption of physical energy"[96]. As for the performers, we can't find a single one who wouldn't attest to what Claude Helffer very successfully calls "a philosophy of self-surpassing"[97]. Marie-Françoise Bucquet's comment on performing *Evryali* sounds like an echo of Solomos' previous quote: "It is not a question of catching one's breath, but of finding enough consumable energy within one's own body"[98].

Xenakis has clearly been very conscious about triggering this utopian drive of performance, a kind of expression resulting from the sheer strive to realize the unattainable. This can be easily deducted from his own testimonies- for example his interviews to Balint Vargas[99]- or some of his performance prefaces to notoriously difficult works, like the piano concerto *Synaphaï* :"The pianist plays all the lines, if he can"[100], in an explicit invitation to the impossible.

As for the other pole evident in the piano performers' contribution, the *disembodied approaches*, those could be epitomized by Stephanos Thomopoulos' ending lines on learning *Synaphaï*: "The pianist must be prepared to deconstruct his/her physical reflexes in relation to the keyboard.[..] Xenakis keyboard can never be considered as physical space in association with the physiology of one's hands, nothing is there to reassure or stabilize one's physicality"[101], echoing Xenakis' own anecdotal saying: "music is not realized by one's hands, but by one's brain" (Kanach 2010, p. 121). Other disembodied examples of performers' discourse are plentiful, ranging from traditionally analytical approaches to descriptions of the learning processes mostly

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[96] Solomos, Makis. *Iannis Xenakis. To syban enos idiotypou dimiourgou*. Alexandria: Athens, 2008. p. 157 (Translation in Greek of Solomos, *Makis. Iannis Xenakis.* Paris: P.O. Editions, 1996)

[97] Claude Helffer, “On *Herma*, *Erikhthon*, and others”, in Kanach 2010, p. 112

[98] Marie-Françoise Buquet, « On Evryali », in Kanach 2010, p. 69

[99] Varga, Balint. *Conversations with Iannis Xenakis.* London:Faber and Faber, 1996

[100] Xenakis, Iannis. *Synaphai pour piano et orchestre.* Paris: Salabert, 1969. [musical score].

[101] Stefanos Thomopoulos, “The Olympian Piano: Iannis Xenakis’ *Synaphaï*”, Kanach 2010, p.127-128

involving mental work away from the keyboard. Roger Woodward's learning account of the piano concerto *Kekrops*[102] is very characteristic in that respect, bringing to mind Leimer's and Gieseking's ideas on memorization as exposed in their *Piano Technique* (1972).

The suggested "deconstruction of physical reflexes and of keyboard space" is a latent manifestation of what New Complexity theorist Frank Cox has called a "High-Modernist Model of Performance Practice", assuming a“ [..] “noise-free”, transparent relationship between all elements of the communicative chain [between conception, notation, performance and reception]”(Cox, p. 71), and against which New Complexity allegedly provides a paradigm shift. A fully deterministic notational image is assumed able to fully represent the sonic phenomenon, and dictate concretely specified tasks to the performer, turning physicality into a *transparent tool* (what Heidegger would call *equipment ready-to-hand*[103]).

This is also the context, from which attempts of "para-human" realizations, heavily rejected by Xenakis himself, are trying to draw their validity: "None of the present compositions is really capable of being interpreted "correctly" [..], which triggers "the desire to hear a composition exactly as Xenakis had in all probability imagined it", writes Tom Sora, in the booklet of a CD of MIDI realizations of Xenakis’ keyboard works by Daniel Großmann.[104]

If the body is indeed considered as a transparent tool for interpretative purposes in Thomopoulos’ sense, I cannot see the reason for not considering para-human renditions as completely legitimate (other than a generic notion of human fallibility, which results in striving as expressive element). But it is exactly Xenakis' paradoxical and ingenious ambivalence, *the production of a complex disembodied score to be physically attempted*, which not only invites a *reconstruction* of physical reflexes (in

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[102] Roger Woodward, “Conquering Goliath : Preparing and Performing Xenakis’ *Keqrops*”, in Kanach 2010 p. 129-158

[103] Heidegger, Martin. *Being and Time.* trans. J. Macquarie. Oxford: Blackwell, 1962 [1927].

[104] Sora, Tom.“Komplexität-Unspielbarkeit-Werktreue” in *I. Xenakis Music for Keyboard Instruments, Solo piano and solo harpsichord works realised by computer,* D. Grossmann: MIDI programming [CD Booklet] EOS Music GmbH 10707.2008.

place of Thomopoulos' deconstruction), but also grants them with the possibility of an elevated ontological status.

E. Navigation As A Formal Model: Boulez 3ème Sonate

While the Xenakian opposition to serial determinism produced works that combine probabilistic results with visceral embodiment, the serialists themselves, indirectly addressing the very essence of the early Xenakian attack against them in *Gravesaner Blätter*[105], were not too late to acknowledge that formal renewal could only pass through chance operations of some sort. Paul Griffiths has dedicated the seventh chapter of his book *Modern Music and After* to the emergence of *mobile form: 1956-1961*, as one of the landmarks, which bridge the early gap between the total serialism of Boulez's *Second Sonata* and the chance and charts techniques of Cage's *Music of Changes* as explored above:

By the mid-1950s, however, many of the most prospering musical developments in Europe—Stockhausen's concern with statistical events, Boulez's pursuit of open form, extensions of instrumental and vocal technique by Berio and Mauricio Kagel almost everyone's effort at electronic music and so at ways of composing un-tempered sounds—were making Cage seem far more relevant than could have been the case earlier [106].

One of the monumental works of this tendency in modern music was the third and last piano sonata by Pierre Boulez. Its differences from the monumental, Beethovenian in scope and fabric, second one cannot be overstated, even more so since Boulez has dedicated one of his seminal texts ("Sonate, que me veux-tu? / Sonata, what do you want of me?"[107]) to the former.

The text starts by addressing directly the subject of mobile / open form and navigation:

"Why compose works destined to be renewed at each performance? Because a development that is fixed in a final way has struck me as no longer coinciding exactly with the current state of musical thought, with the very evolution of musical technique, which it must be recognized is turning more and

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[105] Xenakis, Iannis. "La crise de la musique serielle", in *Gravesaner Blätter* Nr.1 (1955): pp 2-4

[106] Paul Griffiths, Modern Music and After, 3rd Edition, Oxford University Press, 2010, p. 107

[107] Pierre Boulez, 'Sonate, que me veux-tu. Third Piano Sonata', in *Orientations*, p. 143-154

more toward the search for a relative universe, toward a permanent discovery-comparable to a "permanent revolution". A deeper investigation of this point of view is my real motive, more than a simple, rather banal preoccupation with rebaptizing the ear each time according to a certain innocence." (p. 143)

As also hinted at in his *Penser la musique aujourd'hui*, it is exactly the evolution of the language itself which cannot anymore fit in the "old molds", in the classical forms of the past:

"The task of placing the formal possibilities of music on an equal footing with morphology and syntax seems more and more urgent; fluidity of form must integrate fluidity of vocabulary" (p. 144).

The resolution of this tension between content and form is to be found in the rejection of the classic mono-linear forms in favor of *labyrinthine forms to be navigated*:

"What we must do from now on [..] is stop regarding the work as a simple trajectory, traced between a point of departure and a point of arrival. Euclidean geometry tells us that a straight line is the shortest way between two points; that is more or less the definition of Classical Western music, with its predilection for the closed cycle"(p. 144-145).

"Contrary to classical procedure, the most important recent notion, as I see it, is that of the labyrinth, which has been introduced in to creation. I already hear the facile witty objection that will surely be raised: to move about in these labyrinths would require numerous Ariadne's threads, and note very one feel she has the calling of Theseus! But never mind! The modern notion of the labyrinth in works of art is certainly one of the most important leaps accomplished by Western thought-one from which there is no return."(p. 145).

Boulez's models and inspirations for such renewal are not to be found in his contemporaries, for example John Cage (at least not explicitly), but rather in the innovations of modernist literature: James Joyce, Franz Kafka, and above all Stephane Mallarmé's *Un Coup de Dés*[108]:

"To me, the labyrinth notion in a work of art is rather like Kafka's *The Burrow.* Everyone creates his

[108] Mallarmé, Stéphane, *Un coup de dés jamais n'abolira le hasard*, Armand Colin, *Cosmopolis*, mai 1897 (T6 N17), p. 417-427

own labyrinth; he cannot move into one that already exists because it is impossible to conceive of an architecture not related to his own secretion. One builds it exactly as the subterranean animal builds this burrow so admirably described by Kafka: resources are constantly shifted about so that everything can be kept secret, and new routes are forever being chosen to mislead. Similarly, the work must provide a certain number of possible routes, thanks to these very precise devices, with chance playing a shunting role at the last moment." (p.145)

Interestingly enough, Boulez is fast in clarifying his differences to Cagean chance:

"[..] this notion of shunting does not belong to the category of pure chance, but in that of non-determinate choice, and this difference is fundamental; in a construction that is as ramified as works written today, there could not possibly be total indeterminacy, for such a phenomenon is contrary—absurdly so- to all organizing thought and to all style. This being so, the work will be made to surrender even the physical aspect it had assumed previously. This is how, step by step, after upsetting the musical conception, one is obliged to reconstruct the way the score is presented physically."

Boulez's emphasis on "the way the score is presented physically" sounds already quite far from his earlier structuralist views on notation and the superiority of symbolic to graphic structures on paper. In order to appreciate more the quality of this shift, we have to take a closer look at what constitutes his ultimate model, Mallarmé's *Un Coup de Dés*:

"Typography had to undergo a metamorphosis for Mallarmé. The "composition in book-form" of *Un Coup de Des* is a basic, fundamental necessity in which typefaces are even more important than the disposition of the text by pages, including its spatial distribution and the blanks paces. The intellectual armature of the poem is concealed and is contained--occurs—in the space that isolates the stanzas and within the paper's whiteness; meaningful silence which is as beautiful to compose as verses, "as Mallarmé himself says. He also writes: "The poem is being printed at this very moment, just as I conceived it regarding pagination, in which lies the whole effect. Such-and-such a word in large type requires an entire blank page by itself, and I believe I may count on the effect.[..] The constellation will inevitably suggest, according to exact laws and to the extent that a printed text can do so, the look of a constellation. The vessel lists, from the top of one page to the bottom of another,[...] for (and this is the whole point of view involved) the rhythm of a sentence about an action, or even about an object, has no meaning and, represented on paper, reproducing in letters the original image, cannot give any account of them at all unless it imitates them [..] Mallarmé speaks in it of a "spacing of the reading" and says specifically: "The paper takes over every time an image, of its own accord, stops or withdraws, accepting the succession of others, and since what is involved, as always, is not regular sound patterns or verses, but rather prismatic subdivisions of the idea, the moment they appear and as long as they make a contribution, in an exact intellectual staging, the text commands attention at variable spots, more or less closely related to the underlying connective thread, according to verisimilitude. "He considers" the page [. . .] as a unit, just as elsewhere the verse or perfect line is so considered." Then he observes:" The difference in typeface between the predominant motif, a secondary motif, and subordinate ones determines what importance it should be given when read aloud, and position in them idle or at the top or bottom of the page will indicate whether intonation should be rising or falling." My quoting at such length is easy to understand: Mallarmé expresses himself with such precision that a paraphrase of these admirable lines would have been completely useless. This kind of arrangement-formal, visual, physical, and, on top of everything else decorative - had stimulated me to search for musical equivalents" (Boulez, p. 146-147).

The excerpt is stunning, not only in the clarity in which it lays out the model for Boulez's *3ème sonate*, but even more so in comparison to his earlier text. Boulez has travelled a considerable distance, from a view of notation as abstract, symbolic, disembodied language which makes its earlier neumatic and graphic forms redundant on a neurochauvinist basis, up to the appreciation of the "decorative, formal, visual and physical" in the period of only seven years! Our review of several strands of embodied and extended cognition on the second section will come to reinforce Boulez's later position.

Boulez goes on to describe in considerable detail the *Formants* of his sonata, of which he gives greater emphasis to *Constellation-Mirroir*:

"Certain directions are obligatory, others optional, but everything has to be played. In some ways, this Constellation is like the map of an unknown city (which plays so large a role in *L'Emploi du Temps*, by Michel Butor). The itinerary is left to the interpreter's initiative; he must direct himself through a tight network of routes. This form, which is both fixed and mobile, is situated, because of this ambiguity, in the center of the work for which it serves as a pivot, as a center of gravity" (p. 151).

While Boulez is avoiding any reference to the performative physicality –something which is after all characteristic of, for example, Brian Ferneyhough's similar predilections for path searching and prioritization processes-, it is however the very procedural, dynamic and extended nature of this navigation which grants performers with a different role than the one hitherto assumed in the history of western classical music: the role of co-creators of the final shape of the musical work in time.

F. Virtuosity As A Dress, Not As A Straightjacket: Berio's Sequenzas

If the inscription of multiple possibilities of performative exploration is attempted in Boulez's mix of open and fixed form, it is the primordial mobility of the virtuoso, together with the re-inscription of Brechtian theatrical elements (the notions of *Verfremdung* and *Gestus*), which grant Berio's *Sequenzas* with a central position in the history of post-1945 embodiment. As Griffiths puts it,

"All the *Sequenza* pieces are composed performances: What also distinguishes the earlier pieces, especially those for voice and for trombone, is that the performance are theatre as much as music – that they belong with the music theatre of the time"(Griffiths, p. 211).

The *Sequenzas* are a collection of virtuoso pieces that explore the capabilities of a solo instrument and its player. They are "making extreme technical demands of the performer, whilst developing the musical vocabulary of the instrument in compositions so assured and so distinctive, that each piece both initiates and potentially exhausts the vocabulary of a new genre"(Janet K. Halfyard, p. xix)[109]. The collection addresses issues of performer-specificity in the sense of embodiment through the fact that "sequenzas are rather notated performances". At the same time, they constitute a cornerstone in the exploration of extended techniques, theatricality of performance (through the Brechtian elements), modularity and commentary (through their considerable re-workings and extensions in the *Chemins* series).

One of the most interesting aspects of the *Sequenza*, one that apropos will also become central in the creation of Helmut Lachenmann, is the *recontextualization of musical gesture*, the inevitable historicity and the compositional task of "emptying-out" the gesture's inherent historicity. As Berio himself puts it:

[109] Janet K. Halfyard, *Berio's Sequenzas : Essays on Performance, Composition and Analysis*, Ashgate Publishing Limited, 2007

“One cannot invent a gesture entirely anew, because it always implies a relation with the diverse histories and customs, both social and expressive, that cohabit within it. The gestures of Brechts epic theatre are in part inhabited by the gestural repertories of silent cinema and Noh theatre.[110]

Another interesting aspect of some of the *Sequenzas*, central to a number of seminal performance studies, is Berio’s time-space notation (for example in *Sequenza I*) and its later revision with a fully notated version. To be sure, Umberto Eco lists the Sequenza alongside Stockhausens *Klavierstück XI* and other works of the period that offer a multiplicity of interpretations, based on the performers’ choices[111]. Thomas Gartmann considers this inclusion of Berios work in this list as “a terrible misunderstanding“ of Berio’s intent[112]. And Berio rather confirms this impression:

“At the time I wrote *Sequenza I* in 1958 I considered the piece so difficult for the instrument that I didn’t want to impose on the player specific rhythmical patterns. I wanted the player to wear the music as a dress, not as a straightjacket. But as a result, even good performers were taking liberties that didn’t make any sense, taking the spatial notation almost as a pretext for improvisation. Certainly some sort of flexibility is part of the conception of the work. But the overall speed, the high amount of register shifts, the fact that all parameters are constantly under pressure, will automatically bring a feeling of instability, an openness which is part of the expressive quality of the work –a kind of a “work in progress” character if you want”.[113]

It is interesting to note again, comparing to Boulez’s early text, how extreme virtuosic feats are deemed capable of destabilizing and “opening” the notated musical form. This thread will return in a different guise in the performance of complex music, under the negatively connotated term “energetic striving” by Frank Cox.

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[110] Luciano Berio, ‘Du geste et de Piazza Carità’, La musique et ses problèmes contemporains, Cahiers Renaud-Barrault 41 (1963), reprinted in a revised Italian Version in *Sequenze per Luciano Berio*, Milano 2000, p. 255-257

[111] Umberto Eco, L’opera in movimento e la conscienza dell’ epoca », *Icontri Musicali 3* (1959) : 32-54, translated by Anna Cancogni as *The Open Work* (Cambridge, 1989).

[112] Thomas Gartmann „Das neu erschlossene Kunstwerk: Luciano Berios Überarbeitungen der Sequenza, in Kathrin Eberl and Wolfgang Ruf Musikkonzepte – Konzepte der Musikwissenschaft. *Bericht über den Internationalen Kongreß der Gesellschaft für Musikforschung Halle (Saale)* 1998 (Kassel, 2001), vol.2, p. 611

[113] Theo Muller, « Music is not a Solitary Act » : Conversation with Luciano Berio, *Tempo,* 199 (1997), p. 19

G. Towards A Performance Practice For Complex Music : Franklin Cox

In his influential article "Notes Towards a Performance Practice for Complex Music"[114], Franklin Cox, an American composer, cellist and theoretician, presents us with an elaborate analysis of performance in "New Complexity". Cox's account of the new challenges is measured in relation to what he terms the "High-Modernist Model of Performance Practice" (from now on abbreviated as " hmmpp"): " [..] A "noise-free", transparent relationship between all elements of the above mentioned communicative chain [between conception, notation, performance and reception]"(Cox, 2002: 71).

The hmmpp elaborates on the idea of a fully deterministic score-image. Such notation is considered able to enclose every possible characteristic of the sonic phenomenon it represents. As a result, it is supposed to assign concrete tasks to the performer and well-defined perceptual tropes to the listener. Cox suggests that complex music has brought about a "fundamental paradigm shift" away from that model. The reason is its purely quantitative characteristics, namely*:* "[..] extreme degrees of both density and fine detail, and [..] coalescence of highly rationalized materials, notated challenges and organization with an extreme physicality and almost irrationality of results" (2002:70). The paradigm shift consists in the transformation of the above mentioned communicative chain into "[..] an overlapping series of volatile conflicts between incompatibles. Thus, notation is treated as an essentially opaque medium, (to paraphrase Derrida, notation is always already "writing", with all its historical sedimentations) and such notation demands less reading than decipherment" (2002:76).

Cox's response to this perceived shift is contradictory. On the one hand, he suggests three major revisions of the hmmpp: He acknowledges the legitimacy of a properly interpretational level independent of the purely technical skill in the performance of

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[114] Cox, F. (2002). "Notes Toward a Performance Practice for Complex Music" in Claus-Steffen Mahnkopf, Frank Cox and Wolfram Schurig, eds.: *Polyphony and Complexity, New Music and Aesthetics in the 21st Century*, i. Hofheim: Wolke Verlag, pp. 70-132.

radical complex music (2002:102); he perceives performance as part of a project of responsible translation between the incompatibles of the communicative chain (2002:103); he is calling for the substitution of the concept of an *absolute performative solution* with one of *varying degrees of tension and resolution* (2002:106-107). On the other hand, his practical suggestions reveal a re-tuning into the hmmpp task-oriented perception: Tasks and challenges of an even higher order, requiring equally heightened abilities and training, are outlined as the necessary counterpart to his previous ideas (2002:103, 109-118). To our mind, this acknowledgement of a vague “interpretational level”, to be followed by the absolutist management of tasks and challenges, is a return of the traditional Technique/ Interpretation dichotomy. It is thus, in practical terms, contradictory to the claimed paradigm shift. Moreover, it still adheres to a highly internalized and quasi-biological super-human development concept. The difficult tasks have to be patiently tackled with intelligence and moral will power, as has ever been the case. As for the body, its role is clearly subservient: It has to tune into a model and burn it into “muscular memory”. The fundamentally Cartesian idea of a mind in absolute control of its storage system and tool is here fully at work.

The concluding part of Cox’s article, though, does bring fresh considerations as to the role of embodiment. In the beginning of this last section, Cox acknowledges that the sets of tasks he has actually dealt with thus far are corresponding to their traditional equivalents (2002:118) and sets off to define those, which distinctly break into new territory. Their novelty is defined as such: “They can almost certainly provide no useful ‘sound-image’, because many of the [score] indications specify not specific types of sounds towards which coordinated physical movements are oriented, but rather different types of independently-organized physical movement whose sonic outcome is the result of their interaction.”(2002:122-123). The treatment of these elements as distinct parametrical strata in the compositional and notational practice of figures such as Frank Cox himself, Klaus K. Hübler, Wieland Hoban, Aaron Cassidy and others, yields very challenging and finely differentiated, still sonically unstable and unpredictable results. The major point here is that this conception “open[s] the possibility of a new sort of ‘embodied’ thinking transcending means/ends oriented training (for example, of traditional virtuosity) [….] and value[s] that which is so consistently denigrated in Western philosophy -the physical body and physical motion- without fetishizing the physical domains in expense of the mental/ideal (2002:129). He goes even further as to suggest that: “A fitting thought-experiment would be that of treating human bodies and physical motion as though they were potentially self-conscious.” (2002:129). With this last proposition, not only does the physical body enter the score-representation as a legitimate compositional factor, but its ambivalent ontological position in relation to consciousness turns into a theme of compositional reflection.

H. The Body Stratified: Klaus K. Hübler

Expanding String Technique[115] is an influential text by the German composer Klaus Karl Hübler. In his preliminary remarks on the *Geist* (spirit) of instruments, Hübler hints at the disregard of the instrument and its limitations by both serialists and Lachenmann. According to Hübler, their progressive rejection of the traditional instrumental technique and performance style has been a rather deplorable development. Hübler thinks instead of “an expansion of sound and technique that has its roots in the specific resources of the instrument and its manner of performance”(p. 233). The instrument and its affordances are positioned at the center of a positive expansion of the possibilities from the “polyphonic production of tones” (p. 233). Hübler meticulously examines both right hand techniques (bowing), as well as the left hand finger positioning, in the form of tablatures for handgrips. The most interesting characteristic of his proposal is the decoupling of parameters, which in traditional technique are considered as coupled, in order to produce a “good tone” or a “good rhythm”. Those parameters are in Hübler *decoupled*, so that the final sounding result of conflicting independent actions is indeterminate. Such actions include: String change without necessarily horizontal bowing accompanying it; rhythmic independence between bowing movement and movement of the fingers; parametrical handling of the point of contact of the bow and the types of bowing. All these actions are noted in different staves. The result is a stunning polyphonic treatment of the actions, which very often reminds of serialist stratifications of sonic

[115] Klaus K. Hübler, « Expanding String Technique », in Claus-Steffen Mahnkopf, Frank Cox and Wolfram Schurig, eds.: *Polyphony and Complexity, New Music and Aesthetics in the 21st Century*, i. Hofheim: Wolke Verlag, pp. 233-244.

parameters. Such polyphony brings about a *de facto* deconstruction of the idiomatic, organic, historically situated string gesture.

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One of the most original contributions by Hübler is the use of a stopping technique based on the handgrip. The composer must manually assimilate such techniques by working on the instrument. The tablature technique is judged as exceptionally well-suited to enabling syntheses and mediations between result-oriented and action composition. The use of different dynamics for different action-layers influences the dynamic and timbral result alike.

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In his afterthoughts, Hübler stresses the need for a compositional imagination that shuttles back and forth between the concept and the materiality of the instrument. The instrument confronts the composer with a source of resistance to a degree impossible to determine in advance, since the writing specific to the instrument requires a higher degree of penetration into the purely physiological aspects of its treatment. Permanent tension between the instrument and the intention reaffirms the primordial relationship between instrument and composition.

Hübler’s ideas on the primordial meaning of the instrument and the stratification of action as definitive of the sound result form one of the main sources of inspiration for the model of embodied navigation of complex notation, both in its representational (tablature) and in its enactive forms through interactive systems. It is also worth noting, how such centrality of the instrument resonates with the latest developments in the field of interaction in computer music, notably the research on New Interfaces / *Nouvelles Lutheries*.

I. Towards Complex Somatics : Brian Ferneyhough [116]

Ferneyhough's work has been important not only for the embodiment of complexity, but also for a constitution of the musical body beyond its image. As far as visuality is

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[116] Parts of this chapter have been included in my published chapter « Corps, que me veux-tu ? Embodiment and Visuality in Post-1950 Music », in Sarah Posman, Anne Reverseau, David Ayers, Sascha Bru, Benedikt Hjartason (eds.) *The Aesthetics of Matter. Modernism, Avant-Garde and Material Exchange*, Walter de Gruyter Berlin/Boston, 2013, pp. 319-334.

concerned, both his notation of impenetrable graphic thickness and his collected writings seem to contradict claims for a conscious iconoclasm on his part. His writings are pervaded by persistent iconologies[117], concepts with an obvious visual origin, such as *the figure*, and explicit influences from the visual arts -predominantly Francis Bacon's and Giambattista Piranesi's work[118]. At the same time, "bodily comportment" in the form of expressive musical gesture is explicitly criticized as a means to stylistic regression[119]. How could someone plausibly claim that embodiment is central in Brian Ferneyhough's music, transcending and problematizing the notion of visuality, or body image?

Our arguments revolve around three distinct themes, with their epicenters located in respectively three of Ferneyhough's theoretical texts, namely:

a) The development of *a perpetually refinable navigational model* and the *psychologizing of virtuosity* on the part of the performer, as a result and ideological trait of notational complexity (in his “Aspects of Notational and Compositional Practice”, *CW*, pp. 2-13).

b) The poetics of *time as palpable somatic presence* against musical events or objects (in “The Tactility of Time”, *CW*, pp. 42-50).

c) The poetics of *discursive, form-generating energy*, as exemplified in the discussion of *the figure* in relation to *the gesture*; thus the nature of musical events or objects themselves (in his “Il Tempo della Figura”, *CW*, pp. 33-41).

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[117] A telling example: "One point of departure for an iconology of compositional activity: the representation of the act of composition as a polyphonic membrane, whose scale of resonance encompasses and reflects the common ground linking the several interlocking connotational complexes making up the nature of composition as signifying action in the widest sense of the term", *Brian Ferneyhough: Collected Wrtings*, 3.

[118] Next to works like *La terre est un homme*, based on a canvas by Matta, or *Lemma-Icon-Epigram*, stemming from Walter Benjamin's emblem speculations, and many more: "Many of my works of the last fifteen years have been engendered by contact with some form of concrete image". *Collected Writings*, 131.

[119] A sort of "pavlovian semanticism", characterized by "transparency of the musical sign [..] to emotive intentionality". *CW,* 23.

These three themes constitute traces of an *invisible somaticity*, which grants Ferneyhough's work with a paradigm-shifting position in the recent history of body-discourses in music.

Aspects of Notational and Compositional Practice

I start the exploration of *somatics* in Ferneyhough's work with some reflections on the implications of his notational ideology[120] for performance, and in particular, for performative embodiment.

Complex notation is a startling graphic feature of Ferneyhough's scores, but its quantitative aspect should not be misleading as to the qualitative effect of this conscious compositional choice. As Richard Toop puts it, complexity is a state, in which

> "there are not necessarily many things, yet in which I sense many levels of relationships between the few or many things".[121]

The distinction is crucial for performance: While a sheer focus on graphic impenetrability would -and often does- result in the type of "heroic" performative attitudes to complexity, which Frank Cox has characterized as "energetic striving"[122], Ferneyhough's "total textural homogeneity", "degree of performative difficulty as relativizing filter" and "internal polyphony" (*CW*, 5-7) are explicitly inviting a radical rethinking of performance. In the place of *understanding, technique and interpretation,* Ferneyhough proposes a refined *navigational model* and an embodied exploration of notational *affordances*[123] on the part of the performer :

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[120] "An adequate notation must (should) incorporate [..] an implied ideology of its own process of creation". *CW*, 4.

[121] Toop, Richard, "On Complexity", in: *Perspectives of New Music*, 31, 1993, 42-57. Here p. 48.

[122] "the raw gestural energy and the large-scale vectors and formal shapes" assumed to be more powerfully realized through intuitive rather than analytic (or *navigational* as I will be suggesting) approaches. In Cox 2002, p. 69

[123] meaning "the constraints placed upon and the potential for action contained in the specific matrix which each self-consistent notational system offers"(*CW* 3). It is exactly this potential for action which urges me to suggest terms such as *navigation* and *affordances*, pregnant with connotations in the field

" A notation which demands of the performer the formulation of a conscious selection-procedure of [..] the information [..] and a determination of the combination of elements (strata) which are to be assigned preferential status at any given stage of the realization process". (*CW*, p. 4).

Although Ferneyhough's description never fails to stress the internal, mental, conscious component of this performative approach, there is a muted but crucial implication I would like to bring to light: when the causal chain between understanding, technique and interpretation is explicitly problematized in the ways described above, both qualitatively, as multiplicity of "paths", layers and relations to be performatively explored, and quantitatively, as sheer informational explosion in the problematized notational interface, inviting "energetic striving", then the performative body cannot anymore assume the traditional role of a transparent means to a disembodied end. The break of this chain automatically questions the watertight distinction between the mind and the body of the performer and, practically as well as ideologically, it craves an *embodied cognitive* model to performance: a model, that is, whereby the suggested exploration of paths, layers and multi-parametrical relations is realized by thinking bodies and embodied minds alike.

The Tactility of Time

Ferneyhough's Darmstadt lecture “The Tactility of Time” presents his unique strategies for producing and manipulating a tactile *presence* of time. Ferneyhough justifies the metaphorical use of the term *tactile* for temporal perception with reference to common practice:

"We have sufficient frequent recourse to physical, bodily analogies when referring to musical events for such an extension to have some inherent intuitive plausibility",

bringing as further examples the commonplace association of loudness with weight and the less known definition of silence as a contextually defined empty class by Webern (*CW*, p. 43).

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of embodied cognition, originating in J.J. Gibson's *Ecological Theory of Perception* as will be shown later.

According to Bob Snyder, in a chapter of his *Music and Memory*[124] dedicated to musical metaphor, such ways of speaking about music are far from arbitrary rhetorical tropes to assist communication: Research in cognitive linguistics has argued that metaphorical language is rather *constitutive* of our concepts than mere embellishment, indicating the firm grounding of musical phenomena in

"fundamental embodied cognitive structures generalized from recurring physical experiences, especially the experience of our own bodies". (Snyder, p. 108)

Those are often referred to as "image schemas" and, interestingly enough for our argumentation over a non-visual embodiment,

"they are different from either visual images or abstract concepts [because] they can have a kinesthetic component and represent muscular sensations in relation to particular experiences; they can have a particular physical 'feel' to them." (Snyder, p. 108)

Although Snyder refers to basic image-schemas central to musical experience[125], Ferneyhough's strategy of producing and exploiting the suggested tactility of time is explicitly assumed to relate to a basic form of experience, namely

"the relationship established between the body's somatic condition and the mediating metric lattice. We perceive of this latter as being 'fast' or 'slow' according to our bodily condition" (*CW*, 43).

It is this fact that fuels his interest for

"the creation of fore-, middle and background transformations which would evince different somatic densities"(*CW*, 44),

through the *complex layering of temporal frames in relation to sovereign, resistant musical objects.* The nuts and bolts of Ferneyhough's techniques, as employed in his work *Mnemosyne* for bass flute and tape, reveal a dazzling interplay between three layers in transformation: the slow-moving temporal background of the tape, the subcutaneous rhythmic models of the live flute part -a click track constantly clarifying

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[124] Snyder, Bob, *Music and Memory: An Introduction*, Cambridge, Massachusetts, 2000, 107-120.

[125] Gravity and tension, centrality, motion-linkage-causation, path and goals and containment, are the basic image-schemas according to Snyder (after Johnson, Mark, The Body in the Mind, Chicago, 1987).

this sort of metric contextualization for the performer- and the interruptive nature of three independently notated lines to be pursued by a monophonic instrument. The metaphorically described result of

"time frame becoming rather gluey, standing apart and offering relentless resistance to linear energies" (*CW*, 45),

is further explicated through resort to an even more specific form of bodily experience:

"[..] a dream of attempted escape from some unnamable fear in which our feet are caught in some substance such as glue or molasses, so that it's a tremendous, step by step effort to keep moving", *CW*, 45).

A rather unique element of Ferneyhough's aesthetic agenda may have already become clear by now: the organizational vigor of his materials and the array of strategies for stratification and deconstruction seem to fervently avoid the impasse of a neo-serialist, disembodied and abstracted obsession for order and for sonic exploration *per se*. The vehicle for this is their pervasive grounding on the embodiment of perception, an embodiment moreover utterly disengaged from visuality. The production of a particular 'feel' is not intuitively pursued, but is consciously triggered and manipulated through the most sophisticated and often artificial (for example a three-voice polyphony to be accomplished by a monophonic instrument) compositional tools. One might even go as far as to say, that Ferneyhough doesn't invent another musical language, but fosters new understandings of what sort of an experience music *can* be, while never leaving the basic ground of '"music itself [as] one form of metaphor that may express image schematic implicit knowledge"[126]. That’s why after all he *can* and *does speak* about his music: because of its explicitly embodied background.

Il Tempo della Figura

After the focus on *embodied navigation* fostered by notational complexity and the perceived *tactility* of temporality in its interaction with musical objects, the last text I

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[126] Blacking, John, Music, *Culture and Experience*, Chicago, 1995, 239-242. In Snyder, 109.

will be dealing with might be the most difficult and elusive of all three. While focusing on an explicitly graphic notion (the *figure*), it thematizes the dissolution of the deictic quality of musical gesture (as a derivative of physical gesture) into a diffused, constantly present somaticity, in the form of *lines of force* and *energy circulation*.

The compositional transfiguration of the creative potential into *discursive, form-generating energy* is the central theme in *Il Tempo della figura* (1984). Its main vehicle is the explicit distinction between the notion of the *gesture* and the notion of the *figure.* This distinction, along with a haunting image from a poem by John Ashbery, seems to lead the thread of Ferneyhough's thoughts around how music *means*.

Talking about dreams, Ashbery writes:

"They seemed strange only because we couldn't actually see them

And we realized this only at a point where they lapse

Like a wave breaking on a rock, giving up

Its shape in a gesture that expresses that shape".[127]

Ferneyhough uses this wave metaphor for differentiating between the "natural, unformed undertow of creative potential" as sheer physical force in music and the discursive energy produced upon application of this force to what he calls "a resistant musical object" (*CW,* 35). The first type of energy unleash seems to correspond in his discussion to *gesture*: the sonically perceptible surface of a physical-performative act, which acquires meaning through extra-musical

"symbolic conventions-either artificially established ones, or those deriving, by means of abstraction and analogy, from species of bodily comportment" (CW, 33).

According to Ferneyhough, this sort of semanticity can easily denigrate to the status of an open-ended act, "a meaningless maneuvering in an uncaring, arbitrary void" of self-contained, semantically "burnt-out" gestures.

[127] Ashbery, John, *Selected Poems* (Expanded Edition), London 1987. From *CW*, 33.

The problem is drastically superseded by what he calls the *figural* activity -the above-mentioned application of force to a resistant musical object, that is, one structurally coherent, parametrically derived process-, which renders *lines of force* and *energy circulation* between successive gestures palpable, or as he puts it, it achieves

"the liberation of a surplus of discursivity/volatility hitherto locked in the interstices of the sonic object" (p.36).

This "surplus of discursivity" refers in his case to the astonishing amount of notational details -immanently physical tokens as well, considering that they are to be performed-, comprising the individual gesture. Their contextual disposition, rather than their innate referential capacity, produces meaning as process, not as a frozen stylistic trigger. Ferneyhough's phrasing:

"The synchronic is replaced by diachronic successivity as the central mode of 'reading' musical states" (p.34).

The point which is crucial for our analysis of a music-specific, anti-visual embodiment is once more the *circulation of energy* along the aforementioned *lines of force*. The trajectory of this circulation extends from the physical performative (functional and expressive) gesture, through its abstraction into musical gesture, to the gesture's figural potentials. Ferneyhough certainly remains through this and other texts (including “Form-Figure-Style: An intermediate Assesment”) rather ambivalent, as to if the "wave" refers only to the composer's still unformed intuitions or to the sheer physical energy in music-making. My suggested interpretation is that the very transfer of a force and energy-based terminology to the realm of composition refers indiscriminately to both: Composition is defined not as invention of forms, but as management of tensions and energies[128], which are immanently physical tokens as well as abstracted processes. What in music is music-specific, namely its fragile and indeterminate state of being between "dead material" (gesture) and "abstract form"

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[128] The Deleuzian influence becomes explicit in many points in Ferneyhough's writings: "En art, et en peinture comme en musique, il ne s' agit pas de reproduire ou d'inventer des formes, mais de capter des forces" is the paradigmatic epigram of Ferneyhough's „Form-Figure-Style: An intermediate Assesment“, originally to be found in: Deleuze, Gilles, *Francis Bacon: Logique de la sensation*, France 1981, 39.

(the process which generates figures from gestures)[129] manifests here as a unique resonance between the physicality of performance and the act of composition and its perception. In that sense, Ferneyhough's terminology may be then considered not as *metaphoric*, stressing similarities between the independent domains of performance, composition, perception, but rather as *metonymic*, stressing the actual contiguity and self-structuring feedback loop between the three domains. And extending his metonymy, one can consider his meaning-production as performing body.

J. Primordial Instrument: Helmut Lachenmann

In his text on the stratification of decoupled action parameters, Klaus K. Hübler describes it as a positive alternative to both the disembodiment of serialism and Helmut Lachenmann’s negative and primordial approach.

Lachenmann’s steady influence in the New Music scene necessitates a closer look at his work as one of the forefathers of action notation. Particularly important in this respect is his *Pression* for cello solo as a model for his „musique concrète instrumentale“. The term is tailored after Pierre Schaeffer’s *musique concrète*.

Lachenmann defines *musique concrète instrumentale* as follows:

“With it we signify a music, whereby the sound events are chosen and organized in such a way, so that the mode of their production becomes at least as important as the resulting acoustic qualities in themselves. Those qualities, such as timbre, amplitude etc. are sounding, so to speak, not for themselves, but rather describe or signal the concrete situation: We hear in them, under which circumstances, with which materials, which energies and against which resistances is a certain sonic- or noise-producing action performed.”(381)[130]

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[129] "Music is not dead material, nor yet abstract from" (*CW*, 41).

[130] “Gemeint ist damit eine Musik, in welcher die Schallereignisse so gewählt und organisiert sind, daß man die Art ihrer Entstehung mindestens so wichtig nimmt wie die resultierenden akustischen Eigenschaften selbst. Diese Eigenschaften wie Klangfarbe, Lautstärke usw. klingen also nicht um ihrer selbst willen, sondern sie beschreiben bwz. signalisieren die konkrete Situation: Man hört ihnen an, unter welchen Bedingungen, mit welchen Materialien, mit welchen Energien und gegen welche Widerstände eine Klang- oder Geräusch-Aktion ausgeführt wird „ in Helmut Lachenmann, *Musik als Existentielle Erfahrung, Schriften 1966-1995.* Josef Häusler. Breitkopf und Härtel, Wiesbaden, 2004.

For Lachenmann, this primordial focus on the sounding body is inextricably tied to what he calls "sound-alienation", meaning the de-contextualization of familiar sounds and instruments from their classical music background:

"Naturally the sound-alienation plays here an important role. It has neither expressive nor absolute acoustic meaning. It is not produced as an extreme case[131], but rather in a totally rational way and without any external speculation out of the necessity, to employ the already mentioned energetic conditions, under which the sound is produced, as well as to inter-relate them in different hierarchies / scales, that is: the necessity to compose them."[132] (p. 381)

Lachenmann continues with the very concrete example of *Pression* for solo cello:

"In this sense *Pression is* a model. What is here interrelated and composed are pressure relations in the context of sound-producing cello actions. The pure "full and nice" cello sound is in them (cello sound-producing actions) only a special case among varied possibilities of bow pressure, bow position, bow movement, in specific points of contact to the string, with specific preparation of this point through the player's left hand etc., whereby all those conditions, normally in synergy {in the case of normal, nice tone}, can be decoupled each one from the other. In the case of beautiful, professional cello sound, the relationship between action and result is especially well rounded, in relation to effort and resistance –as is the case for all "beautiful sounds" in our society. In other cases, such as the extreme pressure of the gliding fingertip over a stopped bowing, the relationship becomes much more complex: A barely audible result reveals at the same time a maximal expenditure of power".[133] (p. 381)

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[131] Compare here to the commonly used term "extended techniques"

[132] Natürlich spielt hierbei auch die klang-Verfremdung eine wichtige Rolle. Sie hat so weder expressive noch absolut akustische Bedeutung. Sie ergibt sich keineswegs als Extremfall, sondern ganz logisch und ohne äußerliche Spekulation aus der Notwendigkeit, die erwähnten energetischen Bedingungen, unten denen Schall erzeugt wird, abzuwandeln, sie in ihren verschiedenen Abstufungen aufeinander zu beziehen, dh: zu komponieren.

[133] In diesem Sinn ist Pression ein Modell. Abgewandelt und komponiert werden hier Druckverhältnisse bei Klang-Aktionen am Cello. Der reine „schöne volle" Celloton ist darin also nur ein Sonderfall unter verschiedenen Möglichkeiten des Bogendrucks, der Bogenhaltung, der Bogenführung, an einer bestimmten Strichstelle, bei besonderer Präparierung dieser Stelle dieser Stelle durch die linke Hand des Spielers usw., wobei alle diese Gegebenheiten, die hier zusammenwirken, einzeln für sich abgewandelt werden können. Im Fall des schönen, professionellen Cellotons ist –wie bei allen für unsere Gesellschaft „schönen Klängen" – das Verhältnis von Aktion und Resultat besonders ausgewogen, was Anstrengung und Widerstand betrifft. Woanders, etwa bei dem äußerstem Druck der gleitenden Fingerkuppe über die aufgelegte Bogenstange, ist das Verhältnis viel komplizierter: Ein kaum zu hörendes Klangresultat kündet gleichsam von einem maximalem Kraftaufwand

For Lachenmann, the focus on primordial energies constitutes an active rethinking of bourgeois modes of listening:

"That might be only a game: It is in any case an offer to the listener, to listen: To listen differently and to be conscious and to question the listener's usual modes of listening and the underlying, buried aesthetic taboos through a characteristic provocation. At the same time it is an attempt of understanding in the face of simpler, more concrete situations of tension, which are not to be resolved, but rather initially very realistically to be experienced. Listening means here in no way: to agreeably participate, but rather: to make conclusions, to change, TO THINK."[134] (p. 381)

While Lachenmann's predilection for those primordial decoupled actions, which constitute social critical thinking, do remind us of Hübler's typologies, it is important to note here how the latter mixes and polyphonically treats those techniques, while the former allows them to become only a trace of situations, some sort of metonymic re-contextualization.

The trope of the instrument rather than the actions becomes also important in Lachenmann's aphorisms on what it means to compose, and in particularly the following:

Komponieren heißt, ein Instrument zu bauen. (Composition means to build an instrument)[135].

As is the case with Hübler, such a material base for composition seems to directly even if unintentionally foreshadow the developments in the field of technology and more particularly NIMEs as the vehicles of composition today. Their common ground is the creation and exploration of instrumental affordances as the quintessence of composition, as opposed to a disembodied and abstract sonic ideal.

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[134] Das mag ein bloßes Spiel sein: Es ist auf jeden Fall ein Angebot an den Hörer, zu hören: anders zu hören und seine Hörgewohnheiten und die dahinter verborgenen ästhetischen Tabus anhand einer charakteristischen Provokation bewußt zu machen und zu überprüfen. Es ist außerdem ein Versuch über die Verständlichkeit, und dies anhand einfacher konkreter Spannungsprozesse, die es nicht zu entschlüsseln, sondern zunächst ganz realistisch zu erfahren gilt. Hören heißt hier auf jenen Fall wieder: zustimmend mitvollziehen, sondern heißt: Rückschlüsse ziehen, umschalten – DENKEN.

[135] Ibid., p. 77

2.3 Second Axis : Embodiment And The Electronic Medium

The second axis of a brief history of embodiment & complexity after 1945 deals with the introduction of the electronic medium, its transformation through digitalization, and the consequences for contemporary performance practice. We argue that those consequences necessitate the paradigm-shift from the ancient composer-centered culture of textual interpretation to a performer-specific culture of embodied interaction with both traditional media (instruments and scores) and the electronic medium in particular in the hybrid form of mixed music for instruments and electronics (*musique mixte*).

The advent of electronic sound and digital musical cultures has shaken the very ontological foundation of musical creation, including musical embodiment and representation in the form of notation. The dissolution of the very causal connections, primarily the one between sound source and acoustic result, has raised aporias concerning both the organic entity of the traditional elements and roles in a WAM musical culture. In what follows, we will review some of the historiographiess of electronic music; we will present a critical position on the relation between the non-electronic, "old" New Music, and the new medium; we will explore positions on the changing perceptions on embodiment, instruments and scores; and we will overview some technical rather than ontological problems set by the co-existence of human performers and live electronics, as well as issues of representability and notation from a compositional perspective, and how those affect performance.

A. Histories Of Electronic Music

The histories of electronic music have been mostly registered from the perspective of technological breakthroughs and composer-pioneers, reserving questions of performance and interaction for the end of the historical time-line in the form of MIDI-based controllers, mixed music and live-electronics. A quick look at central works in the field, as diverse as Curtis Roads' The *Computer Music Tutorial*[136], Peter Manning's *Electronic and Computer Music*[137] or Miller Puckette's *The Theory and*

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[136] Curtis Roads, *The Computer Music Tutorial*, MIT Press, 1996

[137] Peter Manning, *Electronic and Computer Music*, Oxford University Press, 2004

Technique of Electronic Music[138] affirms their focus on the two poles of *musique concrète* versus sound synthesis, the music studios in Paris and Cologne, Schaeffer versus Stockhausen, as the origins of a trajectory which will only gradually assign new roles to the performer.

According to Douglas Keislar in his “A Historical View to Computer Music Technology”, at the Oxford Handbook of Computer Music[139]:

“Whereas the first half of the computer music era was dominated by the composer, the second half has witnessed the ascent of the performer. There had already been a long history of performers participating in analog electronic music. Most often, they simply performed on conventional acoustic instruments alongside a tape recorder that played back electronic sounds. “Tape music” was for years the main outlet for computer music as well—often pieces were conceived for the tape recorder alone, but music for performer plus “computer-generated tape” was not uncommon.” (p. 29)

Similarly, Paul Doornbusch in his “Early Hardware and Early Ideas in Computer Music: Their development and their current forms”[140] reserves the discussion of performance for later chapters on “General Digital Control Systems” (p.66) and “Real-Time Computer Music, Controllers and New Music” (p. 68). While such a deferral of questions of performance is partially justified by the technological and computational limitations of early systems of electronic and computer music as far as real-time processing is concerned, it certainly does not do justice to the importance of early electronic instruments and their performers in the long history of electronic music.

After all, as Doornbusch puts it,

“There is no linear trajectory or chronology to the history of computer music; it consists of a disparate conglomerate of discrete events. However, it is this milieu of events that makes computer music

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[138] Miller Puckette, *The Theory and Technique of Electronic Music*, 2006 http://msp.ucsd.edu/techniques/v0.11/book.pdf accessed 30.03.2018

[139] Douglas Keislar, “A Historical View to Computer Music Technology”, in Roger T. Dean (ed.) The Oxford Handbook of Computer Music, Oxford University Press, 2009, pp. 11-43

[140] Paul Doornbusch, “Early Hardware and Early Ideas in Computer Music: Their development and their current forms”, in Dean 2009, p. 44-84

possible. There have always been those musicians and composers who engage with the latest technical advances, whether they are drawn steel strings, advanced mechanical instrument construction possibilities, or general-purpose machines such as the computer. These people have imaginative, creative uses for the technology, and they use it to expand their creativity." (p. 44-45)

An alternative to the composer-centered narratives of electronic music histories can be found in Atau Tanaka's "Sensor-based Musical Instruments and Interactive Music"[141]. Tanaka's account is as broad as to accentuate the equal footing of performers, composers and instrument builders:

"Musicians, composers, and instrument builders have been fascinated by the expressive potential of electrical and electronic technologies since the advent of electricity itself". (p. 233)

While the objective of his particular contribution is to focus on "musically driven efforts to exploit analog and digital technologies to capture musical gesture and afford new forms of sonic articulation and musical expression" (p. 234), in association to the field of research often labeled as NIME (New Interfaces for Musical Expression) after the homonymous conference and community[142], it does transfer the core of electronic music history from the realm of sound to the realm of instrument-making and related practices. He thus proposes a genealogy of the electronic, which is not necessarily composer-oriented.

Tanaka begins his account with what he calls "the close coupling between audio and electricity" (p. 235), alluding to the fact that the very first electric devices such as the telegraph, the telephone and the radio all operated on the principle of *sound transduction*, that is transformation and transmission of sound in the form of electric signals.

It is no accident then that, before composers came into play, it was rather engineers and amateur musicians with a practical orientation who made the first original contributions in the field of electronic music. Leon Theremin, the inventor of the

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[141] Atau Tanaka, "Sensor-based Musical Instruments and Interactive Music", in Dean 2009, pp. 233-257

[142] http://www.nime.org/ accessed 30.03.2018

homonymous early instrument that consists of two orthogonal antennas generating an electrostatic field controlled directly by hand gestures, is the classic example of a totally new instrument. In other cases, such as with the electric guitar or later with Tod Machover's notion of *Hyperinstruments*, it was the urge to extend traditional acoustical instruments, which led to the invention of new ones. The solid-body electric guitar is a good example of an instrument which, though starting as an acoustic one, ended up being an instrument with little acoustical properties, still hugely influential for the developments to follow. In this line of thought, it is not accidental that even Max Mathews, the inventor of Digital Audio at Bell Laboratories and pioneer of the digital transformation of electronic music through the MUSIC family of computer sound synthesis and composition programming languages, had developed an instrument called GROOVE (Generated Real-Time Output Operations on Voltage-Controlled Equipment), a hybrid analog-digital system, in which a two-dimensional joystick controller modulated electronically generated sound output.

The fact that Tanaka's and NIME's historical overview sets the instrument and the changing notions around the instrument at the very heart of electronic music's history has important repercussions, one of which is the redefinition of the notion of the instrument itself. While we will save Tanaka's account for a later point in this dissertation, namely chapter three dealing with interaction, and for the whole discussion as to why notation can be seen as an extension of the instrument, we should already stress how the general notion of *instrumentality* becomes the interface that interconnects embodiment, causation and representation, physical gesture and notation, performance and composition, both as a prior (in the sense of Zenck's "embodied subtext") and as a posterior (in the revised view of interpretation as interaction).

B. The Electronic Medium And The "Old New Music"

Next to the general histories of electronic and computer music, Lehmann's *Digital revolution of music* touches on the relation between the institutionalization of contemporary music and the disruptive power of digital media. His perspective is at the same time philosophical, sociopolitical and technical.

A central aspect in Lehmann's perspective is his critique of *absolute music* and the defense of a relational, multimodal and multimedia new aesthetics, also is in close association to the movement known as New Conceptualism (*Neuer Konzeptualismus*) and to Bourriaud's *relational aesthetics*. The thesis developed below comes from a philosopher who "wants to make himself useful as a complexity specialist"[143](Lehmann 2012, p. 7).

While one of the strong orientations of Lehmann's book is clearly sociological, with a critique of what we previously defined as the *dispositif*, that is the institutionalization forms of New Music, it does focus on the material basis of media such as notation and instruments.

After a rather detailed exposition of the main historical tropes in the evolution of WAM notation, Lehmann argues that the past hundred years have been witnessing a sort of "overuse syndrome" of the notation, in the form of a constant negation or intentional dysfunctionality of its traditional aspects. Lehmann is intentionally citing two diametrically opposing examples to prove his thesis: Lachenmann's action-notation, which through its proclaimed extension to include concrete instrumental sounds has resulted in an abundance of private notations, thus losing its global and communicative claim (p. 51); and Ferneyhough's complex rhythmic notation, which only approximately and selectively can be realized, thus turning into some sort of "oppressed improvisation".

According to Lehmann, the impasse of such notational uses and of other notational reforms (such as graphic notations) raises the simple question, if "notes" are to remain the preferred medium of composition giventhe rise of a new compositional medium in digital culture, namely the medium of *samples*.[144] With extended

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[143] „So ist auch der Autor dieser Abhandlung kein Musikwissenschaftler, kein Musiksoziologe, kein Musikhistoriker und erst recht kein Komponist, sondern ein Philosoph, der sich für die Geschichte der zeitgenössischen Kunstmusik interessiert und seiner Profession entsprechend versucht, sich als Komplexitätsspezialist nützlich zu machen „, p. 51

[144] „Dies (die Tatsache, dass akustische Neue Musik auch in Zukunft traditionell notiert sein wird) bedeutet allerdings nicht, dass „Noten“ auch in Zukunft das präferierte Medium der Komposition für die Kunstmusik sind, Am Horizont der digitalen Revolution zeichnet sich vielmehr ein neues Kompositionsmedium ab: das Medium der Samples“, p.52

references to the work of Steven Tazuo Takasugi, Bernhard Lang and Johannes Kreidler, he sets off to show how this new medium can on the one hand “bridge” the ontological gap between the acoustic and the electronic New Music,[145] while on the other hand surpassing notation and thus democratizing musical creation. Surpassing notation does not necessarily signal its elimination. After all, most of the examples by Lehmann have evolved to include or generate notational equivalents to samples. Such is the case with Takasugi’s work *Ein Gourmet sagte mir* or his *Klavierübungen*, both of which make use of traditional instrumental samples, but have later been transcribed in traditional notation for piano two or four hands, in versions which constitute some form of *Turing test*[146] for the e-player, since the human versions are impossible to be performed in their totality and are so conceived, as to co-exist with the pure electronic versions (p. 53). In Kreidler’s case, Lehmann makes reference to his COIT (*Calculated Objects in Time*) program, as an alternative to traditional notation: It still consists of a line-based system, where however the intervallic value of spaces remains malleable and where notes are substituted by graphical objects representing samples. In any case, the acoustical properties of samples cannot be represented or deduced from this notational form, but rather constitute an operational processing working surface, a form of *soundshopping* (as Lehmann names the process with reference to the commercial image processing software *Photoshop*) (p. 56). The designation of such derivative role for music notation indicates that the primordial compositional act of *writing* tends to be substituted by the act of *editing*. As for the definition of the work, it now can be reduced to the digital carrier of it, in the same way it did in the form of notation (p. 61).

If the sample constitutes some form of composer’s liberation from the medium of notation, then the performer is equally liberated from her old role as interpreter of notes on old instruments and becomes some form of performance artist controlling several media, in the context of the *relational aesthetics* that Lehmann advocates. In the course of his chapter “Alte Instrumente” (p. 62-66), Lehmann argues that old

[145] „Von besonderen Bedeutung für die Neue Musik sind hierbei die Instrumentalsamples, die von den klassischen Orchesterinstrumenten aufgenommen werden und welche die ontologische Kluft zwischen der akustischen und der elektronischen Neuen Musik überbrücken“ p.52

[146] A turing test, developed by Alan Turing in 1950, is a test of a machine’s ability to exhibit intelligent behavior equivalent to, indistinguishable from, that of a human.

instruments embody all the aporias of the old New Music, all the dysfunctionalities associated with Lachenmann's or Ferneyhough's notations, and are thus to be abolished in the course of material progress. Johannes Kreidler's provocative dictum is indicative of such an extreme position: "Wer für Geige schreibt, schreibt ab." ("Whoever writes for the violin is useless"), cited in Lehmann, p. 65. Lehmann concludes that classical instruments may remain part of the apparatus of electronic music through the alienation, processing and amplification of their organic sound (p. 65).

While Lehmann's observations and manifestos are often limited in their scope because of a very partial view of music technology, they are however accurately describing the crisis of institutionalized contemporary music. Lehmann's ideas on notation and instruments in particular seem to ignore the redefinition of both notation and instrument beyond the sample culture. Two indicative examples would be the case of mixed music and live-electronics as far as instruments are concerned, the research on interactive forms of notation and representation as far as notation is concerned. On top of that, Lehmann seems to mostly disregard problems of embodiment and electronic music, as they will be reviewed in the following chapter, with the exception of visual embodiment in the context of *relational aesthetics*.

The solution according to Lehmann is to be found in the substitution of notation with the new medium of samples. The degree of non-equivalence to which such a partial tool can be even said to be able to represent the totality of electronic music (which it obviously cannot), makes the point for one of the most critical evaluations of Lehmann's theory: It is some times based on generalizations and aphorisms, whether those refer digital music reduced to samples or the scores and aesthetic apparatuses of Lachenmann and Ferneyhough: Neither Lachenmann's notations are only about extended techniques, nor Ferneyhough's notation functions in the one-dimensional ways that Lehmann claims, as we have already seen and we will soon develop more.

C. Disembodiment II : Problems Of Embodiment In Electronic Music

The dissolution of the causal chain, which traditionally connects human gesture, instrumental vibration and acoustical perception, becomes the source of both aesthetic aporias as well as constant renewals and recoveries of the musical body in the electronic era. As Deniz Peters[147] puts it, the advent of electronic music has questioned a number of "truisms" about music making, such as: "Music affords bodily expression. It is the direct result of bodily acts"; "It is with one's body, sometimes with an additional artifact, that one makes music"; and "Musicking is something people *do*". (p.1). Such a questioning does not equal though an abolition of embodiment and what has traditionally been its inevitable extension, musical expression, but rather their radical transformation.

Peters sets the following questions, articulating a wide-ranging problematic, which can touch not only on electronic music, but also on recordings:

"*Where* is the body in electronic music? Does it 'disappear' when performers or performing composers are absent from the stage, at least from an audience's point of view, as in some acousmatic music? Is it reduced to an intangible degree, abstracted away? Or does it persist, though in a transmuted form? Is the body transfigured? If so, into what? If its role has been compromised or lost, what else has taken its place? Further: to hear is to hear *something.* It is also to hear *someone*. Where and who is this someone in electronic music, even of the performed sort? Can a performer (or composer) be heard in it, in cases where there is a delayed or otherwise altered performance, or no (human) performance? Or can a performance be heard without a performer? Or, given both performance and performer, can both actually be heard in the music, instead of being something arbitrary to or removed from it? As performance rests on bodily acts, one may reframe these questions in terms of the body, giving the overall question of this book: how can one *conceive* of bodily expression in electronic music?" (p. 2).

Fast-forwarding a bit to the third axis of the current, we need to clarify that those questions are irreversibly entangled with the issue of multimodality and particularly with the issue of the visual investment of the human body, so that Peter's questions may be re-articulated or extended as follows: *To what extent is the visibility of a source and a performer prerequisite for the perception of musical embodiment*?

In what follows, Peters urges us to consider the very plurality of lots of the terms which have been used in the previous section: Bodies may refer to both the living,

[147] Deniz Peters, Gerhard Eckel, Andreas Dorschel, *Bodily Expression in Electronic Music. Perspectives on Reclaiming Performativity.* Routledge 2012.

functional bodies of composers, performers and listeners, as well as to the "dead" bodies of instruments, machinery or circuits, but also to the metaphorical, figurative body of the music, the score, a recorded soundscape or eventually imagined bodies (p. 2). In our own investigation, we will naturally reserve the focus on the performer's functional body, as well as on the body as scenic object.

Peters draws attention to the modality of touch as the quintessential "experiential link between making sound and a sound made, and the felt aspects of touch that come into play when listening only, allowing for the body's extension into instruments and into the sound itself, and harboring the inter-subjectivity of sonic experience" (p.4). In other words, it is the very constitution of musical experience in the acoustical domain as a causal chain of gesture-instrument-sound, which evokes the first two elements even in the absence of performers and instruments, in a genuine metonymical function: The part "sound" substitutes for the whole causal chain.

The opposite problem forms the core of the contribution of the enactivist philosopher Alva Noë, namely the question: If embodiment is evoked no matter which absences and abstractions are at play, then how would disembodiment in electronic music even be possible? Noë's solution passes through a refinement of the notion of sonic embodiment through sensorimotor contingencies and Merleau-Ponty's notion of the "intentionality arc", which accounts for the temporality of the embodied sonic experience.

D. Mixed Music

According to Peters, electronic music presents us with the problem of a

"double altered performativity: (1) recording media and sound synthesis have bracketed the performer in some practices and (2) in the case of electronic instruments there is a gap that needs to be filled between human touch and sound made." p.25

The first case is explicitly referring to what is known as acousmatic music, whereby no performative mediation comes into work between the composer's use of hardware and software and the final result, usually in the form of a recording or a generative algorithm. Even in this case, what Peters calls the "figurative body of the composer"

(p. 26) comes into work, either in the sense of the physical constraints of the machinery used and the corresponding affordances they allow for the composer; or in the sense of Dennis Smalley's *spectromorphology*[148], whereby a distinction between physical gesture and different levels of "surrogacy", or detection of gestural characteristics in the very composed electronic textures, becomes the main medium of a virtual physicality.

In the case of electroacoustic or mixed music, the reintroduction of traditional instruments to be augmented or treated or juxtaposed with the electronic medium does not self-evidently equal a restoration of performativity in the traditional sense, but rather opens-up new aesthetic spaces. Apart from issues of triggering, synchronization and sound control, as nicely summarized by Lalitte, there is the issue that John Croft[149] calls the gap between "procedural liveness" and "aesthetic liveness", drawing from Simon Emmerson's general notion of 'liveness': This refers to the artificiality of the mapping between gesture and sound, as a constant theme in the design of digital musical instruments. We will come back to liveness in the context of Erika Fischer-Lichte's notion of "presence" and the degree to which electronic devices could ever assume the same degree of presence with a live body on stage.

Peters concludes by saying that "a mapping needs to inherit the attributes of what Smalley called "gestural field", at least to some degree, if it is to be expressive in this regard" (p. 27), echoing Guy Garnett's conclusion in his 'The Aesthetics of Interactive Computer Music'[150].

While the ontological problems associated with embodiment in pure acousmatic music are somehow mitigated through the presence of performers and instruments on stage, new problems pertaining to the hybridity of the musical situation come into

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[148] Denis Smalley, 'The Listening Imagination : Listening in the Electroacoustic Era ', in Paynter, *Contemporary Musical Thought*, p. 514-552

[149] John Croft, 'Theses on Liveness', in *Organised Sound* Volume 12 Issue 1, April 2007 Pages 59-66 Cambridge University Press New York, NY, USA

[150] Guy Garnett, 'The Aesthetics of Interactive Computer Music', *Computer Music Journal*, *25*(1), 21-33

play. In our preliminary investigation of Philippe Lalitte's *Analyser l'Interprétation de la Musique du XXe siècle* we have already summarized some of the issues facing the electronic music performer and categorized them in problems of sound control and problems of temporal synchronization with the electronic medium. In his PhD thesis, Eric Maestri[151] has provided a complete typology for the analysis of mixed music, drawing from Claude Cadoz's problematic on the complex relationship between individual instrumental and global sound; Dennis Smalley's *Spectromorphology*, and particularly his distinction between gesture and texture, the former pertaining to human presence while the latter to what Peters would call "the body of the music"; and Jerold Levinson's typology of hybrid art forms, into juxtapositional, synthetic and transformational.

The problem of embodiment and performativity in the context of *musique mixte* is set in a completely different way when it comes to WAM, that is composed music which includes a musical score.

E. The Interpreter And The Electronic Medium

In the last section of his account of compositional innovation and performative response to it, Lalitte deals with the electronic medium. Lalitte traces a long line of development, from the first electronic instruments of the 1920s via magnetic tapes and electronic oscillators all the way to computers, as both influencing the pure instrumental writing without electronics (Stockhausen, Nono, Xenakis, Ligeti, Lachenmann and Murail are some prominent examples) but even more importantly, in the form of mixed music as co-existence of acoustic and electronic sound.

According to Lalitte, the birth of *musique mixte* is driven by two factors: on the one hand the desire to integrate the range of contemporary instrumental sounds with the new medium and on the other hand the need to invest visually concerts which would otherwise be absent in concerts of merely speakers, forging a counterpoint of present and invisible resources (Lalitte, p. 53). The issue of "liveness" of electronic performance overlaps certainly with questions of embodied presence in the context

[151] Eric Maestri, « Geste et texture / homme et machine : Une étude comparative sur la production et la réception de lamusique mixte », doctoral thesis, Université de Strasbourg, 2016.

of the performative turn and a lot can be said on the issue of musical gesture as formant of the electronic sound.

For the moment, we will review Lalitte's treatment of the issue of synchronization and constraints between the live performer and the electronic medium, fixed or live. The latter distinction is most certainly a systematic as well as a historical one, since certain forms of live control of electronics only became progressively possible through the advancement of respective technologies.

As far as the fixed medium is concerned, Lalitte cites a range of different compositional approaches towards the mitigation of the rigid temporal frame of the electronic sound. Those include Mario Davidovsky's composition of temporal relations between the live and electronic sound in his cycle *Synchronisms,* with the intention of a logical and continuous succession of events; the use of click-track, among others in Gerard Grisey's Les *Chants de l'Amour* for 12 voices and tape, aiming at the most tight possible synchronization of the live performance to the fixed medium; but also more loose approaches of organic integration and responsiveness elicited from the performer, such as in Luigi Nono's *…sofferte onde serene…* and its ambiguity between pre-recorded and live piano sound.

The question of live control of pre-recorded samples becomes solved once and for all[152] with the invention of the MIDI protocol in 1984 and the subsequent new forms of virtuosity developed around the new medium, with François-Bernard Mâche providing a prime model for sampling (*échantillonage*). Those forms of virtuosity, often realized by pianists on MIDI keyboards, pertain less to digital dexterity and more to the ability to use multiple controls and controllers at the same time, control parameters such as intensity and pitch which in piano are discontinuous in a continuous way and develop skills of essentially a poly-instrumentalist, as in Stockhausen's *Klavierstück „Synti-Fou",* which requires four keyboards and nine pedals.

[152] Despite the significant contributions of the Open Sound Control protocol, MIDI remains up to today a quintessential component for the control of digital musical instruments.

As for the live electronic medium, Lalitte traces its beginning in Stockhausen's *Mikrophonie I* and the live, analogical manipulations of a gong sound by two microphone and two low-pass filter players. The genre seems to pose exactly the opposite of the problem of fixed media: While the performer has now regained control over time, the malleability that characterizes instrumental performance in either solo or chamber and ensemble contexts, she has nevertheless lost the control over her sound, which is now on the hands of the "sound manipulators", whether in the form of other performers (such as in Stockhausen) and sound engineers, or in the form of automatized solutions.

The digitalization of electronic music in the 1980's marks a new phase in the history of live electronics. One of the defining features here is what Philippe Manoury characterizes as "partitions virtuelles"[153], as the possibility of live interaction between an absolute given score and its live interpretation, which triggers the electronic treatments. The notion of score-following emerges as a natural consequence of this renewed and hybrid form of writing, without however exactly liberating the performer: The methods of score-following, at least those used in the first pieces for the medium, such as Manoury's *Pluton* for piano, allow for a very tight margin of error, confining the performer into a straightjacket, especially when it comes to notations as complex as Manoury's. The technological evolution of score-following, the state-of-the-art at the moment represented by Arshia Cont's anticipatory score following program (Antescofo)[154] has considerably ameliorated the problem of temporal plasticity and error tolerance, remaining always inside the horizon of the paradigm of a virtual score.

In what follows as second axis of a short history of embodiment, and even more in the section termed Interaction, we will complement Lalitte's account with a detailed account of gestural controllers and interactive live music notation, which will later form a central part for our presentation of the *GesTCom (Gesture Cutting Textual Complexity)* as a different paradigm altogether from the notion of the virtual scores.

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[153] Philippe Manoury, *La note et le son : écrits et entretiens (1981-1998*), Harmattan, 1998

[154] https://www.antescofo.com/ accessed 30.03.2018

Almost 70 years after the first pieces of *musique mixte*, issues of obsolete or malfunctioning equipment and incomplete technical documentation become more and more pressing, revealing the need of a historical performance practice for electronics. The issue becomes central in Sebastian Berweck's PhD thesis "It worked yesterday: On re-performing electroacoustic music".[155]

F. Virtual Scores: Philippe Manoury

One of the most important issues, which we will treat extensively in the course of the second axis (electronics and digitalization), but also in the third part (interaction) of the current dissertation, is the issue of notation for mixed music (*musique mixte*). Certain practices, such as the graphical representations of electronic in Stockhausen's *Kontakte* for piano, percussion and tape (1959-1960), the "tablaturisation" of traditional notation in the case of music for samplers (as imperatively represented by the output of François-Bernard Mâche) and the new universe of notational possibilities opened up since the common use of patch-based environments like Max/MSP for the live interactive treatment and control of sound and image (paradigmatically in the work *Metallics* (1994-1995) by Yan Maresz), form the main corpus of Lalitte's reference. In what follows, we will look closely at Philippe Manoury's notion of *Partitions Virtuelles*[156] and the use of Arshia Kont's *Antescofo* score-following system in one of our case-studies: Nicolas Tzortis's *Incompatible(s) V for silent piano and live electronics*.

Philippe Manoury's text constitutes a far-reaching reflection on the representability of *musique mixte* and on the gradual convergence of old and new tools in composition. The problem is originally described as one of integration and confrontation of two heterogeneous *dispositifs* (in Lehmann's/Foucault's sense), which Manoury compares to those of the theatre versus the cinema: The world of composition for instruments or voices and the world of electronic composition. According to Manoury, the initial degradation of electronic music composers as "bricoleurs", otherwise

[155] Sebastian Berweck's "It worked yesterday: On re-performing electroacoustic music", Doctoral Dissertation, University of Huddersfield, 2012, http://eprints.hud.ac.uk/17540/ accessed 30.03.2018
[156] Manoury , p. 59-86

ignorant of the urgent compositional questions, would be overcome in the work of Karlheinz Stockhausen, one of the most successful attempts of hybridization and correspondence between the new tools of sound synthesis and processing and the techniques he had already been developing at his purely instrumental works.

After the advent of the first programs of sound synthesis, which seem mostly oriented towards a rather oral or acoustic culture in the 1960's, Manury proposes the notion of "virtual scores" as the solution to this different ontological status between the instrumental and electronic mediums. The foundation of IRCAM as a privileged meeting point for composers of both genres is deemed quintessential to this development. (p. 61)

The notion of virtual scores is not a method of composition but rather a concept of co-existence of the two media, originally attributed to Boulez. It addresses both the general question " What should the composition be when confronted with live electronics?", as well as the issues of "temps differé" and "temps reel" (the distinction between offline and online processes, especially since the 1980's when the latter becomes a technical possibility), and eventually the seemingly simple question: "why can't the composer of mixed music compose as before?". In that sense, Manoury defines the problem as one of primarily representation: It is not only their different physical reality, but rather the very absence of writing and representation, which creates an unbridgeable ontological gap between the two.[157]

This assertion triggers an interesting review of symbolic notation by Manoury : Traditional notation is *already* virtual, in that it is only a partial representation of the sonic phenomenon it seeks to represent, and in that sense it is characterized as *metonymic*: the part represents the whole[158]. Questions of interpretation form then part of the score's virtual quality, which becomes an unexpected liaison between the electronic and traditional medium.

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[157] « L'absence d'écriture dans la musique électronique est probablement un des phénomènes qui assure une parfaite étanchéité entre ces deux modes d'expression », p. 63

[158] « La notation est une sorte du métonymie du phénomène sonore :le tout est exprimé par une partie seulement », p. 64

Another interesting comment by Manoury concerns the relativity of notation and what we will later refer to as *internalism*: According to Manoury, interpretation operates on “mental zones”, which need to be explored before they can determine sonic phenomena.[159] In that sense, the classically represented parameters of pitch, duration and dynamic are always to a certain degree undefined, and thus already virtual, becoming real only at the moment of performance.

In what follows, Manoury deals with the electronic music representations of his time, both those that represent the morphology of sound (such as sonograms) and the ones that more abstractly refer to musical structure. The main deficit of such representations is that they have no intrinsic perceptual value, since they cannot be read and since they do not correspond to mental representation, so that they can serve neither as creative nor as communicative means (p. 68-72).

Manoury’s somewhat bleak conclusion is that sound synthesis representations refer to the real phenomenon, while instrumental scores are symbolic and metonymic and there is no concept at sight which would reconciliate the two[160]. In the pertinent question, if and how could the two heterogeneous representations be merged into a singular score, Manoury talks about a provisional management of the situation in the form of the *partitions virtuelles*. The solution of the problem is to be found in interactivity, but not as a new invention facilitated by real-time technologies, but very interestingly, as a constant feature of traditional media as well, in the sense of an exchange between writing and interpretation.[161]

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[159] « L’interprétation agit sur des zones, mentales pour la plupart, à l’intérieur des quelles vont se trouver les valeurs qui détermineront les phénomènes sonores. Cette incertitude est la conséquence de l’imprécision, ou disons de la relativité de l’écriture » p. 67

[160] « De ce point de vue, et en acceptant une certaine ironie vis à vis de la situation, nous sommes un peu comme ces peuples de Mésopotamie qui, trois mille ans avant notre ère, inventaient les premiers signes qui permirent non seulement de fixer, mais aussi de faire évoluer notre pensée » (p. 73)

[161] « Si une nouvelle technologie se doit d’apporter de nouveaux concepts dans la discipline qu’elle sert, elle doit également intégrer le savoir-faire qui est en cours dans cette discipline. Ce savoir-faire est construit, selon moi, dans cet échange permanent entre l’écriture et l’interprétation. Les systèmes en temps réel autorisent bien évidemment ce que l’on nomme du terme très prisé actuellement, voire

Manoury then literally transposes the problem of representational hybridity in mixed music to the very original problem between score and interpretation, asserting that virtual scores consist of absolute data, coded in the machine and read as a traditional score, and relative ones, which are affected by the real-time performance, or the interaction between human and machine.

Manoury's account offers us with some unusual insights, which articulate lots of the problems of the current dissertation and serve as an interface between the first and second axis of the current: If notation has always been interactive and the current state of affairs in real-time electronic music is not but a transposition of the original problem of the score's virtuality, then aporias pertaining to complex scores in both the traditional (first axis) and electronic repertoire (second axis) can and will be addressed through a model of performative interaction.

2.4 Third Axis: Embodiment And Intermedia

The third axis of a short history of embodiment in post-war music explores the new conceptions of the body as performance agent and as objectified part of intermedia constellations. Its relation to the first two axes is one of further expansion: If the first axis reveals the hitherto latent embodied subtext in classical new music and if the second one points at embodiment's centrality in the mediation process between classical instruments and electronics, then this third axis will focus on extensions of music into other arts and media beyond sound via the medium of the body. The theatralization of musical performance, and more particularly the emergence of physical theatre out of notational complexity, stands in the centre of our interest here.

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même abondamment galvaudé, d'interactivité. Comme la virtualité était présente dans le couple écriture/interprétation depuis toujours, l'interactivité n'est pas non plus une chose nouvelle en musique » (p.72)

According to Stephan Drees[162], the ontological exploration of embodiment in relation to music constitutes a significant expansion of music's cultural significance: Not only does it reveal a complex network of underlying body-concepts and discourses[163], but it also allows for the opening-up of composed music to previously neglected genres, such as performance and installation art[164]. Similarly, Martin Zenck[165] argues that significant changes in the theatrical praxis since 1950 have been channeled into the composition and staging of new music theatre, as he shows with his analyses of three opera choreographies by Sasha Waltz. Zenck makes reference to the 1960s "happening" and to the 1980s "performance art" as triggers of a shift, which Erika Fischer-Lichte resumes as "the crises of representation"[166] and which is contemporaneous to "the return of the body" in German anthropology[167]. Central in all those developments is the notion of a "performative turn"[168] in literature. (Zenck, p.195).

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[162] Stefan Drees, *Körper Medien Musik. Körperdiskurse in der Musik nach 1950*, Wolke Verlag Hofheim, 2011

[163] „Die Herausstellung dessen, *was Körperlichkeit sein kann* -und zwar bezogen auf ein künstlerisches Handeln, das sich im weitesten Sinn dem Bereich der Musik oder dem Umgang mit Klängen zurechnen läßt- steht im Mittelpunkt der vorliegenden Studie, die sich als Versuch einer systematischen Bestandsaufnahmen unterschiedlicher, teils aufeinander verweisender, teils aber auch einander ausschließender Körperkonzeptionen versteht." p.10. My italics.

[164] „Dadurch lassen sich jedoch auch künstlerische Ansätze vergleichen, die man im Rahmen musikwissenschaftlicher Forschung bislang kaum unmittelbar nebeneinander diskutiert hat, weil sie weniger dem Bereich der komponierten Musik, als den immer noch sehr stark hiervon abgeschotteten Kategorien der installativen und performativen Kunst zugerechnet werden", p.10.

[165] Martin Zenck, "Intermedialität von Performance, Improvisation und Choreografie im neuen Musiktheater. Drei Modelle von Sasha Waltz: « Dido and Aeneas »-« Körper »-« noBody » , in Marion Demuth / Jörn Peter Hiekel (eds.) *Freiräume und Spannungsfelder. Reflexionen zur Musik heute*, Schott Music, Mainz, 2009

[166] Erika Fischer-Lichte (ed.), *Theatralität und die Krisen der Repräsentation*, DFG-Symposion 1999, Stuttgart und Weimar 2001

[167] Dietmar Kamper (Hg.), *Die Wiederkehr des Körpers*, Frankfurt/Main 1982

[168] The performative turn here, even if not unrelated, is not to be confused with the performative turn in musicology, which will be examined in section B of the current. Zenck refers here to John L. Austin's speech-acts in his *How to do things with words* , in itself one of the bases of Erika Fischer-Lichte's *Ästhetik des Performativen*, which will be explored shortly.

In the context of his " digital revolution of music" (Die *digitale Revolution der Musik*), Harry Lehman similarly describes this transposition of music towards multimedia as the emergence of a *relational music:* Absolute music is explicitly judged as irrelevant in a digital culture and advanced art-music is understood as building relations to images, performative handlings and words, or what Lehman describes as the strategies of *Visualisierung*, *Theatralisierung* and *Semantisierung* (visualization, theatralization, semanticization. *Die digitale Revolution*, 115-125). A shift of the traditional musicological dichotomy between *absolute* and *programmatic* music towards a new one, between *visible* and *invisible* music, seems to have emerged[169].

Examples of such shift are plentiful in current practice: The output of composers such as Johannes Kreidler, Stefan Prins, Simon Steen-Andersen, Marianthi Papalexandri-Alexandri -to mention just a few- does indeed increasingly show towards an organic and successful micro-integration[170] of elements of a substantially audiovisual (or more accurately multimodal), media-based culture in the musical praxis, whereby the body assumes an explicit association with body-image[171].

In what follows, we will take a closer look at the origins of what Drees calls “body conceptions”, through an overview of philosophical and sociological constructions of the body in the 20th century, before reviewing some of the most important developments in music (the latter considered in a significantly extended sense).

A. Body Discourses In The Twentieth Century

Cultural anthropologist Jean-Jacques Courtine encapsulates in one phrase a history of body-discourses:

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[169] The term *visible music* (*sichtbare Musik*) originates in Dieter Schnebel's lecture in Darmstadt in 1966. In Schnebel, Dieter, *Anschläge – Ausschläge. Texte zur Neuen Musik*, München 1993, 262-3 300.

[170] Micro-integration as opposed to mere multimedial juxtaposition. See Leman, Marc, *Embodied Music Cognition and Mediation Technology*, Cambridge Massachusetts 2008, 140.

[171] A good example would be S. Steen-Andersen's *Run Time Error*, whereby video documentation of the performance in (and crucially *of*) a labyrinthine space enters in dialogue with the historical genre of *Musique Concrète*. See Lehmann, 119-120.

"Where once we had subjects without bodies, now we find bodies without subjects [...]"[172]

Following the early 20th century impulses away from the Cartesian denigration of the body in front of the *res cogitans* (the bodiless subject)*,* a reversal of the relation between body and subject is reached in the context of post-structuralist discourses in the second half of the century: The body is "carried away by the flow of desire or held in the tight grip of power", leaving a "subject that is nothing more than an 'avatar', a 'residue', a 'spare part' of the body"-be it in Deleuze's and Guattari's *desiring machine* or in Foucault's genealogical turn on body and power (p.166).

Courtine identifies three foundations for the reconstitution of the relation between body and subject in the early twentieth century:

The first of them is Sigmund Freud's *Studien über Hysterie* (1895), after observations of the symptomatology of what he finally called "conversion hysteria" and the conclusion, that "the body was able to give voice to repressed representations through the conversion of unconscious drives into somatic symptoms. The unconscious could speak through the body" (p. 165).

The second is German and French phenomenological traditions, whether in Edmund Husserl's conception of the body as the "cradle of all meanings", or in Merleau-Ponty's *Phenomenology of Perception*, whereby he introduces a subjectivized or "habitual" body as the incarnation of consciousness, in response to the failure of both contemporary physiology and classic behavioral psychology to deal with the sensation of "phantom limbs" in amputees.

The third foundation is Marcel Mauss' notion of the *habitus*, that is "socially determined modes of bodily action, physio-psychological assemblages of series of actions, assembled by and for social authority" (p. 165).

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[172] In Courtine, Jean-Jacques, „The Body", in *The Columbia History of Twentieth-Century French Thought ,* L. D. Kritzman (Hrsg.), New York 2006, 166.

Despite those initial impulses, the body remains marginal in cultural theory until the 1960s. This is the time when the first signs of a shift away from the structuralist focus on language and structure and towards problems of body and power start emerging in the French intellectual scene. Michel Foucault's work sets the example of this characteristic turn -later to initiate a whole branch of biopolitical theory culminating in Giorgio Agamben's work-, which in his case manifests as a turn from "archaeology" and its focus on language, to "genealogy" and its focus on body and power. Deleuze and Guattari complete the Nietzschean reversal of the relation between body and subject: "It is at work everywhere, functioning smoothly at times, at other times in fits and starts. It breathes, it eats. It shits and fucks". (Courtine, p. 166)

In sociology, a determining moment comes with the publication of Bryan Turner's *Body and Society* (1984)[173], which explicitly and officially turns the body into a theoretical and methodological site for social science. The variety of body discourses in sociology since then is meticulously presented at length in Mariam Fraser's and Monica Greco's *The Body: A Reader*[174]*.* According to the editors, the book is written "in the spirit of a 'toolbox'" (p. 3) for an array of problems set by the notion of the body. The book is articulated in eight parts and addresses: the ontological fundamentals of embodiment (the body as subject, object and becoming); the implications of the body in social relations of power; the relations between body and identities pertaining to sexuality, gender, race and class; notions of normalcy and its opposite, as indicatively in the distinction between health and illness; the extension of the human body through technology; the body in consumer culture; and body and ethics (p. 4-6).

As it will soon become clear, almost all of those categories become in one or another way thematic in a variety of musical intermedia.

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[173] Turner, Bryan, *The Body & Society: Explorations in social theory*, SAGE Publications Ltd., 2008 (1984)

[174] Mariam Fraser & Monica Greco (eds.), *The Body: A Reader*, Routledge, New York, 2005

B. An Aesthetics Of The Performative: Erika Fischer-Lichte

Before we move forward with an overview of examples and repertoire of musical intermedia, let us first look at exactly how similar questions concerning the relation of body and visuality are being raised in the context, from which Drees draws the basis for the genre expansion of music: that of *theatrical studies and performance art* as addressed in Erika Fischer-Lichte's influential *Ästhetik des Performativen* (aesthetics oft he performative).

Erika Fischer-Lichte offers an analysis of the *performative turn* in theatre: the turn from the notion of the *work* to that of the *event*. To that purpose, a wholly new aesthetic is considered necessary, based on the revision of the relations between performing *subject* and perceiving *object*, as well as the relations between *materiality* and *sign,* in themselves pointing towards the shift from *representation* to *presence*[175].

Fischer-Lichte's central case study is the historic performance *Lips of Thomas* by Marina Abramovic, which took place on 24.10.1976 in the Galerie Krinzinger in Innsbruck, Austria. According to Fischer-Lichte, the two hour-long performance that *both* the performer and the spectators experienced was an event, that could not be analyzed or even legitimized through the traditions, conventions and standards of either visual or theatrical studies.[176] Crucially, it is the very event of Abramovic's *abuse of her own body*, to the point that the performance was interrupted by the intervention of the spectators themselves, that necessitates the revision of classical relations mentioned above: The spectators turn here into acting agents themselves,

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[175] „ Der performativen Wende in den Künsten läßt sich mit dem überlieferten ästhetischen Theorien kaum angemessen beikommen-auch wenn diese in mancher Hinsicht durchaus weiter auf sie anwendbar bleiben. Das entscheidende Moment dieser Wende jedoch, *den Wechsel vom Werk und den mit im gesetzten Relationen von Subjekt vs. Objekt und Material- vs. Zeichenstatus zum Ereignis*, vermögen sie nicht zu erfassen. Um es in seiner besonderen Eigenart in den Blick nehmen, untersuchen und erläutern zu können, bedarf es der Entwicklung einer neuen Ästhetik: einer Ästhetik des Performativen“. p.30, my italics.

[176] „Im Verlauf dieser zwei Stunden gestalteten die Performerin und die Zuschauer ein Eriegnis, das durch die Traditionen, Konventionen und Standards weder der bildenden noch der darstellenden Künste vorgesehen oder gar legitimiert gewesen wäre“, p.10

instead of mere thinking and feeling receptors; and the bodily and material presence of the acts dominates their potential signifying properties.[177]

In a later chapter dedicated to bodily presence[178], Lichte observes the historical development of the notion in three stages: In what she calls "the soft concept / das schwache Konzept der Präsenz", the sheer appearance of the phenomenal (as opposed to the semiotic, that is emerging from the role) body of the actor and its co-existence with that of the spectators', forms a necessary and sufficient condition for the achievement of the effect of *presence*[179]. Later on in the history of theatre, it is not the sheer bodily presence itself, but rather the *domination of theatrical space* and the *excitement of the spectators' attention through performative actions,* which grants the event with an enhanced quality of *Gegenwärtigkeit,* the perception of its contemporaneity (and that's a "hard version of presence")[180]. In the last twist of her argument, a "radical concept" consists actually in *the experiencing of the embodied mind in its unity and the production and distribution of performative energy through techniques of the body* [181]*.* The chapter is concluded with the following quote:

"An aesthetics of the performative is in this sense an aesthetics of presence, *not* of presence effects, an aesthetics of emergence, *not* of appearance"[182].

If in the very field of theatrical studies the definition of bodily presence disengages from visuality, as a sheer appearance of the body or of gesture, in favor of an

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[177] „Jedenfalls sind die Zuschauer hier nicht nur als fühlende oder denkende Subjekte zugelassen, sondern auch als Handelnde, als Akteure“. And: „Die Körper- bzw. Materialhaftigkeit der Handlung dominierte hier also bei weitem ihre Zeichenhaftigkeit“. Both quotes from p. 21.

[178] „Präsenz“, p. 160-175

[179] „Ich will den Bezug auf die Gegenwärtigkeit, wie sie mit der bloßen Anwesenheit des phänomenalen Leibes des Akteurs gegeben ist, das schwache Konzept von Präsenz nennen“ p. 163

[180] „Den Bezug auf die Beherrschung des Raumes durch den Akteur und die Fokussierung des Aufmerksamkeit auf ihn bezeichne ich als *das starke Konzept von Präsenz*“ p. 166

[181] „In der Präsenz des Darstellers erfährt und erlebt der Zuschauer den Darsteller und zugleich sich selbst als embodied mind, als dauernd Werdenden, die zirkulierende Energie wird von ihm als transformatorische Kraft –und in diesem Sinn als Lebens-kraft – wahrgenommen. Dies möchte ich das radikale Konzept von Präsenz nennen“, p. 171.

[182] „Eine Ästhetik des Performativen ist in diesem Sinne eine Ästhetik der Präsenz, nicht der Präsenz-Effekte, eine „Ästhetik des Erscheinens“, nicht eine Ästhetik des Scheins“, p.175.

emphasis on energy circulation, then approaches to music in the post-war era through the transplantation of theatrical categories and the focus exclusively on its intermedial and iconic elements seem almost ironic. Equally problematic appear to be the exclusion of a large range of absolute music, the alleged mutual exclusiveness between absolute music and embodiment, or the identification of embodiment with visuality, as witnessed in Lehmann and Dress.

Following up from Lichte's *radical concept of presence* as *circulation of energy,* we will be approaching embodiment not only in its iconic property in musical intermedia, but also in relation to how the bodily element strategically radiates through the musical communicative chain (performance, reception, composition) in absolute music, including but not limited to notions of *energetic striving* and material presence. Through complex processes of transformation and transition of energy, a body not to be visually perceived becomes the common denominator of all three fields: body as meaning in composition, body as *psychophysical* presence in reception and body as thinking gesture in performance, corresponding to the three axes inspected here: The body as embodied subtext in composition, as immanent presence in electronics, as objectified part of intermedia constellations. At the same time -and as a side effect-, another pervasive visualization in music is undermined, namely the notion of a *sound-image*.

No genre was left untouched by the performative turn. In visual art, *action painting* and *body art*, as well as *light sculptures* or later *video installation* constitute clear examples of an increasingly performance-oriented visual culture.

According to Fischer-Lichte, the performative turn in music is introduced already in the 1950s with John Cage's "events" and "pieces", such as the *Untitled event* at Mountain College, or the even more famous 4'33", whereby the pianist's silence in front of his instrument serves as a frame for the amplification of the hall's and audience's ambient sounds. In the '60s, more composers include visible actions in an otherwise fixed compositional plane and develop notions, such as Stockhausen's “szenische Music”, Dieter Schnebel’s “sichtbare Musik”, and Mauricio Kagel’s “instrumentales Theater”[183].

C. From A Bodiless Subject To An Objectified Body

Courtine's schema -from a bodiless subject to a centric, albeit objectified, perception of the body- seems to be describing the evolution of contemporary discourses in the field of postwar art music equally well, even if with a very specific twist: body-discourses in music increasingly appear to be insolubly tied to *body image-discourses*, that is to an inevitable *visual* constitution of musical embodiment. Indeed, in his *Körper-Medien-Musik*, Stefan Drees, starting off from theatrical and anthropological ground -namely the turn from *language* to *performance*- organizes a mosaic of central paradigm-shifts in musical embodiment, as a gradual *liberation of the musical body* and as a quintessentially *visual objectification* of it. An outward projection of the body is outlined: From the esoteric experiences of classical performers and from the notion of playing / singing technique as an invisible medium serving compositional ideas, the body turns gradually into a medium for exploration of new expressive sonic possibilities (ones which are *unthinkable* on the composers' part); into an indispensable part of musical theater, valuing visually conveyable gesture as much as sound (paradigmatically manifested in the work of Mauricio Kagel and Dieter Schnebel); eventually into a vital part of intermedia constellations and transhumanist aspirations, as is the case in Nam Jun Paik's installations or Stellarc's performances. According to Drees:

"[..] the body is set on stage not only with the consideration of the sonic outcome of performative handlings, but also taking into account its visual aspects as artistically relevant *object*. From here results the conception of the body as a medium [...]"[184]

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[183] For an overview please refer to: Christa Brüstle, „Performance/Performativität in der neuen Musik“, in Erika Fischer-Lichte und Christoph Wulf (Hrsg.), *Theorien des Performativen*, (Paragrana, Bd. 10, H.1), Berlin 2001, S. 271-283

[184] „Welche wichtigen Stellenwert hierbei ikonologische Aspekte einnehmen, läßt sich leicht erschließen, wenn man bedenkt, dass der Körper gerade in dem mit Musik- oder Kunstausübung verbundenen Gefüge performativen Handels nicht allein über seine klanglichen Hervorbringungen, sondern auch über die visuelle Ebene als künstlerisch relevantes Objekt inszeniert wird. Hierdurch ergibt sich nicht zuletzt *die Auffassung des Körpers als Medium,* das im Kontext umgebender

In this respect, liberation of the body from performative restrictions of the past equals a liberation from the monopoly of disembodied sonic ideals: Through the visual perception of bodily actions and images, music becomes an affair of the eyes as much as of the ears and musicology can according to Drees expand, to include previously neglected genres like installations and performance art. Courtine's schema has been fulfilled, as a move from the bodiless compositional subjectivity of the past to an audiovisual projection of the musical body.

Given such an ocularcentric[185] constitution of embodiment, it is not surprising that Drees, not only focuses on instances of intermedia art, musical theater or sound installations, but also *excludes* a vast part of repertoire of *absolute music*, which thematizes embodiment in distinctively different- *invisible* I am already tempted to write- ways. Thus, the promised expansion of the field rather equals a transposition towards multimedia art forms.

It is important to note how Drees' categories of embodiment in music do reveal overlaps and affinities with the more general theoretical discussion of the body as reviewed in Fraser and Greco, thus supporting his initial thesis, that music inevitably incorporates and materializes wider cultural contexts and discourses[186]. In this sense, and apart from the immanent ontological questions, of what a body actually *is* (subject-object-becoming), important insights are revealed in relation to: the disciplining of musicians' bodies in education and the liberation from traditional constraints, especially in relation to voice (in the second chapter "Leiblichkeit und Stimme" / Embodiment and Voice, especially in his "Die 'Körperstimme' als ganzheitliches Konzept" / the body voice as holistic concept); sex and gender

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Medienkonfigurationen angesiedelt ist und folglich in intermedialer Relation zu diesen sowie zu den durch sie konstituierten Kommunikationsmustern analysiert werden muss" p.13, my italics.

185 Term indicating the privileging of vision. For a review of *anti-occularcentrism* in 20th century philosophy, please refer to: Jay, Martin, *Downcast Eyes. The Denigration of Vision in Twentieth-Century French Thought*, University of California Press, 1994

186 „Diesem Buch liegt die Gewißheit zugrunde, dass Kunst niemals unabhängig von Kulturellen Zusammenhängen funktioniert, sondern dass sie generell als Filter für die Realität dient und daher durch ihre Diskurse über bestimmte Auffassungen vom menschlichen Körper, aber auch über das Verhältnis des Menschen zur Medientechnologie Aufschluß geben kann" p.9

identities, such as in the collaborations of Nam Jun Paik with Charlotte Moorman reviewed in the third chapter “Der Körper im Spannungsfeld von Befreiung und intermedialem Einsatz“ / “the body between liberation and the introduction of intermedia”; the extension of the human body through technology, either in the sense of intermedia constellations, or in transhumanist settings of further hybridization of body and machine (the artist Stelarc is a good example featured in the fourth chapter, “Der hybridisierte Körper im Spannungsfeld künstlerischer Fragestellungen“ / “the hybrid body as artistic inquiry”); notions of social normalcy and disability studies, as thematized in chapter five, “Der Umgang mit dem beschädigten Körper als künstlerische Herausforderung”/ “interaction with the disabled body as artistic challenge”); and certainly notions of performativity, objectification, staging of the body and participation of the spectator, in chapter six (“Das Körper als Instrument und performative Ressource” / “the body as instrument and performative resource”).

3. Performative And Embodied Turns In Musicology

The previous discussion of a third axis of musical complexity from the point of view of performativity in musical creation with intermedia after 1945 leads smoothly to the emergence of parallel turns in both historic and systematic musicology. In this chapter, we will review the *performative turn* in musicology, by way of three contemporaneous, state-of-the-art publications, which reflect to a great extent shared interests but also differences in the Anglo-Saxon, French and German academia; we will focus on the topic of the relation between performativity, the human body and musical representability in the form of musical scores; and we will review the emergence of an embodied cognitive paradigm, as presented in Leman's *Embodied Music Cognition and Mediation Technology*.

Aim of this chapter is to reveal the problematic ontological position of the musical score, and of musical representation in general, in both the performative and embodied cognitive turns. It is exactly this very aporia that is actively being addressed in the current dissertation, through the development of a model of embodied interaction with complex piano notation.

3.1 Overview Of Performance Studies

For an introductory overview of the field of performance studies, *Analyser l'Interprétation de la Musique du XXème siècle* by Philippe Lalitte offers again a comprehensive solution, covering developments both internationally as well as in France[187]. Such overview focuses rather on historical and philosophical aspects in

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[187] Book such as: Lydia Goehr, *The Imaginary Museum of Musical Works: An Essay in the Philosophy of Music*, New York:Oxford University Press, 1992; Peter Kivy: *Authenticities: Philosophical Reflections on Musical Performance*, New York, Cornell University Press, 1995; Stan Godlovich, *Musical Performance. A Philosophical study, London and New York*, Routledge, 1998; Stephen Davies, *Musical Works and Performances. A philosophical exploration*, New York, Oxford University Press 2001; Jonathan Dunsby, *Performing Music: Shared Concerns*, Oxford University Press, 1995;

relation to the concept of the musical work, as being revised in a wave of publications originating in the 1990s and dedicated to performance. According to Lalitte, the core of those studies is the distancing from what is termed *graphocentrisme*, that is the focus on the written musical text as exclusive container of the musical work, towards the study of the musical act in its globality, including performances and musical recordings alike. A similar approach is codified in Alessandro Arbo & Marcello Ruta (eds.), *Ontologie Musicale, Perspectives et débats*, Hermann 2014, and forms the epicenter of LabEx GREAM's research interests around the musical act.

A more systematic line of thinking, summarized under the term *empirical musicology*, is reviewed in Eric Clarke's *Empirical Methods in the Study of Performance*[188], which offers a detailed timeline of landmark studies and achievements in this field of systematic musicology as follows:

"To give a quick overview of how the empirical study of performance has developed, the following is a list of some of the publications that have played an important part in defining the field:

Richard Taruskin, *Text and Act: Essays on Music and Performance*, Oxford University Press, 1995; John Rink (ed.) *The Practice of Performance. Studies in Musical Interpretation*, Cambridge University Press, 1995; Peter Walls, *History, Imagination and the Performance of Music*, Woodbridge, Boydell, 2003; José Bowen "Finding the Music in Musicology: Performance History and Musical Works", in N. Cook and Mark Everist (eds.) *Rethinking Music*, Oxford University Press, 2001; Nicholas Cook "Changing the Musical Object: approaches to performance analysis" in Zdravko Blazekovich (ed.) Music's Intellectual History: Founders, Followers and Fads, NY, RILM, 2009 (www.rilm.org/historiography/cook.pdf)

Journals such as: *Music performance research* (since 2007); *Journal of Research in Music Performance* (since 2009); *Musurgia*, vol. 12, no 4, 2005; *Musimédiane*, No 2, 2006; *Contemporary Music Review*, vol. 26, No 2, 2007.

In France, important contributions are reported by: Jean Jacques Eigeldinger (ed.) *Interpréter Chopin*, Les Cahiers du musée de la musique, Paris, Cité de la musique, 2006; Jean-Pierre Armeengaud et Damien Ehrhardt (eds.), *Vers un musicology de l'interpretation*, Les Cahiers Arts et Sciences de l'Art No 3 – Ideat, Paris, L'Harmattan, 2010; Nicolas Lagoumitzis *Cinq Pianistes interprètent Beethoven*, Paris, L'Harmattan, 2010; Mara Lacchè (ed.) *L'imaginaire musical entre creation et interpretation*, Paris, L'Harmattan, 2006; Marie Noëlle Masson (ed.) *L'Interpretation Musicalle*, Le Vallier, Editions Delatour, 2012

[188] Eric Clarke, Nicholas Cook (eds.) *Empirical musicology. Aims, Methods, Prospects.* Oxford University Press, 2004

• In the early 1930s, Seashore and his research associates developed an extensive research program in music performance at the University of Iowa, much of which is brought together and reported in Seashore's summative book [1967 (1938)][189]. This represents the earliest extensive and systematic empirical work on performance, and identified many of the issues that have remained the preoccupations of subsequent research.
• Povel (1977)[190] describes expressive timing in a number of Bach harpsichord performances, and Bengtsson and Gabrielsson (1977)[191] in performances of Swedish folk tunes. Together, these represent the first significant publications of the "modern" period of performance research.
• Shaffer (1981)[192] is the first substantial paper to report results obtained from direct computer monitoring of the piano. The paper concentrates on timing, coordination, expression, and the cognitive representation of complex movements.
• Sundberg, Fryden, and Askenfelt (1983)[193] is the first published attempt to produce an artificial model of performance expression, using a collection of separate rules that relate to local features of the music. Todd (1985)[194] is a subsequent attempt to achieve the same goal using only a single rule applied recursively.
• Repp (1990a)[195] is the first paper to look at a larger body of performance data, using commercial recordings and extracting performance data from the recorded sound. Since that first paper, Repp has gone on to investigate larger collections of performances, in some cases analyzing over 100 recorded performances of the same work.
• Davidson (1993)[196] is the first published work analyzing the visual component of expressive performance.
• Rink (1995)[197] represents the first large-scale publication bringing together musicologists and

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189 Seashore, C. E. [1967 (1938)]. The Psychology of Music. McGraw-Hill. (Republished by Dover Books, New York, 1967.).

190 Povel, D-J. (1977). "Temporal structure of performed music. Some preliminary observations." Acta Psychologica 41: 309–320.

191 Bengtsson, I., and Gabrielsson, A. (1977). "Rhythm research in Uppsala," in Music, Room, Acoustics. Stockholm: Royal Swedish Academy of Music, 17: 19–56.

192 Shaffer, L. H. (1981). "Performances of Chopin, Bach and Bartók: Studies in motor programming." Cognitive Psychology 13: 326–376.

193 Sundberg, J., Fryden, L., and Askenfelt, A. (1983). "What tells you the player is musical? An analysis-by-synthesis study of music performance," in J. Sundberg (ed.), Studies of Music Performance, Stockholm: Royal Swedish Academy of Music 39: 61–75.

194 Todd, N. P. (1985). "A model of expressive timing in tonal music." Music Perception 3: 33–58.

195 Repp, B. H. (1990a). "Patterns of expressive timing in performances of a Beethoven minuet by nineteen famous pianists." Journal of the Acoustical Society of America 88: 622–641.

196 Davidson, J. W. (1993). "Visual perception of performance manner in the movements of solo musicians." Psychology of Music 21: 103–113.

197 Rink, J. (ed., 1995). The Practice of Performance. Studies in Musical Interpretation. Cambridge:

psychologists in the study of performance." (Clarke & Cook, p.78-79).

Similarly to Lalitte, Clarke identifies the field of performance studies as "a move away from the primacy of the score and toward increasing interest in music as performance", with "a focus on different performance traditions, the nature of performance interpretation and its relationship to analysis, and the legacy of historical recordings" (Clarke & Cook, p.77).

Finally, in his review-article[198] of Nicholas Cook's *Beyond the Score*, and starting off from John Rink's characterization[199] of the field of 'Performance Studies' as consisting of 'three overlapping domains: historical performance practice, the psychology of performance and analysis and performance', Ian Pace identifies a significant expansion of the field as follows:

"The field has spawned subdisciplines since Rink's essay, and I would identify a further important domain already established at that time - critical, philosophical, and theological reflection on performance, which sometimes draws upon wider scholarship on theatre, performance, and performativity - together with at least eight other latent or subsequently developed fields, some of which overlap with those identified by Rink. These are: performance-as-research and performance-based research (and its continental European counterpart, artistic research into performance), generally undertaken by practitioners and requiring a practical element; study of the performance of contemporary art music, including techniques and practices, a relatively autonomous field and underdeveloped in terms of critical methodology; ethnographic studies of performance and performers; cultural history and study of performances, considering particular performances and groups of performances, relating their musical characteristics to wider cultural and social concerns; studies of performance traditions, a field which incorporates much of the best work in popular music studies and ethnomusicology; detailed study of specific performers and groups of performers, intense investigation of the musical work of individual performers or ensembles, bands, orchestras, choirs, etc. (a tradition which in many Western contexts (art and popular musics) has previously been pursued mostly by amateurs); historical and comparative performance pedagogy; and the study of the theatre of performance." (Pace, p. 2)

Cambridge University Press.

[198] Ian Pace, *The New State of Play in Performance Studies*, Music & Letters @The Author (2017).Published by Oxford University Press. doi:10.1093/ml/gcx040, available online at https://academic.oup.com/ml

[199] In his John Rink, 'The State of Play in Performance Studies', in Jane W. Davidson (ed.),The Music Practitioner: Research for the Music Performer,Teacher and Listener (Aldershot, 2004), 37-52.

A subfield of study central to our interests is the study of expressive musical performance through objective measurement of performance features, enabled by the increasing availability of sensor-based and interactive technologies. Important work has been reported by Dahl, S. (2004)[200], Dahl, S., & Friberg, A. (2007)[201], Caramiaux, B., Wanderley, M. and Bevilacqua, F. (2012)[202], McPherson, and Kim (2013)[203], Broughton & Stevens, (2009)[204], Caruso, Esther, Nijs &Leman (2016)[205], Rasamimanana, N. , Fléty, E. Bevilacqua, F. (2005)[206]

3.2 The Question Of Musical Representation Through A Comparative Study

While the study of musical performance, the ontological extensions of the notion of "musical work", the development of empirical methods in musicology and the notion of musical embodiment have been increasingly important in the past three decades as shown above, the very role of the musical score in relation to those developments and the necessary updating of the notion of musical representation -necessary due to

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[200] Dahl, S. Expressiveness of musicians' body movements in performances on marimba. In A. Camurri & G. Volpe (Eds.), *Gesture-based communication in human-computer interaction*, LNAI 2915 (pp. 479–486). Berlin: Springer Verlag, 2004

[201] Dahl, S., & Friberg, A. Visual perception of expressiveness in musicians' body movements. Music Perception: An Interdisciplinary Journal, 24(5), 2007, 433–454

[202] B. Caramiaux, M. Wanderley, F. Bevilacqua.Segmenting and Parsing Instrumentalists' Gestures. In Journal of New Music Research, vol. 41, no. 1, 2012, 13-29.

[203]McPherson, Andrew and Kim, Youngmoo "Piano Technique as a Case Study in Expressive Gestural interaction", in : Holland 2013

[204] Broughton, M., & Stevens, C. Music, movement and marimba: An investigation of the role of movement and gesture in communicating musical expression to an audience. Psychology of Music, 37(2), . 2009,137–153

[205] Giusy Caruso, Esther Coorevits, Luc Nijs & Marc Leman (2016): Gestures in Contemporary Music Performance: A Method to Assist the Performer's Artistic Process, *Contemporary Music Review*, December 2016 http://dx.doi.org/10.1080/07494467.2016.1257292 accessed 05.05.2018

[206] Rasamimanana, N. , Fléty, E., Bevilacqua, F. (2005), "Gesture Analysis of Violin Bow Strikes", in: Gesture in Human Computer Interaction and Simulation, International Gesture Workshop, 2005, Springer, 2006

both conceptual and technological advances[207]- remain obscure. These questions are central for the proposition of a new paradigm of the musical score in the context of the performative turn. This paradigm acknowledges the primacy of embodied interaction with a dynamic, malleable score as equal part of a constellation of media, opposed to the traditional paradigm of a score-work to be interpreted. Such a paradigm is pursued through the development of "embodied navigation of complex notation" in the second part of the current.

In the context of the *5ème Journée des Jeunes Chercheurs du LabEx GREAM* "L'analyse musicale au-delà de la partition" at the University of Strasbourg[208], I approached the latest developments in the field of empirical musicology and the aporias concerning the musical score through the comparative study of three publications representative of English-, French- and German-speaking musicology respectively: Nicholas Cook's *Beyond the Score. Music as Performance* (2013)[209], Philippe Lalitte's *Analyser l'interprétation de la musique du XXe siècle* (2015)[210], and Jörn Peter Hiekel's & Wolfgang Lessing's *Verkörperungen der Musik. Interdisziplinäre Betrachtungen* (2014)[211].

All three publications share the same skepticism as to the ontological role of the score in contemporary performance-oriented musicology, while at the same time not being able to eliminate the musical score from the proposed methodologies. I will claim that the score cannot be abolished from musicological research, but must rather be re-integrated in a world of multimodal data and become itself malleable

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[207] Some of those advantage are codified in the annual conferences of the TENOR (International Conference on Technologies for Music Notation and Representation) community, which will be reviewed in more detail in part three of the current.
http://tenor-conference.org/ accessed 30.03.2018

[208] https://gream.unistra.fr/evenements/journees-detudes/5eme-journee-des-jeunes-chercheurs-du-gream-lanalyse-musicale-au-dela-de-la-partition/ accessed 30.03.2018

[209] Nicholas Cook, *Beyond the Score : Music as Performance*, Oxford Univerity Press, 2013

[210] Philippe Lalitte, *Analyser l'interprétation de la musique du XXe siècle. Une analyse d'interpretations enregistées des Dix pièces pour quintette à vent de György Ligeti,* Hermann, Paris, 2015

[211] Jörn Peter Hiekel's & Wolfgang Lessing's *Verkörperungen der Musik. Interdisziplinäre Betrachtungen.* Transcript Verlag, Bielefeld, 2014

rather than fixed, revealing its inherent dynamic interactivity with the user, whether she might be composer, performer or listener.

Nicholas Cook’s *Beyond the Score* is the culmination of the years-long CHARM (Centre for the History and Analysis of Recorded Music) project, funded by the AHRS (Arts and Humanities Research Board) in the UK and taking place at the Royal Holloway University. *Beyond the score* articulates a concise thesis against the so-called “structuralist paradigm” of musical reproduction of a musical score. In the course of his thesis, Cook presents a wide-ranging set of empirical methodologies (first part), as well as an overview of non-data-driven performance studies (second part), epitomizing their difference as follows:

> Performance studies approach enhances awareness of the meanings constructed through performance, while the empirical approach provides a foundation for understanding how these meanings are constructed (Cook, p.6)

Cook’s definition of what is interchangeably termed as the *textualist* or *structuralist* or *modernist* paradigm of performance indicates a modernist style of playing, produced by the false ideology underlining the primacy of the score as exclusive container of the musical work (the *Plato’s curse,* as he puts it). Such performances wish to function as “performance analysis in sound”. The distincion between a supposed structuralist paradigm of performance and what Cook calls “rhetorical style” becomes palpable in the form of comparative studies of Schenkerian analyses to historical piano-roll recordings, as well as recordings of differing styles themselves, including both computer-assisted and quantitative listening, and with a strong focus on expressivity as rubato-and-dynamics and phrase-arching. These empirical approaches are complemented by non-empirical methodologies of *scores as scripts of social interaction* or semiotic analyses of body movement in video performances, showing towards *specifically phonographic* ways of experiencing music.

In his own take on the performative turn, Lalitte focuses on the possibilities offered by *Music Information Retrieval (MIR)* methods based on a variety of audio descriptors for the analysis of recordings, with a specific case-study meticulously presented: The comparative analysis of ten recordings of the *Ten pieces for wind-quintet* by György

Ligeti.

Lalitte proposes an interesting taxonomy of performance analysis methods. He differentiates between the *(neuro)psychology of performance* using advanced brain-imaging techniques (EEG, MEG, fMRI) and the *musicology of performance*, distinguishing (similarly to Cook) between qualitative and quantitative methods. The first include field-work such as interviews with performers and study of performance reception (and certainly auto-ethnographic studies, such as my first-person descriptions); the latter foreground the capture of heterogeneous performance data (including MIDI, audio, video, gesture, ocular movements), as well as the comparative study of recordings, which constitutes Lalitte's main method in the publication. As far as the comparative study of recordings is concerned, Lalitte differentiates between methods for comparing scores to recordings, recordings to recordings and recordings to analysis (very similarly to the layout of empirical methods offered by Cook) and allow us a glimpse into the *MIR Toolbox* of audio descriptors for intensity, timbre, noise, dissonance, pitch, harmony, rhythm, tempo, temporal structure etc.

In their colletive volume *Verkörperungen der Musik. Interdisziplinäre Betrachtungen (2014),* Jörn Peter Hiekel and Wolfgang Lessing introduce aspects of music pedagogy and music physiology[212] that were absent in the other two case studies and, more readily than Cook, identify the performative turn as post-structural in its treatment of the text, as

> the gradual attenuation of thinking and speaking about music. Texts turn rather into entry-points, through which embodiment becomes palpable into a global quasi subjective-less entity encompassing the "composer-body", "interpreter-body" and "listener-body". (my reduction / translation, p. 7)[213]

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[213] "Allerdings deutet sich gerade in diesem Bereich zumindest punktuell eine substantielle Kehrtwendung an: jene im weitesten Sinne strukturalistischen Paradigmen, die nahezu selbstverständlich das Denken und Sprechen über Musik in den vergangenen 150 Jahren bestimmt haben, sind in jüngerer Zeit ins Wanken geraten, Im Anschluss an den Postsrukturalismus, der die akademischen Disziplinen nicht ohne Grund als zu eindimensional kritisierte, wird nun nicht mehr nur ein wie immer auch gearteter musikalischer „Text" zur Basis der Auseinandersetzung erhoben; dieser bildet lediglich eine Einsatzstelle durch die die Artikulation des Körpers im Sinne einer gleichsam

The critique of notions such as *technique* and *practice*, especially in Lessing's important chapter contribution " Versuch über Technik „[214], resonate with lots of our

subjektlosen, den „Komponistenkörper", den „Interpretenkörper" und den „Hörerkörper" gemeinsam umgreifenden Instanz beobachtbar und thematisiertbar wird".p.7

[214]Lessing offers a most meticulous overview of the development of the notion of technique from a philosophical and pedagogical point of view, which is here useful to revise. According to Lessing, around 1850 the notion of *technique* is already widely used in the musical praxis, pedagogy, critique and life, having already been introduced around the mid-18th century and in resonance with modern machine production and the first industrial revolution (p.13). One of its most conspicuous characteristics is its antithetical use, already present in the Aristotelian contrast between *Techne* and *Praxis*. Techne and Praxis differ in their relationship to the product: In the case of Techne, the work (or technique) disappears in the final result (for example a vase). In the case of Praxis, result and actions cannot really be differentiated, the virtue of actions and the resulting *Eupraxis* (the good action / product) are interconnected. The extension of the notion of technique in the 18. Century is marked by further antitheses. Particularly important is the coupling of technique with the modern ideas of progress, especially in its definition as pairing of science and manipulation and certainly the first industrial revolution, which brings about its differentiation from manual labor and also from nature and culture (p. 14-15). In music, those antithetical pairs take the form of "instrumental technique versus music". Very often, technique is theorized as the prerequisite of music making. This opposition mirrors other paradigmatic oppositions, such as body-mind (*Kopf-Bauch*). The negative definition of technique as the opposite to music becomes rather handy in the face of the fact, that a positive definition of either (music or technique) is actually very hard to articulate and differentiate. The opposition between music and technique serves also, and most centrally, the social role of a distinction between the professional and amateur, that is the sense of belonging to a "community of practice", and as selections' criterion. Through those developments, the notion of technique is established as deep paradigm in the Western music education and praxis, persisting up to our days. Purpose of Lessing's text is not to transcend the notion of Technique, but rather to address some of its aporias through the notion of "Handwerk", which is introduced by the sociologist Richard Sennett in the context of Hannah Arendt's neo-aristotelean antithesis between *Homo Faber* and *animal laborans*, between Work and Labor. (p. 18) Early piano pedagogy (for example, in Krall, Emil (2010): *Spielmannskunst. Die Kunst des Übens und die Ausbildung der Kunst. Zwölf Briefe an einen jungen Instrumentalisten*, Leipzig 1910) offers with its military allusions a prime example of the body as obedient agent of a will to power. Technique is defined as essence and result of a disciplining process, what Foucault would call a central institutional dispositif of the late 18. and 19. Century. Despite the organicity of musical life in the 19th century, aspects of this "schwarze paedagogik" become augmented in the 20th century to the point of attracting critique by Rudolf Maria Breithaupt (Die natürliche Klaviertechnik, 1905). Attempts of a liberation from this institutionalized subordination of music to technique are offered according to Lessing by : Breithaupt, as the pioneer of the notion of technique as liberation of physiological

considerations to follow. Central is also Zenck's notion of a *corporeal subtext* (as reviewed previously, p. 72), as well as views from the field of *evolutionary musicology*[215].

Characteristic of all the three publications examined above is the persistence of important dichotomies: quantitative versus qualitative, data versus signification, technique versus culture, historic versus systematic, body versus descriptors, education versus praxis. Let us elaborate on those:

a) Quantitative vs. Qualitative : While Cook has offered us an interesting signpost as to the relation between qualitative and quantitative methods (the first defining what meanings are produced through music-making, the latter how this is happening), the realization of this bridging is more complicated than it seems. To give a concrete example, the interview with an instrumentalist as to her priorities during a certain performance could create bias, which would shape the selection of captured data and vice versa. Eventually, each measurement, method or descriptor contains already the ideologies inherent to the technology used and the scientists conducting the experiment, so that the claims to objectivity might be put at question.
b) Data vs. Signification: Data are so to speak « wrapped » in-between

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untapped potential accessible to everyone (gravity), while however staying inside the cartesian dualism of body-mind ; Jacoby's notion of the „Nachreifung" (rippening), as liberation from Technique, but always serving the musical „Vorstellung", intention, mental image ; Gerhard Mantel's notion of „Der Mensch als Mobile", as a first attempt of describing performance as a dynamic system, in the sense that body mind and soul are considered as components of a dynamic system. The emergence of technique as channelling of attention in different components with rotating attention (p. 40) (equaling our notion of navigation) and an extensive take on *flow* (p. 42), foreshadow important notions reviewed later ; and finally Wolfgang Rüdiger : the idea of music as mimetic and gesticulating communicative art, a body language shaped as sound (p.44). The notion overall of the musical body as a kind of gravitational centre of all music-making, which interconnects music, the body the instrument, and the communication through corporeal articuations, echo significantly current research in embodied cognition.

[215] Eckart Altenmüller und Reinhard Kopiez. „Was kann uns die Gänsehaut lehren? Ein Beitrag zum evolutionären Ursprung der Musik". In Hiekel, J. P. and Lessing, W., Verkörperungen der Musik, Bielefeld:transcript, 2014

signification attractors, which have to be carefully located and at times dismantled. There is no ideology-free data, but rather ones which are more or less properly attuned to the task at hand.

c) Technique vs. Culture: The production of cultural meaning necessitates the constant calibration and evaluation of the notion of technique (Lessing) or equally technology in relation to research attractors, which cannot solely be defined by technology in itself, but from wider cultural determinants.
d) Historic vs. Systematic: Cook's critique of the notion of modernist style of performance against a Schnekerian background shows clearly how there is no history-free approach to music analysis.
e) Body vs. Descriptors: Audio descriptors remain as abstract a representation as the musical score in itself. Both are lacking the real embodied experience, manifested either as composer's projections of a musical performer's body, as lived performer-specific experience, or as shared experience in reception via the communication through corporeal articulations à la Leman.
f) Education vs. Praxis: Education and praxis are shaping each other in ways that are not always unproblematic. Lessing's overview of the notion of musical technique has shown how the rationalization of musical embodiment can become a burden to musical creativity in education.

A set of pertinent questions as to whether notation can eventually be left aside, so that we could move towards forms of analysis which do away with notation altogether, rises out of these dichotomies and takes the form of the following research questions:

a) Do comparative empirical methodologies afford signification without the score?
b) Are new media mere representational layers on top of a score-palimpsest that can never be erased?
c) Is the dynamicity and embodied presence of performance even representable?
d) How can non-dynamic descriptors and representations move beyond a reproduction model?
e) Longitudinal studies: How do performances evolve in time?

The current dissertation proposes answers to those questions, which can be for the moment summarized as follows:

a) Comparative empirical methodologies can never ignore the musical score, given that a musical score is involved. The question is not to move beyond the score, but rather to re-introduce the score as a sheer dynamic part in a web of interactions and representations.
b) The musical score forms indeed a primordial mode of representation, a *palimpsest*, which is not to be erased, but rather continue living in the accumulated layers of new modes of representation and meaning-creation.
c) The introduction of video analysis has already allowed for the representation of the embodied musical act. However, we should not forget, and along the consideration of embodiment and visuality before, that the image of the body does not capture what Erika Fischer-Lichte would call *the circulation of energy* in the context of her radical definition of presence (or what in the field of musical gesture, Shaun Gallagher would differentiate between *body-image* and *body-schema* processes). In this sense, embodiment should be thought as a multimodal interactive phenomenon, including semiotic and social aspects, rather than as a sheer visually staged phenomenon.
d) The answer to this question stands in the heart of this dissertation: Any sort of static fixed representation, including video and audio recordings as well as musical scores, fails to represent the vulnerability, fragility, dynamicity and interactivity of the musical act. In that sense, recordings in themselves are essentially no different from scores.
e) Longitudinal studies, of how an actual performance evolves over time, are deemed necessary for both pedagogical and performance analysis applications, present us though with significant logistical challenges, which are to a certain degree addressed by the current auto-ethnographic study.

All these questions will be addressed in detail in the course of our study, which sets the score at the centre of the empirical investigation, albeit a dynamic score that changes over time.

3.3 Embodied Versus Cognitive Paradigms

We have already identified above some of the tensions between the notion of performative turn and the primacy of the musical score, as well as the representability of the body. Such tensions reveal the necessity of an embodied cognitive paradigm. In the second chapter of his seminal book *Embodied Music Cognition and Mediation technology,* under the title “Paradigms of Music Research”, Marc Leman offers a concise overview of the gradual transition from a cognitive to what he calls an embodied paradigm in systematic musicology, from the point of view of mediation technologies. Leman’s contribution in relation to the musicological turns cited above, is that he sets technology and the respective methodologies at the center of the question as to how musical research has shifted from a brain-centered (cognitive) towards a body-centered (embodied) paradigm. In that sense, he achieves the alignment of systematic musicology with a huge corpus of work in cognitive science, stretching over both human and artificial intelligence, as will be reviewed in detail in part two of the current.

A. Cognitive Paradigms

Leman traces the Cartesian gap between the study of music as a physical phenomenon, as sound, and the study of its purely affective or inter-subjective qualities, in the ancient Greek philosophers, namely in the divide between Pythagoras, who considered the mathematical and acoustical properties of sound as an expression of universal order and beauty, and Aristoxenos, Plato and Aristotle, who rather focused on music’s perception, expression and ethics respectively. Such divide is neatly summarized by Descartes himself (*Musicae Compendium*, 1618) and the passage to the modern era with the scientific revolution affirms a superior interest in the mathematical / physical aspect (Euler), while musical practices are rather analyzed through rule-based accounts (Zarlino, Rameau, Mattheson).

Leman claims that the subjective aspects of music-making start becoming an object of scientific inquiry in the late 19th century, with fields such as psychophysics and psychology. Leman summarizes these approaches as *the cognitive paradigm*, in the sense that between the musical matter and the subjective experience, a brain perceived as an information-processing mechanism provides the missing link. With the provision, that such terminology (information-processing and even the focus on brain as opposed to mind) is rather a foreshadowing of much later developments in cognitive science (which will be exhaustively treated in part 2), here are some main cornerstones of this early cognitivist approach.

The work of Hermann von Helmholtz, founder of psychoacoustics, constitutes a breakthrough in the cognitivist paradigm, in the sense that it attempts to provide the missing link between acoustics and perception, assuming physiological mechanisms which are explored through quantifiable relationships between sonic inputs and perceptual outputs. In that sense, and to continue Leman's metaphor, the brain functions indeed as a computer, which transforms physical properties into perceptions. According to Leman, the second major stop in the cognitivist approach to systematic music research has to be traced in the *Gestalt* theory movement, with Max Wertheimer, Kurz Koffka and Wolfgang Köhler as its main proponents in the 1920s and Strumpf, Kurth, Seashore and Revesz as the founders of Gestalt theories in music in the 30s[216]. The main idea after Leman is the emergence of musical meaning as a "global pattern from the processing of information patterns contained in sound" (p.30).

The postwar advent of technology and information theory allows for the explicit manifestation of a model of music information processing based on the notions of *entropy* and *channel capacity* (after Shannon and Weaver[217]). Concurrent with the early pioneering developments in electronic music, and in particular sound synthesis (by Stockhausen in Köln, for example), such approach focuses on abstract compositional parameters like pitch and duration, providing their higher ordering through computation. Pretty much in the same vein as the dispute between

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[216] In short, *Gestalt* theory refers to visual perception and posits the perception of simple forms or rough sketches under the complexity oft he perceptual surface. Interesting revivals include the work of Marr in visual perception (computational model of vision as a gradual construction of the retinal image from primordial sketches), which will be reviewed in part two in relation to Gibson's ecological psychology.

[217] Shannon, C. E., & Weaver, W. (1949). The Mathematical Theory of Communication. Urbana: University of Illinois Press.

Pythagoras and Aristoxenos, the dichotomy between objective structural understanding and subjective perception persists in the era of mediation technology, manifesting as a dichotomy between the information processing model and the *theory of sound objects* articulated by Pierre Schaeffer[218]. Schaeffer's approach is pioneering, in that it offers a perceiver-oriented account of sound in relation to its production by the analog audio equipment of his time.

The computational modeling of music, as a description based on the information-processing of musical scores considered as objective descriptions of musical experience, has its origins in the need for a more reliable, objective model for the description of musical experience, than Schaeffer's subjective and interactive notions. In that sense, music processing can be conceived in terms of "a machine that manipulates representations of musical content (Fodor 1981)[219]" according to rules and symbols, as a simulation of mental processes. In that sense, the act of musical composition can be algorithmically conceived as a two-stage process, first of the production of symbol-based musical structures embodied in scores, and then as the mapping of those structures to musical sound. The result is the first attempts in algorithmic composition. One of the main limitations of a symbol-based computational modeling is according to Leman *methodological solipsism*: The relationship between the world as a collection of features and their encoding in symbols is mediated by a human actor, the encoder, who actually constructs or generates an image of the world hermetic to humans who don't understand the code.

The problem of methodological solipsism is addressed through a paradigm-shift towards *subsymbol-based descriptions* and modeling, initiated by research in visual perception and connectionism. Characteristic in that respect is the technique of *perception-based feature extraction*, a computational simulation of the constraints of the human auditory modeling as a mediated model proper for human information processing (as opposed to the processing of abstract symbols). From the real sound signal, as the input to the system, the system extracts those features which are

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[218] Schaeffer , Pierre, *Traité des objets musicaux. Essai interdisciplines* , Paris, Éditions du Seuil, 1966.

[219] Fodor, J. A. (1981). *Representations: Philosophical Essays on the Foundations of Cognitive Science*. Cambridge, MA: MIT Press.

relevant to human auditory experience according to physiology, and not those dictated by some abstract planning or programming. The main building block for empirical modeling is an auditory image, which is collection of extracted from the signal features, which are subsequently further processed, so that the information can be compared to behavioral data. Leman himself has provided a bottom-up, sensory-based approach to tonal perception, using auditory models and principles of self-organization in order to simulate the growth of long-term memory structure for tonal key relationships from audio signals. Feature extraction can be extended into emotional and semantic aspects of the musical experience, such approaches have however been fragmented and rather unsuccessful in providing a modeling based on the real signal, rather than on symbolic descriptions and representations.

Apropos to subsymbol-based versus symbol-based descriptions, the main distinction to be made lies in the bias created by the *a priori* definition of the symbol-based processing, as opposed to the emergence of the proper feature extraction from the real experience of the physical world, in the case of subsymbolic systems. The idea is that a bottom-up statistical methodology intervenes less in the perception of the world by applying pre-fabricated models. Problems of proper statistical distribution arise, given the fact that the data for feature extraction must be properly sampled. This is not always possible, as in the case of semantic features, which brings us back to the problem of an *a priori* modeling, as in the case of symbol-based processing. In that sense, statistics substitutes for rules and images substitute for symbols, transposing the aporias of symbolic to subsymbolic systems.

B. Embodied Paradigms

An ecological understanding of the acting subject as environmentally constituted brings us into the realm of embodied cognition. The human body is revealed as the mediator, or missing link, between physical energy and meaning formation.

Leman mentions Varela, Maturana and Piaget as cognitive science pioneers, who re-introduce environmental interaction in the center of a renewed embodied paradigm of musicological research. In terms of the ancient Greek tripartite scheme (the Pythagorean abstraction, the Aristoxenian perception and affect, and the Aristotelian *mimesis* as shared enactive experience), such strands of research seem to reintroduce the Aristotelian link.

In systematic musicology, important predecessors of an embodied paradigm include pre-war (pre-mediation technology would be a more accurate characterization researchers, who, influenced by *Gestalt* theory, focused on *corporeal articulations* as the basis of musical praxis. For such researchers, embodied expression of an innate and ubiquitous perception of music-as-movement is key for inter-subjective musical experience. Lipps[220] refers to this movement as *Ausdrucksbewegung* (expressive movement), which when interfaced with the body allows empathic access to the emotional content of a musical situation (*inneres Mitmachen, Einfühlung*). Truslit[221] attempts to identify what he calls the *inner motion* of music, with tracing studies, which predate today's tracing experiments on music reception using graphic tablets. Becking[222] takes a step back in terms of abstraction, talking about dynamic rhythmic flow and *metrical weights*, which underlie the surface movement of music. Such metric profiles become for Becking the signature of personal compositional language, informing the conductor's choreographies.

Fast-forwarding to the 1990's, Leman comes to examine how such primordial tracings of musical movement are being addressed in the context of sensor-based technologies, enabled by increased processing capabilities. Interactive music systems and interactive multimedia platforms (*Max / MSP*, *Pure Data*, *EyesWeb*, physical computing with platforms such as *Arduino*) allow for the rapid expansion of the developer and user base for both musicological and creative applications focusing on gesture. Parallel to *gesture modeling*, Leman attributes great importance to *physical modeling* in sound synthesis, as a shift from the abstract spectral characteristics of an audio wave to the physical characteristics of instrument's components moving in time, thus as a focus into the sound source. Still, more research is needed for the bridging of gestural and physical models, which are mediated by *biomechanical constraints* and *psychomotor laws.* A good example for a

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[220] Lipps, T. (1903). Aesthetik: Psychologie des Schönen und der Kunst. Hamburg: L.Voss.

[221] Truslit, A. (1938). Gestaltung und Bewegung in der Musik. Berlin-Lichterfelde: C. F. Vieweg.

[222] Becking, G. (1928). Der musikalische Rhythmus als Erkenntnisquelle. Augsburg: Filser.

motor theory of perception is Liberman and Mattingly's[223] research on speech production and perception. According to them, speech production and perception operates like an *articulatory synthesizer*, which associates perceived gestural patterns with muscular contractions of the vocal tract. "Perception of sound, in that view, is an inhibited resynthesis of that sound, in the sense that the resynthesis is not actually carried out but simulated" (Leman, p. 47).

Leman's general conclusion is the identification of a concrete arrow of time in the development from "purely physical issues (music as sound) to more subjective issues (music as experience)", culminating in the emergence of the human body as a mediator, the interface *per se*, between matter and subjective experience.

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[223] Liberman, A. M., & Mattingly, I. G. (1985). The motor theory of speech perception revised. *Cognition,* 21(1), 1–36. Liberman, A. M., & Mattingly, I. G. (1989). A specialization for speech perception. *Science*, 243(4890), 489–494.

4. Towards A Performer-Specific Paradigm Of Embodied Interaction With Complex Piano Notation

In chapter two of the current first part, we investigated developments in musical creation since 1945, which invite the rethinking of the link between performative embodiment and notational complexity along three distinct axes. In chapter three, we showed how musicology has responded to an increased focus on the musical act, beyond the musical score.

In the current section, we will resume those conclusions and we will address the aporias they invite, revealing the need for the formulation of a performer-specific paradigm of embodied interaction with complex piano notation. In other words, we will address the central question: Why do we really need a new model of interaction with rather than interpretation of complex piano scores.

As far as musical creation is concerned, the answer to this question lies in the multiple facets of musical complexity in itself. Whether in the form of an intrinsic complexity of the score (intra-complexity), or in the form of an extrinsic complex relationship of the score with the elements of the musical performance (inter-complexity), traditional notation is problematized as the privileged medium for containing the musical work and for enabling musical communication between composers, performers and listeners.

As far as musicology is concerned, the tendency to abolish the score, to move beyond the score and towards performance, is often as shown above too ambitious: The score remains in the centre of every analytical approach based on other types of data.

In other words, we are faced with the following situation: Musical scores have become in many ways inadequate or dysfunctional in encapsulating performance and musicology has not as of yet developed score-free tools for analyzing performance.

Our response to this aporia is

a) the reformulation of the very paradigm: what does a performer actually do with a musical score

b) The development of interactive tools, which incorporate performance into the score itself and transform into a malleable, dynamic sort of tablature.

We will schematically resume this shift as the transformation from a UTI into a TUI paradigm.

UTI stands for *Understanding-Technique-Interpretation*. It refers to the hegemonic paradigm of interaction with a score, as transmitted in musical education and musical praxis. According to this paradigm, the basis of music-making is the comprehension of the information contained in a musical score. This comprehension allows for the employment of instrumental or vocal technique as a tool of realization of the composer's vision. At a third stage, mastering of both the mental and the physical aspects of the work eventually allows for an indeterminate degree of interpretative or personal freedom of expression, which depends on the style of the music being performed. Modernist music assumes traditionally the minimization of this margin.

TUI stands for *Tangible User Interface*. It refers to the proposed paradigm of performer-specific embodied interaction with complex notation. It assumes that, due to its intrinsic and extrinsic complexities, notational surface information and relations can never be fully understood before being realized. What happens in reality is that most performers process notation in an embodied way, through their active interaction with the score and the instrument. Performers touch notation and transform it, in the course of learning, into embodied structures, which contrary to the symbolic notation are dynamic, malleable, and interactive.

The use of the term TUI here is metaphorical. The original term in the field of Human-Computer Interaction denotes real interfaces that enable tangible interactions with the environment. A notable example is the work produced at the Tangible Media Group of the MIT Media Lab, led by Hiroshi Ishii. His vision is to give physical form to digital information. He has invented *Tangible Bits*, a technology that enables the seamless "coupling of information bits with everyday physical objects and architectural surfaces"[224]. Another example of an actual tangible interface with notation properties, the *Tangible Score*[225] by Tomás and Kaltenbrunner, will be referenced in detail in part three, 2.2B., in relation to the amlgamation of notation and instrument.

The objective of this dissertation in what follows is to a) found this process in the findings of the wider field known as embodied cognition, beyond its manifestations in systematic musicology thus far; b) develop tools which represent and effectuate this process, drawing from gesture modeling, interface design and human computer interaction; c) present a series of case-studies which materialize the TUI paradigm.

224 Ishii, Hiroshi, "Tangible bits: towards seamless interfaces between people, bits and atoms". In: Proceedings of the ACM SIGCHI Conference on Human factors in computing systems, CHI 97, 234-241

225 E. Tomás, M. Kaltenbrunner, "Tangible Scores: Shaping the Inherent Instrument Score", *Proceedings of the International Conference for New Musical Expression*, 2014.

PART TWO:
EMBODIED COGNITION AS THE BASIS FOR EMBODIED NAVIGATION OF COMPLEX PIANO NOTATION

1.Abstract

A. Resuming Part One

In the first part we presented three axes, along which embodiment becomes thematic in post-war piano music: a) notational complexity, b) the electronic medium and c) theatrical or other intermedia elements in musical performance. Those three axes contribute independently as well as interdependently to a wider definition of notational complexity: not only in the sense of intrinsic textual complexity or *intra-complexity*, but as complexity of interactions between the parts of a dynamic performative system, comprising the text, the performing body, the instrument and other media. We define the latter as *inter-complexity*. It was also shown, how embodiment becomes central in the context of the *performative turn* in musicology, as well as in an embodied cognitive turn from the point of view of mediation technology. Eventually, we defined the traditional UTI paradigm (*Understanding-Technique-Interpretation*) of interpretation and we hinted towards the necessity of an embodied dynamic paradigm of interaction with notation and instruments. Such paradigm generalizes the notion of inter-complexity.

B. Part Two And Its Link To Part Three

The search for an alternative to the UTI paradigm, one which acknowledges the primacy of embodied experience rather than symbolic cognitive processing of a text, takes us inevitably into the domain of the philosophy of mind and of cognitive science. This paradigm seeks to substitute textual interpretation for embodied interaction. Its main assumption is that the text encodes and guides embodied experience in composition, but is also actively transformed by embodied experience in performance. This transformation takes place both internally, in the mind of the performers during the learning trajectory, and externally, through annotations. We take the latter form of processing to a wholy new level, developing means for its registration and representation. We generally describe the process as *embodied navigation of complex notation* and we represent it through multi-layered tablatures deriving from the original musical score. At a second stage, which coincides with the third part of the dissertation, representations and means will be upgraded to dynamic ones, through the use of interactive multimodal systems.

Thus, the current second part explores the origins, definitions and first implementations of the paradigm of embodied navigation of complex notation.

C. Structure Of Part Two

The second part is articulated as follows:

First, the vision for a model of embodied navigation of complex notation is shown as emergent property in my longitudinal development as a pianist, through three distinct stages: a) internalization, b) direct perception and annotation, c) use of interactive systems. Those stages are shown to parallel the movement from internalism to externalism in the philosophy of mind, and the shift from standard cognitive science / computational theory of the mind to embodied cognition, in the field of cognitive science. Self-reflexivity coupled with those shifts forms the ground of my practice-led / artistic research.

Second, internalist and externalist approaches to piano playing are identified through the comparison of two classic texts on piano interpretation: Leimer-Gieseking's *Piano Technique* and György Sándor's *On piano playing* .

Third, the identification of main strands and themes in the field of embodied cognition (*constitution*, *conceptualization*, *replacement* and *radical embodied cognitive science*) guides concept-formation for the embodied navigation paradigm.

Fourth, embodied navigation is defined in three versions corresponding to different strands of embodied cognition.

Soft version of embodied navigation: Performance necessitates the internalization of notation in the form of mental representations and is only ergonomically assisted by the the body, the instrument and the score as external structures.

Hard version: The musical score is being transformed by embodied experience in the mind of the performer and as external annotation; the performer develops *action-oriented representations* in the course of learning and performing.

Radical version: The interaction with the musical text can be explained *even without the need for mental representations*, as a dynamic dance between the elements of the system: body, mind, instrument, notation and interactive systems. Such version does not negate the mental representability of the process, but claims that mental representations are epistemologically only contingent and not a *sine qua non* for musical performance.

Fifth, embodied navigation is further clarified through two examples from Iannis Xenakis' *Mists* and one toy-example for the clarification of the notion of affordance for notated music. The affordances are visualized as multilayered tablatures for complex music.

Sixth, embodied cognition is surveyed in systematic musicology, with an emphasis on perspectives on gesture and movement and how they relate to embodied navigation.

Seventh, the emerging issue of mental representability of the navigation paradigm becomes the link to the introduction of interactive systems and thus to the next chapter. The passage from multilayered tablatures to interactive systems corresponds to Leman's distinction between first- , second-, and third-person descriptions.

D. General Sources And Concepts Of Embodied Cognition

The current chapter reflects on the aporias discussed in the first part in relation to the interdisciplinary field known as embodied cognition. Drawing from original sources in the field, such as James Jerome Gibson's *ecological psychology*, Mark Rowlands' / Shaun Gallagher's notion of *4E cognition*, Andy Clark's functionalism and *predictive processing*, Lawrence Shapiro's *three themes of embodiment*, Anthony Chemero's *radical embodied cognitive science*, with an extended reference to dynamic systems applications to cognition, Lakoff and Johnson's / Nuñez *cognitive linguistics /*

metaphor theory, I propose basic concepts for a paradigm of embodied interaction with complex notation under the name “embodied navigation”.

Those basic concepts include:

a) A pragmatic proposition on learning and performing efficiency, dealing with the purely quantitative aspects of textual complexity through physical movement.

b) Notions concerning the dynamic modeling of the performance system after dynamic systems theory.

c) Notions concerning the linguistic conceptualization of the system, or the development of performer-specific discourses based on metaphor theory.

d) Notions concerning the ecological understanding of those interactions under the general influence of Gibson’s central concepts of direct perception, action-perception coupling and affordances.

E. Sources From Embodied Cognition In Systematic Musicology

Next to the prime sources from the field of embodied cognition, our research relates to the emerging field of music embodied cognition, and in particular Marc Leman’s *theory of mediation through corporeal articulations*, his latest theory on *expressive interactions*, Godøy’s *theory of co-articulation* and Mazzola’s mathematical theory of *hypergestures*. Eventually, there is a branch of research relating directly gesture to the creation of DMIs (Digital Musical Instruments) and NIMEs (New Interfaces for Musical Expression) in general, as well as the issue of gesture modeling as conducted by the ISMM team at IRCAM. These issues will become the object of the third part in the current dissertation.

The model of embodied navigation can be seen as the extension of current models of the performer-listener relationship, into the composer-performer relationship, through the interface of notation. A characteristic example is offered by Marc Leman’s theory of mediation through corporeal articulations: Similarly to corporeal articulations forming the communication link between performer and listener, we will claim that embodied navigation of notation extends this model of communication between composers and performers, tending towards a radical embodied anti-representationalist stance, after the definitions of Anthony Chemero.

2. Introduction To The Notion Of Embodied Navigation

2.1 Self-Reflexivity: From Internalization To Interactive Systems

The embodied navigation paradigm originates in reflection on the longitudinal development of my praxis as a professional pianist. Self-reflexivity is further coupled with advancements in cognitive science, to form the basis of my practice-led / artistic research, which I have resumed under the title “embodied navigation of complex notation”.

The longitudinal development of my piano playing skills can be resumed in three distinct stages:

a) Learning as internalization of the musical text and performance as reproduction from memory.
b) Learning as direct perception of the musical text in terms of action and performance as reproduction from a correspondingly annotated score.
c) Learning and performance through customized interactive systems.

A. Internalization

The first stage, internalization, corresponds to my early formative experiences as a pianist.
Some pre-history first: during my early music education from the age of eight, the instrument I picked up was not the piano, but rather the *Yamaha Electone*, a bimanual electronic keyboard with foot pedals. Instead of focusing in the unique features of this electronic instrument, my instruction would be piano-oriented, as if this instrument were a piano split in two keybards, with the occasional exception of organ pieces, which would make use of the foot pedals, or of playing around with the rhythm section of the instrument in more popular music. Due to the lack of dynamic touch, volume was also pedal-controlled. The result of this unidiomatic formative experience was that, by the age of sixteen, I had developed strong reading and

memory skills through the study of mainstream classical piano repertoire, as well as a finger dexterity strictly adjusted to the light-weight small keys of the instrument, with a weird decoupling of my two hands due the different height of the two manuals (so that my right hand would be always higher than the left), but no sense of dynamic touch and acoustical sound control.

Given this twisted background, my transition to a real acoustic piano was far from smooth. After the initial enthusiasm due to my light-weight finger dexterity, I was faced with insurmountable difficulties. My muscular system would simply need time to adjust to the new reality of the piano keyboard and so would my listening skills. I was faced with a totally different musical ecology of touch, movement and sound, which I had to explore while at the same time de-learning very successfully implemented habits.

My guiding thread through this transitional phase consisted in two pillars: The first was the sensible and slow-moving instruction by my first piano teacher, Chryssi Partheniade, who steadily rewired my reflexes towards the piano keyboard and towards musical understanding and expression. The second, and more important for the current discussion, was my initial reliance on what seemed to be the only skill transferable to my new situation: Internalization and performance from memory. The ability to learn musical scores without the need to actually play them was relieving, given my discomfort at the piano keyboard. This ability was now complemented by my early interest in music analysis as a Bachelor's student at the musicology department of Athens University, as well as my reading of classic piano pedagogy textbooks, in particular Heinrich Neuhaus's *The Art of Piano Playing* and Karl Leimer & Walter Gieseking's *Modern Piano Technique*. The latter textbook had a rather pronounced bias in favour of mental preparation through internalization of both the musical text and the instrumental technique, as will be discussed in detail later.

Despite the initial relief, this reliance on internalization was actually inhibiting, at least in part, my pianistic development and performance, because it would perpetuate the gap between my already developed skills and the ones I urgently needed to develop. For example, my mental rehearsal of a Bach Fugue would immediately relate to my "old musculature", so that when I practiced on the piano keyboard, I would experience this decoupling between mind and body in an amplified way.

Despite the steep learning curve, a workable equilibrium seemed to have been reached after a few years of practice, whereby my internalization skills would sync with the acoustic piano ecology of touch, movement and sound.

B. Direct Perception And Annotation

The situation was due to change again through my acquaintance with the British pianist Ian Pace, initially at *Centre Acanthes*, Metz, in 2005. Ian's monstrous contemporary repertoire and ability to sight-read was a revelation to me, at a time when I still relied on my memory for performing repertoire as demanding as Pierre Boulez's *Première* Sonate or Wolfgang Rihm's *Klavierstück VII*. When I first asked Ian for private lessons in London, he assigned me with what at the moment seemed like an impossible task : To learn Charles Ives's *Concord Sonata,* a dense virtuosic piece lasting about 50 minutes, in three weeks. The result of this shocking initial assignement, and many similar to follow, was a radical rewiring of my primordial responses towards the musical score. Instead of spending much time away from the instrument memorizing the score, I was now developing my sight-reading skills and my ability to directly tap into the score through Ian's technical instruction, essentially his own teacher's, György Sándor, shorthand way of symbolizing piano technique on the musical text itself. This new skill, sight-reading through technical patterns, was revealing a non-internalizing mode of learning as direct, action-oriented perception of the musical score. The fact that my preferred repertoire was one which would not invite traditional analysis or easy memorization, for example Iannis Xenakis's *Mists* or Brian Ferneyhough's *Opus Contra Naturam*, was only reinforcing this mode of learning. The same applies to my experiences as a Master's student at the University of California, San Diego or my early professional experiences as ensemble musician at the International Ensemble Modern Academy. Ensemble playing necessitates by default the use of a musical score, as well as the further complexification of the musical interaction through collective musicianship. Thus, both complex notation and contemporary music ensemble playing were two of the enabling factors for the switch to a direct perception model.

It is exactly those sets of skills, which form the basis for the model of embodied navigation as it will be presented shortly.

C. Embodied Navigation Through Interactive Systems

My meeting with Frédéric Bevilacqua in 2012, when some first steps towards the embodied navigation paradigm had already been formulated, opened up a new horizon of possibilities through the integration of multimodal interactive systems developed at IRCAM in my practice. At the time, my way of representing this paradigm was through complex static representations of the affordances of a musical score in the form of extensive annotations, what I call *multilayered tablatures for complex music*. Through the use of multibuffer recordings of gesture and sound, of the *motionfollower* architecture, the notion of augmented interactive scores via *INScore*, and the development of the *GesTCom* (*Gesture Cutting through Textual Complexity*), we had the chance to gradually upgrade what was a static representation of a dynamic model into real-time interaction with the musical score. Since this stage will be reviewed in maximum detail in the third part, I will keep this reference as laconic as that.

It will be argued that such *ontogenetic* development of my piano skills is not incidental, but rather reflects the *phylogenetic* shift from internalism to externalism in the philosophy of mind and the corresponding shift from a computational theory of the mind to embodied cognition in cognitive science. The reliance on memory and internalization of the musical text as prerequisites for musical performance corresponds to the mind-centered philosophy of internalism or its equivalent computational model of the mind; while the increased reliance on external means, including the body, the text and the instrument, as well as the introduction of interactive multimodal systems, correspond to the theory of externalism in the philosophy of the mind, or several strands of what is known as embodied cognition in cognitive science.

Let us now take a closer, albeit only introductory, look at the core ideas of externalism and embodied cognition, often characterized as non-cartesian.

2.2 Non-Cartesian Directions In The Philosophy Of Mind And Cognitive Science

A. Internalism And Externalism [226]

A central distinction, which forms the basis of otherwise disparate theories and debates, is the one between internalism and externalism in the philosophy of mind. This distinction is mirrored in cognitive science after the cognitive turn of the late 1960s, in the form of a distinction between the computational theory of the mind and the several strands of what we will for simplicity refer to as embodied cognition.

According to the philosopher Mark Rowlands (2003, 2010)[227], internalism draws attention to a structural, albeit often unnoticed, element of the classic cartesian dichotomy between physical body and non-physical mind: the idea, that the mind is located *inside* the bodily machine, somewhere in the head[228]. Challenging this idea is

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[226] A summary of the ideas to follow has been presented in my previously published texts : Pavlos Antoniadis, « Körperliche Navigation. Verkörperte und erweiterte Kognition als Hintergrund der Interpretation komplexer Klaviermusik nach 1945 », in Jörn Peter Hiekel & Wolfgang Lessing (eds.), *Verkörperungen der Musik. Interdisziplinäre Betrachtungen*, transcript, Bielefeld, 2014 ; «Corporeal Navigation: Embodied and Extended Cognition as a Model for Discourses and Tools for Complex Piano Music After 1945 » in Pedro Alvarez (ed.) *CeReNeM Journal*, Issue 4, pages 6-29, March 2014. http://issuu.com/cerenem/docs/cerenem_journal_issue_4 accessed 31.03.2018

[227] Mark Rowlands, *Externalism. Putting Mind and World Back Together Again*, Acumen, Durham, UK, 2003 ;

The New Science of the Mind. From Extended Mind to Embodied Phenomenology, MIT Press, Massachusetts, 2010.

[228] “The Cartesian conception of the mind in fact has two distinguishable aspects. First, there is the claim that the mind is a nonphysical thing. Second, however, there is the idea that the mind is something that exists inside the head. So, when Ryle (1949) dismissed Descartes’ view as the myth of the ghost in the machine, this dismissal actually has two distinguishable aspects. First, Ryle was rejecting the idea that the mind is a ghost — that is, a nonphysical thing. But second, and for our purposes more significantly, he was rejecting the idea that the mind is the sort of thing that can be found inside the bodily machine. If you reject only the first idea, then you have not fully rejected the Cartesian conception of the mind, but only part of it. And that, in effect, is precisely what the mind – brain identity/exclusive neural realization combination did. It rejected Descartes’ idea that the mind is ghostly or nonphysical, but it left intact the second defining idea of the Cartesian conception: the idea that the mind is something that exists inside the head. In other words, the mind – brain

according to Rowlands vital for the development of what he calls a “non-cartesian” cognitive science:

“Non-Cartesian cognitive science is based on a more complete rejection of the Cartesian view of the mind. This science is, of course, materialistic: there will be no reversion to nonphysical substances - that particular Cartesian ghost remains well and truly exorcised. However, non-Cartesian cognitive science also rejects Descartes's second idea, the idea inherited by the mind-brain identity / exclusive neural realization model. That is, it rejects the claim that mental states and processes occur purely inside the brains". (Rowlands, 2010, pp. 12-13)

With this very last sentence, Rowlands draws attention to the fact, that Cartesian internalism has often survived the cognitive turn itself, in the sense that it influences Standard Cognitive Science (SCS)[229], in the form of a body-brain dualism, which comes to substitute the classic body-mind one. According to Standard Cognitive Science SCS, mental processes are identical with brain processes or exclusively realized in the brain. *Mental representations* and *rules for information processing* in the form of algorithms are its two central premises. Mental processes are in other words described as abstract programs (software), which are realized in the computer of the brain (hardware)[230]. Subsequently, the aim of CS is to identify the programs (cognitive psychology) and to find out how exactly they are neurally implemented (cognitive neuroscience). This description is in a nutshell the core of what is called the computational theory of the mind: the idea that the mind-brain is an information-

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identity/exclusive neural realization model is a view fashioned partly, but as things turned out, decisively in the image of the Cartesian view of the mind.” Rowlands 2010, p. 12

229 Another advocate of embodied cognition, Lawrence Shapiro, mentions projects such as Allen Newell’s und Herbert Simon’s *General Problem Solver,* Saul Sternberg’s research on memory retrieval, und computational models of visual perception, such as David Marr’s, as core examples of Standard cognitive science. Shapiro, 2011, p. 7. Here, one should add the work of Jerry Fodor and Hilary Putnam.

230 Developments in computer science and artificial intelligence have been driving the history of cognitive science from the very beginning, legitimizing this metaphor. Here is a definition by Gerhard Strubes, 'Center for Cognitive Science', Universität Freiburg :"The subject of CS is the research of cognitive systems, of their cognitively relevant structures and of the relevant processes. Through the basic premise, that cognitive processes are considered as computational processes, CS refers to both biological and artificial systems" (Strubes cited in Paul Natterer, Philosophie des Geistes, Vol. 5 von Edition novum studium generale, Norderstedt 2011, pp.104-105), my translation.

processing system and that thinking is a form of computing, with Hilary Putnam, Jerry Fodor and John Searle as some of its main exponents.

In opposition to internalism, *externalism* demonstrates a hybrid and non-cartesian approach to cognition. Cognition proper is not located exclusively in the head, but is rather distributed, stretching over the boundaries of both brain and body into the environment. The mental processes are partly enactive, embedded, embodied and extended (what Rowlands refers to as 4E Cognition, after Shaun Gallagher[231]). Or in relation to the computer model:

"Very roughly, to build a mind it is not sufficient that one builds a computer; one must build a robot". (Rowlands, 1999, p.30[232]).

This idea of externalism, often referred to as “vehicle externalism” or “environmentalism”, has to be differentiated by the notion of *content externalism* by Hilary Putnam, still the most likely use of the term.[233]

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[231]Rowlands' virtuosity in drawing fine distinctions between these four strands cannot be properly resumed. In short: embodied cognition is a thesis of *constitution* of cognitive processes of wider bodily structures and processes, in contrast to embedded cognition which assumes only *dependence* of cognitive processes on extra-neural structures. Similarly, extended cognition, after Clark and Chalmers, suggests that cognitive processes extend out into the environment, in the sense that they partly *consist* of actions in it. Its difference from enactivism, by O'Regan and Noë, lies in that, in the latter, it is rather actions as potential and knowledge, as expectations and possibilities, (sensomotoric contingencies), but not as real actions, which frame our cognitive activity.What is important is Rowland's conclusion, that enactive and embedded strands can be thought of as rather cartesian fallback positions, effecting then the reduction of the initial quartet in the duet we will be referring to as embodied and extended cognition (EEC). (Rowlands, 2010, pp. 51-84) A more thorough look at the implications of those four strands for the model of embodied navigation of complex notation follows shortly.

[232] Mark Rowlands, *The Body in Mind,. Understanding Cognitive Processes*, Cambridge University Press, 2004.

[233] This position is in fact what most people have in mind when they use or hear the word “externalism”. Content externalism is the idea that the semantic content of mental states that have it is often dependent on factors – objects, properties, events and so on – that are external to the subject of that content. It is not possible, to use a classic example by Hilary Putnam, to entertain the content that water is wet if you inhabit a world where there is no water. If you inhabited a world where there was no

B. Embodied Cognition

Shaun Gallagher defined the field of embodied cognition EC as

> " a third wave in the history of cognitive science, after the early computational model (first wave-SCS) and after *connectionism* as a second wave inspired from neuroscience"
> (Gallagher, 2012[234], p. 320, my translation)

Although the field of EC is recognized as the point of convergence of disparate scientific fields[235], both the opposition to the first wave of computational models, as well as the meaning of connectionism[236] as a step towards EC are rather indisputable. Equally indisputable is the importance of earlier theories, such as *the ecological theory of visual perception* by James Jerome Gibson[237], Lev Semyonovich Vygotsky's and Alexander Romanovich Luria's account of memory[238], and the phenomenology of the body by Merleau-Ponty[239], as well as the role of *The*

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water but only, for example, something that was superficially indistinguishable from it, whatever content you entertained would not be the content that water is wet but, rather, that this superficially indistinguishable substance is wet. The content one is capable of entertaining depends on the nature of the world one inhabits. Rowlands 2003, p. 5

[234] Shaun Gallagher, »Kognitionswissenschaften – Leiblichkeit und Embodiment«, in *Leiblichkeit. Geschichte und Aktualität eines Konzepts*, hg. von Emmanuel Alloa, Thomas Bedorf, Christian Grüny und Tobias N. Klass, Tübingen 2012

[235]Those include situated robotics and artificial intelligence, psychology of perception, developmental, psychology, cognitive neuroscience, phenomenology, philosophy of the mind.

[236] Connectionism is a set of approaches in the fields of artificial intelligence, cognitive science and philosophy of mind, that attempts to represents mental or behavioral phenomena as emergent processes of interconnected networks of simple units. There are many forms of connectionism, but the most common forms use neural network models.

[237] James Jerome Gibson, *An Ecological Approach to Visual Perception*, Psychology Press, London, 1986

[238] Alexander Romanovich Luria & Lev Semyonovich Vygotsky, *Ape, Primitive Man, and Child,* Cambridge, MA, MIT Press, 1992

[239] Maurice Merleau-Ponty, *Phénoménologie de la Perception*, Gallimard, 1945

Embodied Mind by Varela, Thompson and Rosch[240], as cornerstones for this third wave. According to Gallagher, it is in the latter book, that for the first time a more articulate relationship to the phenomenology of the body, that is the idea that cognition is not pure brain process, but involves also the body and the environment, comes into play[241].

In my own overview of the field of Embodied Cognition, I will deal with three partially overlapping taxonomies, which enable a deeper understanding of the field's main ideas, and more importantly, provide the basic concepts to be employed in my own model of embodied navigation: Mark Rowlands's *4E Cognition*; Lawrence Sapiro's *three themes of embodiment*; and Anthony Chemero's *Radical embodied cognitive science*.

C. Conclusion

The overview of my pianistic development and of the shift from internalism to externalism and from computationalism to embodied cognition reveals an interesting parallelism, namely the increasing reliance on embodiment and external structures, such as the notation, the instrument and technologically advanced systems, for the realization of the complex cognitive task of learning and performing complex piano music.

While one can probably attribute a certain *a posteriori* cognitive bias to this self-reflexivity, namely the fact that the perceived distinctions have in themselves been shaped by my studies in the field of embodied cognition, it does not however lessen the power of the initial core realization: that pianistic development is not relying exclusively on the traditional categories of understanding and technique, as the foundations of the UTI model described in the first chapter, but rather that those very

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[240] Francisco Varela, Evan Thompson, Eleanor Rosch, *The Embodied Mind. Cognitive Science and Human Experience*, MIT Press, Massachusetts, 1991

[241]Shaun Gallagher, "Kognitionswissenschaften -Leiblichkeit und Embodiment",
in *Leiblichkeit.Geschichte und Aktualität eines Konzepts*, hrsg. von Emmanuel Alloa, Thomas Bedorf, Christian Grüny und Tobias N. Klass, Tübingen 2012, p. 321. The same idea shares Marc Leman, who mentions Varela and Maturana, as well as Piaget, as major influences for the embodied cognitive turn in systematic musiclogy, in Leman 2010, p. 43.

categories are constantly shaped and dynamically shifting through the use of external structures.

Next, I will investigate how the central distinction between internalism / externalism and subsequently computationalism / embodiment can be traced in two famous accounts of piano performance: Leimer-Gieseking's and György Sándor's.

2.3 Case Study : Internalist And Externalist Concepts In Piano Playing [242]

Contrary to the axiom, that learning notated music is identical to the internalization of images and motions, we would like to explore what other points of entry and resources than the mind might one be employing. It will be shown that the manipulation of external, or - to put it in Rowlands' terms – "environmental" structures, not only is equally important for learning, but that it can also be extremely successful in dealing with the new problems posed specifically by complex music. And that it can possibly serve to signpost somewhat clearer the " [..] path [..] to the rich delta where the mental and manual meet" (Schick 2006: 93[243]). Basic for the following arguments will be the acknowledgement of the hybrid nature of learning to perform through both internal and external resources, in a way which privileges learning as performance, as an action itself.

Before we proceed with the examination of two treatises on piano playing, indicative of both the privileging of internal cognitive processes and directions away from that, we would like to make a brief summary of environmentalism a.k.a externalism, as presented by Mark Rowlands in the second chapter of his book "*The body in mind*" (1999).

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[242] Part of these arguments has been previously presented in my conference article : Antoniadis, Pavlos. "Learning complex piano music: Environmentalist applications" in *Proceedings of the International Conference Beyond the Centres: Musical Avant-gardes since 1950* Thessaloniki, Greece 1-3 July 2008, http://btc.web.auth.gr/proceedings.html accessed 28.04.2018

[243] Steven Schick, *The Percussionist's Art. Same Bed, Different Dreams*, University of Rochester Press, 2006

A. Rowlands' Environmentalism

Environmentalism suggests a radical view of the nature of cognitive processes, in opposition to the Cartesian idea of a mind inside the head, which structures the world functioning as the exclusive locus of cognitive processes. In the author's words:

> "Environmentalism is understood as the conjunction of an ontological and an epistemological claim: […] cognitive processes are not located exclusively inside the skin of living organisms and […] one cannot understand those processes by focusing exclusively on what is occurring inside the skin of living organisms [..]" (Rowlands 1999: 22)

A word of caution should already be uttered: The adverb "exclusively" is particularly important in the above claims. As Rowlands himself keeps repeating throughout the book, and we will keep repeating through this dissertation, environmentalism doesn't oppose the obvious fact that some cognitive processes do take place inside the organisms' skin. What it does suggest is that some of those processes are essentially hybrid in nature, partly consisting of physical manipulation of structures in the environment of organisms. In the context of this claim – termed "the manipulative thesis" (Rowlands, 1999: 23-24) - and given the special interest of the current thesis in a manual activity *par excellence*, such as piano playing, it is important to make the following clarification: "Manipulation" doesn't necessarily imply a manual or intrusive relationship to the environment (although in our case it will some times assume this very literal meaning). It rather indicates any sort of physical interaction with the environment, in order to accomplish a given task. In particular, the environment is conceived as consisting of *information-bearing structures*, which organisms can potentially identify and appropriate. The manipulation itself is identified as indispensable for cognition: a form of information processing. The crucial point here is the proposition that "in performing any given task, the more information the organism can process externally, the less information it has to process internally" (1999:30). This is a proposition for the maximization of efficiency by minimizing internal costs, epitomized in the principle "don't multiply effort beyond necessity" (1999: 22).

The entire first part of *The body in mind*, labeled "psychotectonics", is devoted to the support of this manipulation thesis along two distinct lines. The first includes argumentation stemming from evolutionary biology. According to that, evolution on the part of the organisms is conceived as the ability to accomplish tasks posed by the environment at the least possible expenditure of the organism's energy, what Rowlands terms "evolutionary cost" (1999: 24). The key to this minimization is the adoption of strategies, which employ appropriate manipulation of environmental structures. The second line of argumentation puts distinct cognitive processes, namely visual perception, memory, thought and language, under the microscope. Traditional internalist views are compared to environmentalist alternatives, in support of the manipulative thesis. Some of the relevant argumentation will be presented later, in the course of our examination of potential environmentalist applications to learning and performing complex piano repertoire.

One of the most exciting aspects of environmentalism, next to its different insight into practical efficient strategies, is its ontological claim: The mind and body are not disconnected subjectivities, but rather worldly in themselves, involved in a subtle net of interactions. Similarly, we will claim that the performer's "drama", as a consciousness trying to harness matter through mind, is just a privileged way to look at things, intrinsic to the way notation and practices developed. An alternative, which yields both pragmatic and metaphysical results, is thinkable and can find application in complex music. Such alternative considers the learning process as a hybrid one, partly taking place internally and partly relying on manipulation of environmental structures, namely: the gravity, the body, the instrument, and, most importantly for this thesis, the musical score.

We would like to start our account of possible environmentalist applications on the learning strategies adopted for complex piano repertoire with a short comparative study of two very influential treatises on piano playing: *Modernes Klavierspiel* by Leimer and Gieseking (1931)[244] and *On Piano playing* by György Sándor (1981)[245].

Both books are essentially presenting basic principles of what is usually termed "modern piano technique", a rationalized use of the human performing mechanism in

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[244] Karl Leimer und Walter Gieseking, *Modernes Klavierspiel*, Mainz 1998 (Originalausgabe 1931).

[245] György Sándor, *On Piano Playing. Motion, Sound and Expression*, New York 1981.

the direction of effortless mastery of the mainstream piano repertoire. Despite some similarities to be outlined later, both books carry very distinct overtones of underlying preconceptions about the nature of the cognitive processes involved in learning pieces and performing them on the piano: Leimer and Gieseking develop a method which relies heavily on internalization through mental work away from the instrument as a first step to the learning process; on the contrary, Sándor interweaves the performer's body and gesture, the instrument and the score in an interactive schema which prioritizes a performer- specific feature as the entry point to learning : physical motions. If –in Rowlands terms- we consider the score, the instrument and the performing body itself as *information-bearing structures* in the pianist's environment, then we can claim that Leimer and Gieseking's reflections are presenting us with a hard version of internalism in piano playing; while Sándor's account stresses an understanding of the process as hybrid: combining the pianists' internal efforts with an actual physical manipulation of those structures.

Before a more detailed account of these treatises, a word of clarification is needed in relation to the inclusion of the performing body in the categories of environmental structures: While we are aware of the fact that a latent Cartesianism might be at work in the perception of the body as a performing mechanism at the mind's will, we believe that it would be equally misleading to assume that the body as an incarnated subjectivity is separate from the world itself (a sort of "corporeal Cartesianism"). The physical body, through its specific structure, invites a dual mode of perception of itself as an inside (subjectivity) and an outside (objectivity) at the same time: Depending on my point of focus, I (as a subjective consciousness) can feel and be my finger, but I also have the ability to bring it in front of my eyes and perceive it as another object, or use it in specific ways. This does not necessarily mean that I acknowledge a superiority of the mind over it; it might well mean that I recognize its oneness to the surrounding environment and manipulate it as if it was part of it -as I can do with my own consciousness. In an article-reference to Merleau-Ponty's ideas on perception, E.T. Gendlin 1992[246] writes:

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[246] Eugene T. Gendlin, "The primacy of the body, not the primacy of perception", *Man and World*, pp. 341-352, Kluwen: University Publishers, 1992

"If we think of the living body not as a piece of merely perceived material, neither as perceiving, but as interaction with its environment, then of course *the body is environmental information*" (Gendlin,1992: 349) – my italics

It is this interactive concept of the body, which will inform its inclusion in our account of environmental or external structures.

B. Leimer-Gieseking's Internalism

We will begin our account with a discussion of the most important points of Leimer's and Gieseking's (abbreviated from now on as LG) *Piano Technique* (1972)[247], originally published in 2 books, *Modernes Klavierspiel* (1932) and *Rhythmic, Dynamik, Pedal* (1938). We will identify their internalist assumptions in the use of the score and the use of the body; and we will connect those to the Rowland's discussion of cognitive tasks in relation to memory.

The foundations of the LG method, as manifested in the very first chapter of their first book, are three: training of the ear towards the direction of absolute control of tone-quality, duration and strength for the smallest bits of the work; training of memory through reflection; and what they call "natural" piano technique employing the least possible physical strain. The first principle (ear-training), is complemented by two axioms manifested very early in Gieseking's Foreword (1972:5,6), the urge for absolute following of the composer's markings and the subsequent substitution of "interpretation" with absolute correctness. The last points evoke, not accidentally, Frank Cox's "High-Modernist Model of Performance Practice" as discussed in part one, showing the persistence of traditional schools of thought in some of the most radical developments. But for now, let us concentrate on memory.

Throughout their book, Leimer and Gieseking passionately advocate memorization of the score, through internal representation away from the instrument, as the cornerstone of any subsequent learning process. In the chapter 'Foundations of our method', we come across a very clear statement of that point:

[247] English translation of *Modernes Klavierspiel* : Walter Gieseking & Karl Leimer, *Piano Technique*, New York, Dover, 1972

“it is essential, before beginning with the practice of the piece, to visualize the same, whereupon, if this has been done thoroughly, we shall be able to play it correctly from memory. To be capable of doing that in short time, the memory must be trained by means of reflection (systematic logical thinking)” (1972:11)[248]

In other words, the experience of performing on an instrument begins with a completely disembodied mental activity, which includes visualization, reflection and training of the memory. Looking back to Rowlands and our own definition of the body, the instrument and the score as the three basic environmental structures at the performer’s disposal, we realize that the LG strategy essentially does away with all of them: it ignores the two first and it wishes to re-locate the third from the actual score to the performer’s mind. Under the light of the manipulative thesis, this seems to constitute an expenditure of energy, which maximizes effort – the word “training” is not accidental at all in suggesting an investment of internal resources.

A closer look at this process, which is thoroughly described in several examples through the book, will enlighten what is the author’s perception of visualization, reflection and memory training, and will allow specific connections to environmentalist ideas on memory as exposed in chapter six of *The body in mind*.

The authors offer analyses of the mental working-out of pieces of increasing difficulty, starting with a simple technical study and proceeding to a Bach two-part *Invention*, a three-part *Sinfonia*, a Beethoven *sonata*. In the second book, a Bach’s *French Suite* is serving as a model for mental practicing.

The process remains relatively standard through all of the examples, with a small addition in the second book (written six years later): After the performer orientates in the time signature and key, there starts an exhaustive note-by-note and hand-by-

[248] »Eine unerläßliche Voraussetzung für diese Schulung des Ohres ist genaueste Kenntnis des Notenbildes. Es ist daher notwendig, daß wir vor Beginn des Studiums das Notenmaterial vollkommen beherrschen, und dies ist nach meiner Meinung nur dann zu erreichen, wenn wir das Notenbild vollständig im Kopf haben, also das betreffende Stück tadellos auswendig können. Um dies auf schnelle Weise zu erreichen, bedarf es wieder um eines speziellen Trainierens des Gedächtnisses. Ich benutze dazu die Reflexion, und zwar in sehr ausgiebiger Weise« p. 16

hand verbal description of each individual measure. Points of focus are: pitches and intervals, their movement in space and their relation to simple chords; rhythm; simple similarities of musical material which articulate form. In contrapunctal music, relevant terminology accompanies the observations (motif, counterpoint, sequence, inversion etc.). In the Beethoven sonata, priorities of focus remain the same; other musical parameters such as dynamics and articulation are reserved for the discussion on "interpretation" -always following up from technical mastery. The addition coming with the French Suite description in the second book is a short verbal description, a sort of title, for specific spots in the work (for example "the Chord-spot"). From this account, it is quite evident that the analysis is highly detailed, but in a prioritized way: pitch and duration as the barebones of the composition are exhaustively examined, while the more physical ones, that is articulation and dynamics, are not initially entering the mental frame. Structural observations are active in a relatively loose way, not with a rigid intention to grasp an overarching formal schema or reflect on the process. In other words, there is a moment-to –moment memorization which brings to mind the notion of *episodic memory* as exposed by Rowlands.

In his discussion of memory, Rowlands suggests that the development of modern human memory has followed a clear path from the employment of *episodic* and *procedural memory* systems to the development of *semantic memory*. The first two systems are primordial, still incompatible: episodic memory is employed for concrete, specific, detailed events in time and space, while procedural involves action patterns. Semantic memory, on the other hand, is a memory of facts, stressing some sort of semanticity in the bare events which constitute episodic memory. After all, the border between semantic and episodic memory seems to be so vague, as to suggest that their difference is one of degree, not of kind. Rowlands argues that the key to their actual differentiation and to this development of semantic memory has been the employment of external means of representation, such as visuographic (the music score is one instance of them), which are being seen as external information stores, into which modern humans tap. This increased reliance of modern people on environmental structures is accompanied by an involution of episodic memory; on the contrary relatively “primitive”[249] peoples and children seem to make heavy use of episodic memory storage strategies, the fact itself puzzling the modern observer as outstanding “natural” or photographic memory. (Rowlands, 1999:123-129)

Going back to the LG memorization process, and under the light of Rowlands' remarks, it looks like the balance between its episodic and semantic properties is considerably leaning towards the first. The highly localized, measure-by-measure, hand-by-hand, nature of the description of the musical text, and the simplicity of the syntactic relationships observed, point toward an episodic experience of “being in one place at a time”, only that this happens mentally, not in real time and space.

This memorization strategy after all seems to be in perfect harmony with their description of the process on the instrument. The relevant discussion of the Beethoven example is exemplary for the prioritization of refinement and perfection of the smallest bits of the composition (1972:33-42). A metaphor employed by the authors is telling about how the process is to continue:

“When a part of a composition has been played for the first time, a picture of the same becomes imprinted on the brain. This picture varies in clearance according to the mental constitution of the pupil. In general, a very faint impression is left on the memory, similar to a photograph which is not clear or has been under-exposed. Through constant repetition the picture becomes more and more distinct and finally resembles a clear, sharp photograph” (1972:47)[250]

The clarity of the mental image of the music acquired in the very beginning of the learning process is a factor persistent through the actual formulations of the performance -the actual playing. Again, the crucial point here is that an experience which is fully corporeal, or at least hybrid, is reduced, in Cartesian fashion, to an impression on the brain.

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[249] Politically incorrect term by Luria and Vygotsky, whose work Rowlands draws from for his environmental model of memory.

[250] „Bei dem ersten Spielen eines Teiles einer Komposition bleibt davon im Gehirn ein Bild, das nach der Veranlagung des jeweiligen Schülers verschieden deutlich ist. Im allgemeinen ist es ein ganz schwacher Eindruck im Gedächtnis, ähnlich einer undeutlicher Photographie, die zu schwach belichtet ist. Durch öfteres Wiederholen wird das Bild immer stärker und gleicht schließlich einer absolut klaren und scharfen Photographie“. p. 41

Internalism could not leave LG discussion of piano technique intact. The internalization of the notes is followed up with the internalization of technique:

“By further development of the idea, one acquires the ability even to prepare the technical execution through visualization, so that, without studying at the instrument itself, the piece can be perfectly performed and this in a most astonishingly short time’ (1972:11)[251]

The absolute banishment of the instrument from the learning process is later praised as an aim, and even as a sign of superiority:

“Only a very few of the elect are born with the talent of immediately and intuitively grasping the meaning of a composition; and they alone have the capability of reaching to so high a degree of mental and manual ability that they can mentally comprehend and correctly render a composition, by means of the fingers, practically without further practice” (1972:33)

But let’s take a closer look at LG conceptions of piano technique. The very first principle seems to be lined-up with the efficiency axiom towards minimum energy expenditure: “natural” playing employing the least possible physical strain. The account becomes more convoluted later, in detailing how one is to avoid strain: Relaxation has a key importance, but this should be achieved consciously as a complement to the conscious exertion of the muscles, without any ancillary movements :

“I contrive to raise a feeling of relaxation from within, as it were. This is generally attempted by the aid of visible movements. All movements are injurious” (1972:12)[252]

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[251] »Bei weiterer Vervollkommnung dieses Verfahrens ist man sogar in der Lage, auch die technische Aufführung durch Reflexion so vorzubereiten, daß ein Stück ohne jede Übung am Instrument auswendig einwandfrei vorgetragen werden kann, und zwar in verblüffend kurzer Zeit«. p. 17

[252] »Ich versuche, das Gefühl für die Relaxation (Entspannung der Muskeln) von innen heraus zu erreichen (während dieses Ziel im allgemeinen durc die äußeren Bewegungen anstrebt wird), da ich alle überflüssigen Bewegungen für schädlich halte und danach strebe, die Tätigkeit des Klavierspielens mit dem kleinstmöglichen Aufwand an Muskelarbeit ausführen zu lassen«. p. 17-18

The muscles, in particular, seem to be the only source of energy a performer occupies. While acknowledging the fact that co-ordination of these muscles is indispensable, LG advocate also the strengthening of the muscles. Fixation of joints is constantly mentioned during the description of the individual modes of touch, and the contradiction of these remarks to the idea of relaxed playing is to be acknowledged later:

"A strong fixation is unavoidable in forte and fortissimo playing. But one should always think of relaxing the muscles whenever the opportunity arises, so that the fixation will be interrupted and lessened. As we have already stated, the relaxation must ensue from within, minus any noticeable movement"(1972:111)[253]

The points we would like to keep from this brief presentation are: the conscious control of muscular relaxation and exertion; the muscular strengthening; the fixation of joints and avoidance of movement. As it will be made clear very soon, in the context of Sándor's book discussion, these three features, plus the manifested intention of an exclusively mental practicing, consider the pianist as an entirely self-contained system, which is dedicated to a perpetual quasi-biological development, both mental and physical.The reluctance to employ any structure other than the mind in the course of learning and performing is total- in fact considered as a sign of weakness, almost inferiority, if it does happen.

C. György Sándor's Interweaving Schema

Sándor's account in his book *On piano playing* presents us with an altogether different concept, which stresses the interaction of all elements involved in piano playing - what we termed the "pianists' external information-bearing structures". For the sake of clarifying LG points on technique stated above, in Sándor's case we'll start with the technique and save his ideas on the use of the score for later.

[253] »Eine starke Fixierung ist bei *forte* und *fortisimmo*-Stellen nicht zu umgehen. Ständig aber muss man, sobald es angängig ist, an die Erschlafung der Muskeln denken, damit die Fixierung immer wieder unterbrochen und gemildert wird. Diese Relaxation muss ohne sichtliche Bewegung von innen heraus erfolgen « . p. 115

A quote from the very first chapter of the book, where basic ideas are formulated, will serve as a very good example of environmentalist traces:

“In order to mobilize the playing apparatus and generate the desired speed in the hammers, there are no other but two sources of energy available: the force of gravity, which pulls everything down towards the centre of the earth, and muscular energy, […] which pulls the finger and the arm towards the affixed portion of the contracted muscle [..] Most of the time, it is the participation of both energy sources that provides the optimal solution. Our aim is to achieve the optimal results with the least expenditure of energy. It will be up to us to determine when to utilize the force of gravity exclusively, when to use muscular energy exclusively, and when and how to combine both.” (Sándor, 1981:7)

We have here a clear manifestation of Rowlands’ manipulation thesis: Playing the piano is hybrid in nature, tapping into both internal and external resources; the aim of saving as much of our own energy as possible is achieved through the manipulation of a structure, which is external to the performer’s body, that is gravity. The LG similar requirement of experiencing the least possible physical strain, through the somehow mystified idea of constant relaxation consciously controlled by the mind, finds here a surprisingly environmentalist-friendly counterpart.

But are our bodies to be considered exclusively as an internal resource? Talking about relaxation, here’s Sándor take on the issue:

“Total relaxation is non-existent in piano playing. Even when we rely purely on the force of gravity, we must use the necessary muscular equipment to lift and place the arm and hand in their proper positions. Most motions are executed by antagonistic sets of muscles: while one group (for example flexors) works, the other group (extensors) relaxes. Partial relaxation alternates with muscular activity at all times; complete relaxation exists only if we lie down and rest” (1982:7)

The idea of partial instead of constant relaxation foregrounds the issue of muscular interdependence: where LG advocate muscle-building and finger independence, Sándor stresses the need for complementarity and co-ordination:

“ [..] piano playing is not a matter of muscular strength and endurance.[..] Some of the muscles are small and weak, made for precision work, others are strong and powerful. If we can activate these larger muscles properly, we do not need to strengthen the weaker ones. We must learn the kind of coordination that enables us to put to use the necessary equipment and to play without any trace of fatigue [.].” (1981:16-17)

While someone could argue that this take on bodily function, based on simple physiological facts, is just reproducing the Cartesian body-as-a-machine conception, with a ghost (the mind) controlling it, the tone is very different from the LG take in the following way: The body (or memory, in their account) is not a field of biological development; the body is already a *locus of information*, such as the fact that smaller muscles can be supported by larger, when the task in question demands it; or that gravity is collaborating with the muscles themselves. This is “information” not in a linguistic sense (as phrased in the previous proposition), but rather information about how can the body interact with the environment at less internal cost in the course of playing the piano. In this sense, the body can be seen as an environmental structure, where the performer can tap into, given that she is in possession of the right “code”. Thus, the manipulative thesis recognizing the body as internal and the gravity as external has to be reformulated: There is instead a conscious part in the process of playing the piano manipulating two environmental structures: the force of gravity and the body itself.

Before we go on with investigating what is the proposed by Sándor “code” , so that the performer can plug efficiently into these structures, let’s see his take on the third environmental structure involved in a piano performance, namely the instrument itself. The first hint has already been given in the very first quote and in the formulation of the argument about energy sources: The performing mechanism “generates the desired speed in the hammers” (1981: p.7). In other places, it is argued that the volume of the sound is not depending on either finger strength (as in the LG case) or on some sort of weight (as a response to Breithaupt’s[254] notion of weight technique, the first to acknowledge gravity in the history of piano playing), but exclusively on the speed with which the hammers will hit the strings. This is part of the reason, why the pianist’s technique is not an isolated phenomenon to be developed in a vacuum: because it interacts with the specific piano mechanism / interface and its special features. Other features, explicitly examined by Sándor,

[254] Rudolf Maria Breithaupt, *Die natürliche Klaviertechnik*, 1905

include: the sound's decay after hitting the key (excluding thus any sort of *over-pressure* to the keys, appearing in LG as a form of touch called the "pressure-touch"); the arrangement of the keyboard in white and black keys, the latter being higher and narrower (which brings about an adjustment of the physical motions when playing on them); the special case of moving from the extremes to the centre of the keyboard, which brings about similar adjustments; the rebound from the keybed, when one plays rapid and loud staccato; the elasticity of the piano mechanism's materials, which afford a limited amount of speed in the production of a sonorous forte; and so on. Our claim is, that this not only is a sign of a rationalistic / scientific understanding; it also is an insight into piano playing as *environmentally constituted*, in a way that, one could claim, the instrument itself generates the correct motions, after personal anatomical features.

We are reaching the point, where the three already examined and interdependent structures -gravity, body and instrument- have to be connected to the structure *par excellence* for notated music: the score. In his account of the development of modern humans' memory through an increased reliance on external representational systems, visuographic (such as the musical score) or not, Rowlands claims that

"invention of such a system is inherently a method of external memory storage. As long as a person possesses the 'code' (and such possession presumably is constituted by an internal store of some sort) for a given set of representational symbols, the information stored in the symbol is available to the person." (Rowlands,1999:142)

The "code" that Sándor develops is, ingeniously enough, performer-specific and score-related: It is grounded on performer-specific experience in that it is embodied, employing five motion patterns and four modes of touch (and their combinations), but not in the abstract: Those correspond to exact visual patterns on the score. Let us take a closer look at this simple gamut of interrelated patterns, whose implications we consider to be far-reaching.

Five letters are used respectively for the five motion patterns in Sándor's own notation:

“A” stands for “Free fall” , the motion employing gravity almost exclusively and used for big sonorities, such as chords in a slow or moderate tempo.

“B” stands for “Five-fingers/scales/arpeggios”, used for every sort of movement towards the same direction as indicated in the score, but also for physical groupings indicated through slurs, beams etc. on the score (or not indicated and left to the performer’s discretion).The definitive factor here is *wrist-adjusting motions*, which align the fingers with their respective forearm muscles and promote musical continuity through facilitating a uniformity of gradual key-releases (legato).

“C” stands for forearm “Rotation”, corresponding to constant alternation of direction in the score.

“D” stands for “Staccato”, a complex throwing motion for separated sounds, visually recognized in the score with dots, wedges, isolated events, octaves , repeated notes, etc.

“E” stands for the “Thrust”, the only motion which employs muscular energy exclusively. The Thrust is proper for massive sonorities, in slower tempi where the pianist has the time to be on the surface of the keys just before the attack. Next to the legato (associated with B) and staccato (associated with D) touch, there are also the portato and tenuto touches.

Someone who has learnt this ‘code’ (and Sándor claims that this is something achievable in six to eight months) and has good music-reading skills, can now plug into the score and engage in a simple *pattern-recognition* and *pattern-completion* internal process, translating automatically the information into gesture and sound. Of course, nobody could claim that all problems are solved: The refinement of musical detail itself, questions of extreme tasks such as speed, accuracy and control, even the idiosyncratic manifestation of these motion patterns themselves, are questions to be perpetually addressed.The point, though, remains that this ‘code’ provides an environmentally-constituted interface between the performer and the notated music.

The mention of pattern-recognition and pattern-completion operations as part of the Sándor suggestions brings us to chapter seven in Rowlands' *The body in mind*: Here, it is argued that some thought processes (such as mathematical calculation) can have their own environmental take, seen as hybrid, with an internal 'pattern-mapping'component and an external "environmental structure manipulation" component. A multiplication of three-digit numbers using pen and paper (environmental structures) and an algorithm of small, easy steps, is an informative example. What resurfaces is a renewed and probably unexpected role for the "primordial" procedural memory, a type of *knowing-how-to-do* things instead of knowing things (1999:164).

Taking Sándor's idea even further, we would be tempted to suggest the following:
At the moment the performer makes the conscious decision to engage with a score, s/he is triggering an environmental system of several elements (the score, the instrument, gravity and his body), which interact towards the actual performance. In a zen - like sense, after this initial conscious decision, not only does the performer play the piece on the instrument, but also the instrument plays (that is, regulates, controls) the body, by dictating the necessary adjustments; the body controls the performer (when, for example, experiencing some sort of discomfort / strain alarms the conscious mind that something is imbalanced and must adjust); and, quintessentially, the score plays the performer, in that its visual patterns and instructions can automatically trigger motion patterns; and so on, towards an infinite net of subtle interactions.

D. Conclusion

The brief comparison between the piano performance textbooks above has served the disclosure of their respective underlying cognitive paradigms: Leimer-Giesekin presents us with an exemplary case of internalism applied in every aspect of piano playing, as opposed to Sándor's environmental traces in the use of gravity, the body, the instrument and the score. It will shortly be shown, how the idea of a 'code' interrelating physical and musical patterns of movement can be extended into the idea of embodied navigation of complex notation.

3. Taxonomies Of Embodied Cognition

The brief comparison of two major works on piano interpretation and the uncovering of their underlying cognitive paradigm, under the influence of Rowlands' thesis on memory retrieval, constitute only one case study of how the field of embodied cognition can provide concepts and tools for the rethinking of traditional paradigms. In what follows, I will make an overview of central ideas in the field of embodied cognition and extract concepts, which form the basis of the embodied navigation model.

In our overview of the main themes of embodied cognition, we will follow Lawrence Shapiro's 2011[255] taxonomy of the field, according to three major themes or hypotheses, integrating alternative or overlapping ones, such as Rolands 2010 *4E cognition* and Chemero's distinction between embodied cognition and radical embodied cognition.

Such overview will provide the pool of grounding concepts for the model of embodied navigation of complex notation, as well as the necessary distinctions between three versions of the model (soft, hard, radical).

3.1 The Constitution Hypothesis

According to the proponents of the *constitution hypothesis*, certain cognitive processes *partly consist in* interactions, which involve the body and the environment. The thesis comes in many varieties and attracts multiple criticisms. Here are main manifestations of the constitution thesis.

A. 4E COGNITION

Mark Rowlands' concepts have played a triggering role in my development of the concept of embodied navigation, through the reading of his work in the context of

[255] Lawrence Shapiro, *Embodied Cognition*, Routledge, London and New York, 2011.

seminars with Jerry Balzano at the University of California, San Diego. According to his analysis, "attenuation of the role of representations combined with augmentation of the role of action" (Rowlands, 2010, p. 49) is the landmark of all four strands of non-cartesian approaches as described above: cognition embodied, embedded, enactive and extended. The role of mental representations in earlier computational models is now *partly* taken over by *external information-bearing structures*, which the cognizing subject *exploits, manipulates and transforms*. This external information processing may be energy-saving when compared to a purely internalist, mind-based process (Rowlands, 2010, p.18). The idea is explicitly connected to Gibsonian psychology, and in particular to the idea of exploitation of the structure of light reflexion and diffusion (the so-called *ambient optic array*), through the navigation of the environment from the perceiving subject; as well as to the idea of the so-called *affordances*, that is the properties of the environment, which invite opportunitites for particular sorts of actions (Rowlands, 2010, pp. 33-37).

In this sense, in the target task "Learning and Performance of a complex piano score after 1945", learning as *understanding*, as brain processing of the graphic representation called notation, is partly *substituted* by manipulations in external structures, as also discussed in the Sándor example: the score, the instrument, the performative embodiment and even gravity. And, as will be shown in the third part, proper technological tools can further enter the equation in the embodied navigation paradigm. These manipulations are, according to Rowlands, *constitutive* of the cognitive processes, as opposed to possible interpretations of mere *dependence* of the cognitive processes on an environmental scaffolding. The exploration and evaluation, of how can someone externally process the information contained in the score, steadily changes the qualitative and quantitative properties of the mental component. This fact already points towards a *feedback circle* between the brain, the body and the world.

Let us now take a closer albeit quick look to the four strands of non-cartesian cognition proposed by Rowlands / Gallagher:

a) embodied cognition

Cognitive processes are constituted of wider bodily structures and processes, that is structures and processes other than the ones associated with the brain and the central nervous system. For the defense of this thesis, Rowlands cites Antonio Damasio's[256] *embodied mind thesis*:

"minds profoundly reflect the bodies in which they are contained, " and, therefore, "it is often possible to predict properties of the body based on knowledge of properties of the mind "
(Damasio 2004, 174)

"a description of various perceptual capacities cannot maintain body-neutrality and it also means that an organism with a non-human body will have non-human visual and auditory psychologies. (Ibid., 190) "

Were there more than two eyes or fewer, or if the distance between the eyes differed, the processes in the brain that compute depth from disparity would require significant revision:

" Human vision requires a human body " (ibid., 191).

One other fine example, which demonstrates how cognition includes extra-neural body structures and processes, is the phenomenon known as *Interaural Time Difference*. According to this thesis, it is this very time difference in the perception of sound from our two ears, that contains important information concerning the exact localization of a sound source. That's why any account of sound perception, which remains focused on brain processing of the audio input, would be wrong. The fact of *natural stereophony* shapes the neuraly implemented computational algorithm and must be considered as an integral component of cognition, or inversely: The mental representation of the ITD contains bodily properties, namely the distance between the two ears. The brain itself is, so to speak, calibrated by the existence of ITD.

So, the brain uses the distance between the ears as a way of determining the

[256] Antonio Damasio, *Descartes' Error*, New York 1994.

direction of the sound source. The rules, by way of which the brain manipulates and transforms mental representations, depend, partly but crucially, on the body in which that brain belongs.
According to Shapiro's metaphor, in the same way that the manual for a submarine depends on the construction of the submarine itself and is not transferable to, for example, piloting a plane, so are many cognitive processes dependent on wider bodily structures. In its entirety, the thesis is an attack on the idea of *body neutrality*.

Several interpretations of this thesis allow for several degrees of compatibility to the traditional science of the mind : Epistemic (the body as context), ontic (the body as dependence) and ontic (constitution or composition).

The adoption of the embodied cognition thesis for piano playing would go as follows: Cognitive processes associated with piano performance of notated music involve structures and processes external to the ones associated with the brain and the central nervous system. While this thesis sounds almost self-evident and thus trivial, as far as playing an instrument is concerned, the part which remains under-researched is how those embodied processes interact with the mental processing itself (cognition proper according to standard cognitive science), and in particular with its external representation in the form of musical notation.

b) extended cognition[257]

Cognitive processes are stretching out into the cognizing subject's environment, in the sense that they partly consist of actions in the environment.

The actions that the organism performs on the world around it are ones of manipulating, exploiting, and / or transforming external structures.What is distinctive of these structures is that they carry information relevant to accomplishing a given cognitive task. And by acting on these structures in suitable ways, the cognizing organism is able to make that information available to itself and to its subsequent

[257] The terms *vehicle externalism*, *active externalism*, *locational externalism*, and *environmentalism* are equally used.

cognitive operations. That is, the function of the action performed by a cognizing organism on these structures is to transform information, that is merely present in the structures, into information that is available to the organism and / or to its subsequent processing operations.This, according to the thesis of the extended mind, can form part —a properly cognitive part — of a process of cognition.

Thus, as I shall understand it and defend it, the thesis of the extended mind is the thesis that some cognitive processes are made up, in part, of the manipulation, exploitation, and/or transformation of information-bearing structures in the cognizing organism's environment.[258] (Rowlands, 2010, p. 59)

This form of functionalism, developed originally by Andy Clark and David Chalmers[259], will become the object of further elaboration in the context of Andy Clark's version of extended cognition. Rowlands gives special attention to the fact, that external information-bearing structures cannot be equal to cognitive states or mental representations[260]. Thus, the notes in the notebook of an Alzheimer's patient, Otto, -Chalmers' favourite example-, cannot be identified as ontologically identical to the reflections and imagination of a healthy subject (Inga), although their function

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[258] "The Extended Mind :
1. The world is an external store of information relevant to processes such
as perceiving, remembering, reasoning . . . (and possibly) experiencing.
2. Cognitive processes are hybrid — they straddle both internal and external
operations.
3. The external operations take the form of action , broadly construed:
the manipulation, exploitation, and transformation of environmental
structures — ones that carry information relevant to the accomplishing
of a given task.
4. At least some of the internal processes are ones concerned with supplying
the subject with the ability to appropriately use relevant structures in
its environment.

As I shall understand it and defend it, therefore, the thesis of the extended mind is an (1) ontic thesis, of (2) partial and (3) contingent (4) composition of (5) some mental processes. There is always an irreducible internal — neural and, sometimes, also wider bodily — contribution to the constitution of any mental process."
(Rowlands 2010, p. 59)

[259] Andy Clark und David Chalmers, "The Extended Mind", *Analysis,* vol. 58, pp. 7-19, Menary 2010

[260] Rowlands, *The New Science of the Mind*, p. 67

might be exactly the same: to guide the patient to a desired location. Similarly, the often evoked pop-sci thesis, often in relation to McLuhan's media theory[261], that the internet is "humanity's central nervous system", would be philosophically and practically problematic.

The extended cognition thesis seems equally compelling for activities such as musical performance, which depend on instruments and musical scores. In particular, the role of a score, some sort of hybrid between the mental and the physical due to the very fact of notation's symbolic character, becomes more than debatable in this respect. The core of a main criticism here would be: Why are those external structures considered as constitutive and not as mere causal or aids or dependencies of the cognition proper taking part in the brain?

c) embedded cognition

By relying on the environment in an appropriate way, the complexity of what the brain has to do in order to accomplish a cognitive task — that is, in order to fulfill the role that defines a cognitive process — can be reduced. Some of the complexity of the task is, thereby, off-loaded onto the environment, given that the organism has the ability to appropriately exploit that environment.. (Rowlands 2010, p. 69)

Cognitive processes are often embedded, situated or scaffolded in the environment. They are so made, as to only and provisionally function *in tandem* with a certain environment, but they are not ontologically dependent on actions and their environmental prerequisites as in the extended cognition. This approach is judged by Rowlands as a form of functionalism, or of efficiency through the distribution of a task between body, brain and environment. Functionalism is evaluated as leaving essentially the cartesian version of the mind intact. Several forms of functionalism, including Andy Clark's reconciliatory stance towards the combination of computational and embodied approaches, can be seen as falling into this category. Even in such a milder version of *dependency*, embedded cognition provides interesting insights for the ergonomic redesigning of scores and instruments, for applications in music education, and more generally for efficiency considerations.

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[261] Marshall McLuhan, *Understanding Media*, New York, 1964

d) enactive cognition

"As you move with respect to the cube, you learn how its aspect changes— that is, you encounter its visual potential. To encounter its visual potential is thus to encounter its actual shape. When you experience an object as cubical merely on the basis of its aspect, you do so because you bring to bear, in this experience, your sensorimotor knowledge of the relation between changes in cube aspects and movement. To experience the figure as a cube, on the basis of how it looks, is to understand how its look changes as you move." (Noë 2004, p. 77)

In the theory by O'Regan and Noë[262], visual perception is defined through the sensomotoric expectations and possibilities (contingencies) which form the root of motor learning. An example : Given the fact that at each instant, we can only perceive partial aspects of three- dimensional objects, the prerequisite for the perception of whole objects is our expectation of how would our perspective change through the physical manipulation of the object[263].

Same as in the case for extended cognition, action stands here in the foreground, but with a decisive difference : As imagined action, as expectations and possibilities, as *predictions*, not as real action.[264]

In his extended critique, Rowlands hints at the important fact, that not all of those approaches are totally incompatible with traditional cognitive science. This is particularly true of the enactive and also certain embodied and situated or embedded approaches to cognition. Rowlands amalgamates embodied and extended varieties into the definition of cognition as "intentionally directed revealing activity" that is permanently shaped by the structure and properties of a given environment[265]. Even more : Internal activities are shaped constantly by external ones, both qualitatively and quantitatively, pointing towards a dynamic feedback cycle between brain, body and environment[266]. Rowland terms this latter description "the amalgamated mind" .

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[262] J. Kevin O'Regan und Alva Noë, "What it is like to see: A sensorimotor theory of perceptual experience.", *Synthese*, Vol. 79, pp. 79–103

[263] Alva Noë, *Action in Perception*, Cambridge, Mass. 2004, p.77

[264] Rowlands, 2010, p.74

[265] Rowlands, 2010, p. 163-187

[266] Rowlands, 2004, p.122

Let us now recapitulate, how these four categories of non-cartesian or externalist cognition identified by Rowlands relate to the model of embodied navigation of complex notation.

1) Embodied cognition : Embodied cognition makes the strong claim for the constitution of cognition in wider bodily processes and structures. Such a claim seems particularly attractive and proper, almost self-evident, for activities and skills which include such extra-neural structures, for example musical performance. In that sense, the understanding of musical notation from a performer-specific perspective consists in the transformation of symbolic notation into embodied layers and processes, gestures and movements, and the corresponding couplings and decouplings between the two. The understanding of musical notation from the perspective of the performer is impossible without bodily participation.
2) Extended cognition : Understanding from the performer perspective presupposes historically developed media, such as the instrument and the music notation, or even newer media, such as the gesture-capture technologies to be presented in the third part. The manipulation of those external information-bearing structures not only facilitates cognition, in terms of increasing efficiency, but rather shapes cognition in itself, since it changes both the quantity and the quality of the irreducible neural processing that has to take place. So, in the Xenakis example to be presented shortly, a note-to-note memorization before playing would be both qualitatively and quantitatively more taxing than the embodied processing of notation proposed.
3) Enactive cognition : Understanding takes place dynamically through action in time, or rather through interaction with media. This interaction is based on sensomotoric contigencies and models (also to be revised by Leman in his latest (2016) book on expressive interactions, and in relation to the interaction dynamics of entrainment, sensorimotor prediction and expressive alignment).
4) Embedded cognition : While music can have the abstract representation enabled by the platonic presence of the score, music notation is created to function *in tandem* with specific conditions. Efficiency claims and ergonomics of the embodied navigation model are falling into this category.

B. Andy Clark

Further support for the constitution hypothesis of cognition is provided by the philosopher Andy Clark. Shapiro (2011, p.65-67), resumes six characteristic embodied cognition research programmes attributed to Clark as follows:

(1) *Nontrivial Causal Spread*: Mobots and toys, such as a slinky, can take advantage of *passive dynamics* enabled by gravity and friction. Combination of both passive and active dynamics makes the energy expenditure of the system considerably lower. Please note here the similarities to Sándor's constitution of piano technique as a hybrid phenomenon, combining the conscious employment of gravity and of muscular action based on muscular interdependence.

(2) *Principle of Ecological Assembly*: Problem-solving becomes more efficient through the selection of ecological strategies, which are conscious of environmental resources useful for the solving process. For example : Learning by heart a map is hardly ever the case, since one would usually consult the map in real-time, so that memory is partially replaced by perception and action. Similarly, the map can be replaced by even more efficient forms of navigation, such as GPS, minimizing the load of action through verbal instruction, or through employing the modality of sound. Tasks in other words can be off-loaded to the environment. Now imagine a musical score in the place of the map or the GPS, and how consulting the score in live performance offloads part of the mental burden, instead of memorizing the score.

(3) *Open Channel Perception*, or direct perception : The mechanism of constant coupling or tuning, between the world and the cognizer, which allows for the abolition or minimization of internal costs. Navigation of a certain environment substitutes for computation, as it will extensively be shown with the model of embodied navigation.

(4) *Information Self-Structuring* : This idea is extensively exploited by roboticists, who tend to research how information is self-structured through action. More on that will be explored in the so-called *replacement* hypothesis and in particular in Rodney Brooks' *subsumption architecture.*

(5) *Perception as Sensorimotor Experience*: This category refers to O'Regan and Noë's exploration of sensorimotor contingencies, and thus overlaps with Rowlands' enactive approach to cognition.

(6) *Dynamic-Computational Complementarity*: An interesting aspect of Clark's approach is the complementarity of computational and dynamic approaches to cognition, what will be shown later as an essential distinctive feature between embodied and radical embodied cognitive science. Clark's latest embracing of the notion of the brain as a predictive processing, even as a Bayesian probabilistic machine, seems to move further away from embodiment towards computational approaches – more on that soon.

3.2 The Conceptualization Hypothesis

Four overlapping research questions address the issue of *conceptualization*, or of how abstract concepts and language are shaped by embodied experience:

1. The environmental constitution of symbolic information: is symbolic information with inherent meanings to be considered as an information-bearing structure?
2. Conceptual metaphor: is all symbolic information structured after primordial experience?
3. The symbol grounding problem: how is meaning grounded in primordial experience?
4. Neurological evidence for the formation of concepts according to the action-perception coupling: What are the findings in neuroscience which support the above claims?

Our propositions in relation to music performance of complex music go as follows:

1) The ways in which a pianist conceptualizes a complex score differ from the ways a notation-literate listener, an analyst or a composer do the same. Conceptualization of a musical score is performer-specific and action-coupled.
2) Complexity renders the understanding of abstract relations much more difficult and inefficient and requires off-loading of the task to action.
3) Performers ground the meaning of symbols on direct actions, given proficiency in reading.
4) The fact that a performer grounds her comprehension on actions rather than abstract relationships allows for the performance of complex music without having fully (or at all) internalized it.

5) There is a feedback loop between concepts and action. It is exactly one's own capacity for abstract conceptualization that allows for the emergence of a concept such as embodied navigation, but that also inhibits the primordial performative responses of direct perception.
6) The process can be described as a decoding of concepts into primordial action and re-coding them into performer-specific concepts, or a *folding* into action-symbols and *unfolding* in performance.

A. Rowlands : External Visuographic Means

In our embodied navigation model, the musical text has been claimed as an environmental structure to be be directly perceived and exploited, manipulated and transformed, by the congnizing subject, a claim which is supported by theories of dependence and / or constitution of cognitive processes by wider bodily and external structures, as shown in the investigation of 4E cognition and in Clark's ideas.

This claim, however, appears to somehow sidetrack the most important property of music notation: The very fact that it is *symbolic*. In other words, music notation differs from the environmental structures investigated above, in that, apart from its material properties, it is a network of symbols structured as a language. Those symbols signify something, that is they bear concepts. How do these symbols mean? If the instrument with its material properties can easily be compared to the Gibsonian *array of light,* as an environmental structure susceptible to direct perception and action due to its purely physical design and properties, then how can the same be claimed for musical notation, which next to its purely material properties bears semantic or conceptual properties? How can thus a model of direct perception of affordances for action be extended to a symbolic structure, be it a musical score or more generally language? How can the act of interpretation manifest as interaction in a symbolic rather than real environment?

This aporia brings us into the domain of the relation between memory, conceptualization and embodiment, which forms the object of a cluster of related theories.

For Mark Rowlands, the problem of conceptualization and semantification is partially answered in the development of human memory from episodic to semantic through external means, including visuographic ones. He is particularly claiming that principles of external perceptual processing apply equally to memory and symbolic processing (Rowlands 2004, 119).

Rowlands draws on Endel Tulving's (1983)[267] distinction between episodic, procedural and semantic memory and on Luria and Vigotsky's (1992) comparison between cultures relying primarily on episodic memories and others relying on visuographic means of external representation, in order to explain the evolution of human memory through the use of external media. According to Tulving, the basic flashback memories of concrete events develop into abstract memory retrieval systems, either procedural or semantic, but this is not only a biological but also a cultural development. A famous example by Luria and Vigotsky is the comparison of an African envoy, who has developed phenomenal memorization skills based on episodic memory, as opposed to the use of a visuographic means, such as the Peruvian system of knots known as *knivu*, which allows the access to information only to officials who know how to interpret the knots. The latter is an instance of semantic memory, based on a certain procedural component (the 'know how' or 'code' part of it).

In other words, Rowlands focuses on the material and interactive aspects of visuographic media, identifying a continuous process of externalization through mimesis, speech and eventually writing, which respectively shapes the concepts human are internally developing on the basis of their forms of external information retrieval.

Please remember that Rowlands always claims that there two distinct components in cognition, the internal – neural and the external – bodily or environmental, and that augmentation of the latter brings about attenuation of the first, that is there is a way to use external structures in order to reduce the amount of the work to do in the head. Let us see how this structure is transferred from visual perception to conceptualization through environmentalist models of memory retrieval.

[267] Endel Tulving, *Elements of Semantic Memory*, New York, Oxford University Press, 1983

External aids to memory are a self-obvious reality for human beings, from shopping lists to googling information on the internet instead of remembering them. However, the dichotomy between internal processing, remembering proper, and the use of those external aids, is far from dissolved, since the latter are commonly thought of as external heuristic accompaniments to the real cognitive task.

Rowlands claims that the process of remembering is hybrid, consisting of internal representations and physical manipulations in the environment.

His memory model goes as follows:

M1. The amount of internal information processing that an organism needs to perform in order to accomplish memory task T is inversely proportional to the amount of relevant information that is available to the organism in the physical structures around it.

M2. In performing memory task T, we cannot begin to understand the internal information processing task facing an organism unless we understand what relevant information is available to the organism in the physical structures around it.

M3. An organism can process information relevant to memory task T through the manipulation of physical structures in its environment.

M4. In certain circumstances, acting upon, or manipulating, external structures is a form of information processing.

(Rowlands 2004, p.121 -123)

The Rowlands model is crucial for the consideration of conceptualization since, by claiming that memory is hybrid, it claims that the neural component proper of memory retrieval can always be calibrated by the amount of information available in the environment, regardless of whether those information is symbolic or not.

An external representational system is a store of information which can be relevant to the performance of a given memory task. Invention of such a system is inherently a method of external memory storage. As long as a person possesses the ‘code’ (and such possession presumably is constituted by an internal store of some sort) for a given set of representational symbols, the information stored in the symbols is available to that person. (Rowlands 1999, p. 142)

It is then possible, that the inherent symbolic content of this information defines the internal representation load, as well as the transformative potential in terms of extended cognition of those structures. What the symbols mean is equally defined by the ways we are accessing them and the proper code, learnt as procedural, know-how memory, to access them.

B. Conceptualization After Shapiro

The remarks above by Rowlands seem to transfer or bypass the problem of meaning and concept formation: If music notation symbols do depend on their external representation medium in order to define what and how they mean, and if their cognition is hybrid, depending on both internal and external structures, then what does embodied cognition have to say about the first, that is the remaining internal or proper neural component *after* the media and the ways of interaction with them have been fixed?

Lawrence Shapiro (2011) summarizes theories that claim, and some vividly demonstrate, how human concepts and / or conceptions[268], and consequently how language and symbolic systems, are shaped by human embodiment, by the experience of having a body in this world.

The concepts on which an organism relies to understand its surrounding world depend on the kind of body that it has, so that were organisms to differ with respect to their bodies, they would differ as well in how they understand the world. (Shapiro, 2011, p.4)

Shapiro is looking at linguistic biases in cognition, specifically linguistic determination of time and gender conceptions in the work of Lera Boroditsky (2001)[269]; at the conceptualization of color as a "unique sort of embodied coupling with the world" in

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[268] The difference between concept and conception is that, concepts are inter-subjective, shared beliefs, as opposed to conceptions which can have a very subjective coloring or attribute for the same concept.

[269] Lera Boroditsky, "Does Language Shape Thought? Mandarin and English Speakers", Conceptions of Time,' *Cognitive Psychology* 43: 1–22, 2001

the *Embodied Mind* of Varela, Thomson and Rosch (1991); at the shaping of language by the body through metaphorical thinking in the work of Mark Johnson and George Lakoff[270]; and at the so-called *symbol grounding problem*, after John Searle's *Chinese Room* problem[271], through the *indexical hypothesis* by Art Glenberg (1997)[272] and the notion of *perceptual symbols* by Lawrence Barsasou (1999), supported through the experimental verification of the so-called *action-sentence compatibility effect*[273]. Those theories find strong neurological evidence in the discovery of canonical and mirror neurons, which also supports the conceptualization hypothesis, in that it shows how the coupling of action and perception gives rise to highly embodied concepts. Further neurological evidence for the relation between higher cognitive abilities and bodily states has been supported by Antonio Damasio's studies on the role of the *brain stem* (Damasio 2012[274]).

Metaphor theory has had a constant influence in systematic musicology, paradigmatically in the work of Lawrence Zbikowski[275] and Bob Snyder[276], among others.

An important case about the shaping of musical concepts by embodied experience is made by Bob Snyder's (2000) and Lawrence Zbikowski's (2002) appropriation of the notion of *image schemata*, originating in Mark Johnson (1987)[277], as the basis of *cross-domain conceptual mappings* known as metaphors (Lakoff and Johnson, 1980).

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[270] George Lakoff and Mark Johnson, *Metaphors We Live By*, Chicago: University of Chicago Press, 1980

[271] John Searle, "Minds, Brains, and Programs," *Behavioral and Brain Sciences* 3: 417–24, 1980

[272] Art Glenberg, "What Memory is For," *Behavioral and Brain Sciences* 20: 1–55, 1997

[273] Larry Barsalou "Perceptual Symbol Systems," *Behavioral and Brain Sciences* 22: 577–609, 1999

[274] Antonio Damasio, *Self Comes to Mind. Constructing the Conscious Brain*, Vintage, London, 2012

[275] Lawrence Zbikowski, *Conceptualizing Music : Cognitive Structure, Theory and Analysis*, Oxford university Press, 2002

[276] Bob, Snyder, *Music and Memory: An Introduction*, Cambridge, Massachusetts, 2000, 107-120.

[277] Mark Johnson,*The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason,* University of Chicago Press,1987

According to Snyder, image schemas are the fundamental embodied cognitive structures, derived from dynamic patterns of interaction with our environment. They are defined as

"between concrete, specific visual images and abstract concepts". Although image schemas are not so abstract that we cannot form any kind of image in relation to them, the image we do form may have components that are not strictly visual. This is another way in which image schemas are different from either visual images or abstract concepts—they can have a kinesthetic component and represent muscular sensations in relation to particular experiences; they can have a particular physical "feel" to them. This suggests that image schemas are at least in part implicit knowledge; hence our understanding of them is often metaphorical (Snyder 2000, p. 108)

Among the rudimentary human experiences generalized into image-schematic form are those of up and down, of spatial centeredness, of one event being linked to another through some sort of causal connection, of moving along a path toward a goal, and of containment or "inside" and "outside" (Johnson, 1987) in Snyder, p. 109

Snyder goes on to identify several musical phenomena, which operate on the basis of those basic image schemas : *up and down* schemas relate to an imaginary pitch space, whereby increased frequency gives rise to a perception of higher and lower frequency to the perception of spatially lower. A physical phenomenon, which in its basis is temporal, that is vibrations in a certain unit of time, is perceived in spatial terms, giving rise to derivative concepts, such as cadence, closure, climax etc. The extension of this schema into other musical parameters generates the metaphor of *musical tension and release* : The higher the value of certain parameters is, the more tensely is music perceived, and vice versa, resolution depends on the lowering of those parameters.

Another idea, which seems to pervade theoretical musical concepts, is the idea of *physical centrality*, which operates on several hierarchical levels in music. Thus, in the context of tonal music, certain notes or chords are perceived as more grounding or centering than others. The same seems to apply in metric structure based on beats.

Similarly, grounding schemas of *motion linkage and causation* seem to pervade our theorization of the succession of events (producing the effect of motion), the effect of linkage of otherwise unrelated events and eventually the perception of events caused by previous ones. Causation is strongly related to linearity, goals and directions, such as musical works seem to imply specific goals and paths through which they can be achieved in several levels of musical form.

Eventually, the notion of *containment* is again important in the tonal hierarchies of consoncance and dissonance, the latter also related to musical tension.

An interesting thought experiment, which makes palpable the metaphorical nature of language in the music domain, would be an attempt to describe any theoretical entities without resorting to basic spatial or kinesthetic metaphors such as the above. It is the ubiquity of such terminology in musical theoretical vocabulary, which urges Snyder to adopt Blacking's definition of music as a "form of metaphor that may express image schematic implicit knowledge."(Blacking 1995 : 239-242)

Music in perception then means *by virtue of* image schemata and metaphorical extensions, and thus the internal component in the understanding of musical symbols is already embodied, even if we ignore the manipulations of the structures in virtue of their hybrid nature as information-bearing structures (Rowlands).

In the case of musical performance, not musical perception, those considerations become even more urgent and multilayered : The appperceptive content of musical symbols has now to be joined by the actions which realize those symbols in sound, so that one could talk of *symbol-action-sound chunks*, in an extension of Godøy's 2011[278] notion of *sound-action chunks*. In certain cases, as will be shown in a Xenakis example soon, the perception of sound chunks is decoupled from the relevant actions which effectuate them, so that one could speak of a *double grounding* of the performative experience in both the physical movements which effectuate them and the ground embodiment of the metaphors which conceptualize the symbols and the sounds. If one adds to that the annotation acts, which transform the symbols of notation, then we have at least three domains of embodied interaction with symbolic notation : *metaphorical embodiment, performative embodiment,*

[278] Rolf Inge Godøy, "Sound-Action Chunks in Music", in Jorge Solis & Kia Ng, *Musical Robots and Interactive Multimodal Systems*, Springer, Berlin-Heidelberg, 2011

annotating embodiment.

An important extension of the metaphor theory is taking place through the collaboration of George Lakoff with Rafael Nuñez in their work on embodied mathematics[279]. Similarly to Lakoff and Johnson's work on language, they claim that the basic process of metaphorical constructions as cross-domain mapping is not limited to language, but also pervades other symbolic constructions, which are most famous for being abstract, such as mathematics. A set of innate arithmetic abilities, such as counting up to the number three, and of basic grounding metaphors suffices, according to the writers, for the development of abstract mathematical concepts, such as the Boolean algebra and the concept of infinity. An interesting application of this theory can be explored in the domain of notated musical rhythm.

C. The Symbol Grounding Problem

The aporia of how meaningful notational symbols can be ecologically manipulated touches on the so-called *symbol grounding problem,* advocated by a number of psychologists such as Glenberg 1997 and Barsalou 1999.

A famous thought experiment, John Searle's *Chinese Room* (Searle 1980), stands in the centre of debates around the grounding problem. The chinese room is a metaphor for a computer, whereby a non-chinese speaker processes strings of Chinese according to a series of manuals and gives responses to questions. For the external observer, the Chinese Room communicates in Chinese, even though the operator does not actually understand Chinese. He merely manipulates the symbols. That urges Glenberg and Robertson to claim that

> "abstract, arbitrary symbols, such as words, need to be grounded in something other than relations to more abstract arbitrary symbols, if any of those symbols are to be meaningful." (Glenberg and Robertson 2000: 381)[280]

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[279] George Lakoff with Rafael Nuñez, *Where Mathematics Comes From. How the Embodied Being Brings Mathematics into Being*, Basic Books, New York, 2000

[280] Arthur Glenberg and David Robertson, "Symbol Grounding and Meaning: A Comparison of High-Dimensional and Embodied Theories of Meaning," *Journal of Memory and Language* 43: 379–401, 2000

According to Shapiro,

> a criticism of standard cognitive science should be apparent. If standard cognitive scientists think that minds operate like computers, and computational processes range over abstract, arbitrary symbols, then it follows that standard cognitive science cannot account for the obvious fact that people understand language: that language is meaningful. (Shapiro, 2011, p. 96)

Such thought experiment constitutes then a strong critique to the computational theory of the mind, Putnam and Fodor, according to which relations between symbols and rules of processing (algorithms) are sufficient for explaining cognition. In this case, understanding of the Chinese language is shown to be inadequate as processing of the symbols on the base of instruction manuals (of algorithms).

How then does language, or for our case music notation, mean beyond the structural inter-relationship of symbols on paper? Which echoes our original aporia, how can music notation be conceived as an environmental structure since it consists of arbitrary abstract symbols?

The answer is that: Symbols acquire meaning or are grounded through embodiment.

The *indexical hypothesis* by Glenberg describes the understanding of symbols as a three-partite process: indexing or “mapping” words to perceptual symbols; deriving affordances from the perceptual symbols; and eventually *meshing affordances*, which yields an understanding of the linguistic symbols. In the base of the theory stands the notion of perceptual symbols (or modal, as opposed to amodal, symbols) by Larry Barsalou.

In this line of thinking, perception is multimodal, while words are amodal and the connections to their referents is arbitrary.

> Barsalou proposes that the transition from modal representations – representations in the visual, or auditory, or etc., mode – to amodal representations is unnecessary : “Cognition is inherently perceptual,” he argues, “sharing systems with perception at both the cognitive and neural levels” (1999: 577)

Perceptual symbols are simply reconstructions, for the purpose of later cognitive processing, of representations as they appeared in their original perceptual coding. (Shapiro, p. 99)

In that sense, the symbol of the piano's *middle C*, as a perceptual symbol, will be different for someone who associated this through listening to a particular timbre and for the pianist, who associates it with the gesture for reproducing this pitch on the piano. *C* as a perceptual symbol encodes different modal information for a listener, a composer or a performer.

D. Mirror And Canonical Neurons

The discovery of mirror and canonical neurons in the premotor cortex of primates, including humans, seems to be providing strong neurological evidence for the conceptualization hypothesis. If indeed perception and action share common neuronal codes, then objects should also be partly conceived according to how one is prone to interact with them.

According to Rizzolatti and Craighero 2004[281]; Garbarini and Adenzato 2004[282]; Gallese and Lakoff 2005[283], canonical and mirror neurons are bimodal, that is they correlate two different modalities. In the case of canonical neurons, it was observed that the same canonical neuron fires when a monkey sees an object the size of a tennis ball and when a monkey actually grasps an object of that size. In the case of mirror neurons, the same correlation was observed, even when the monkey would watch another monkey seize the object, in other words in the observation of transitive actions.

This powerful observation has urged researchers claim that

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[281] Giacomo Rizzolatti and Laila Craighero, "The Mirror-Neuron System", *Annual Review of Neuroscience*, 27: 169–92, 2004

[282] Francesa Garbarini and Mauro Adenzato, "At the Root of Embodied Cognition: Cognitive Science Meets Neurophysiology," *Brain and Cognition* 56: 100–6, 2004

[283] Vittorio Gallese and George Lakoff , "The Brain's Concepts: The Role of the Sensory- Motor System in Reason and Language," *Cognitive Neuropsychology* 22: 455–79, 2005

> canonical and mirror neurons cause one to conceive of objects and organisms in a manner modulated by one's body. The tennis ball, for instance, is perceived not just as a sphere, but as a sphere-graspable-with-my-whole-hand. The ping pong ball is perceived as a sphere-graspable-with-finger-and-thumb. The agent whose arm extends toward the banana is perceived as reaching for the banana, and the one who moves an object toward itself with a rake is seen as trying to retrieve the object. Shapiro, p. 110

As will be argued and explained in detail later, a pianist similarly conceptualizes musical objects in the form of notational symbols according to their action-oriented properties, so that abstract musical groupings are actually conceived as, for example, graspable or interconnected with arm movements or consisting of disconnected finger events, etc.

E. Conclusion

The formation of concepts has been shown to take place not in the abstract, but rather as a strongly embodied and situated phenomenon. The embeddedness of symbols in external visuographic media, their inherent nature as cross-domain conceptual metaphors, their grounding in perceptual symbols and the neurological mechanisms which interconnect perception and action, are only some of the arguments for the conceptualization hypothesis.

Our propositions in relation to music performance of complex music go as follows:

1) Musical notation constitutes a complex visuographic medium which allows for the off-loading of taxing memory tasks into the environment, similarly to the development of all visuographic media. Musical symbols are embodied, due to their inherent situatedness in the medium of notation, and due to the manipulations, which constitute part of the cognitive processes of understanding or decoding those symbols.
2) Musical concepts are formed as gradually more complex cross-domain metaphorical mappings based on image schemata, similarly to language and mathematics. Despite the possibility of dealing with musical symbols abstractly, similarly to the mode of processing advocated by the Chinese Room experiment, there always is an irreducible experiential and embodied component manifested both linguistically and conceptually.

3) Musical symbols are grounded in multimodal realities or on perceptual / modal symbols, as exploitable affordances. In the case of performers, this grounding is particularly pertinent, since it refers to direct actions relating to performance.
4) The ways in which a pianist conceptualizes a complex score differ from the ways a notation-literate listener, an analyst or a composer does the same. Conceptualization of a musical score is performer-specific and action-coupled.

In that sense, we advocate the following distinction in relation to complexity: Intra-complexity captures the necessity of environmental off-loading due to the higher degree of metaphorical construction and conceptualization, which is inherent in all music; while inter-complexity captures the ubiquitous grounding of symbols in multimodal realities.

Thus, musical symbols are embodied in the following ways: through their embodiment in visuographic manipulable means; through their metaphorical nature, which spikes in the case of intra-complexity; through their multimodal grounding a.k.a inter-complexity; and through the performer-specific neuronal coding of their perception to action.

3.3 The Replacement Hypothesis

The theme of *Replacement* is the most radical, anti-representational direction in Shapiro's three-partite structure of embodied cognition theories. It also corresponds to what Anthony Chemero terms as *radical embodied cognitive science*[284], in opposition to non-radical embodied cognitive science. Its main point is the explanation of cognition through models and tools from Dynamical Systems Theory[285]: The interaction of the body with the environment, a form of dynamic

[284] Anthony Chemero, *Radical Embodied Cognitive Science*, MIT Press, Massachusetts, 2009

[285] Roughly, the theory of systems changing in time. Here is a very handy list of terminology provided by Anthony Chemero in his *Radical Embodied Cognitive Science*.

Dynamical Systems Terminology

"Here, I define some terms that I will use in describing dynamical systems andmodels thereof. I will use them repeatedly throughout the book, so you might want to mark this page. All of these definitions are standard.

"dance", can partly or even fully replace the very need for mental representations and rules of information processing. Thus, the algorithmic causal chains of SCS are being substituted from constant self-organized cycles. This causal cycle involves mind, body and the world as coupled elements of the dynamic system. The non-linear *self-organization* or *emergence* of phenomena can be described without resort to mental representations. Eventually, a mathematical expression materializes the hope to discover the unity in the multiplicity of dynamic phenomena.

Important contributions in the field have come from the developmental psychologist Esther Thelen[286], the philosopher and cognitive scientist Tim van Gelder[287] and the

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1. The state space of a system is the space defined by the set of all possible
states the system could ever be in.
2. A trajectory or path is a set of positions in the state space through which the
system might pass successively. The behavior of the system is often described
by trajectories through the state space.
3. An attractor is a point of state space to which the system will tend when in
the surrounding region.
4. A repeller is a point of state space away from which the system will tend
when in the surrounding region."
5. The topology of a state space is the layout of attractors and repellors in the
state space.
6. A control parameter is some parameter of a system whose continuous quantitative
change leads to a noncontinuous, qualitative change in the topology
of a state space.
7. A differential equation dx/dt . F(x) for variables x1 . . . xn is linear if none of
x1 . . . xn or functions of x1 . . . xn are among the coefficients of F. Otherwise, the
equation is nonlinear.
8. Systems that can be modeled with linear differential equations are called
linear systems. Systems that can only be modeled with nonlinear differential
equations are called nonlinear systems.
9. Only linear systems are decomposable; that is, only linear systems can be
modeled as collections of separable components. Nonlinear systems are nondecomposable.
10. Nondecomposable, nonlinear systems can only be characterized using
global collective variables and/or order parameters, variables or parameters of
the system that summarize the behavior of the system's components. »
Chemero 2009, p. 36

[286] Esther Thelen und Linda Smith, *A Dynamic Systems Approach to the Development of Cognition*

cognitive scientist Randall D. Beer[288], as well as the Sussex roboticists, most famously Rodney Brooks' *subsumption architecture*[289]. We will briefly explore these contributions and we will similarly outline a sketch about how dynamical systems theory could be applied to piano performance.

A. Dynamical Explanation Of The A-Not-B Error In Infants

Esther Thelen and Linda B. Smith at the University of Indiana have proposed a dynamical systems approach to the development of cognition and action, exposed in their homonymous book (1994). Their thesis rejects the reductionist view of ontogeny, as implementation of an abstract plan:

"We propose here a radical departure from current cognitive theory. Although behavior and development appear structured, there are no structures. Although behavior and development appear rule-driven, there are no rules. There is complexity. There is a multiple, parallel, and continuously dynamic interplay of perception and action, and a system that, by its thermodynamic nature, seeks certain stable solutions. These solutions emerge from relations, not from design. When the elements of such complex systems cooperate, they give rise to behavior with a unitary character, and thus to the illusion of structure. But the order is always executory, rather than rule-driven, allowing for the enormous sensitivity and flexibility of behavior to organize and regroup around task and context." (1994, xix)

Computationalism is explicitly attacked through the rejection of the driving paradigm of cognitive science: the mind as a computer of sorts.

"Our commitment to a biologically consistent theory means that we categorically reject machine analogies of cognition and development. For several decades, the preeminent metaphor for understanding human cognition has been the digital computer. The brain may well share certain operations with a digital computer, but it is different from a machine on the most fundamental

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and Action, Cambridge, MA 1994

[287] Tim Van Gelder, "The Dynamical Hypothesis in Cognitive Science", in: *Behavioral and Brain Sciences*, Vol. 21, 1998, S. 615-665

[288] Randal D. Beer, "Dynamical Systems and Embedded Cognition", in: Keith Frankish and William Ramsey (Hg.), *The Cambridge Handbook of Artificial Intelligence*, Cambridge 2013

[289] Rodney A. Brooks, "Intelligence without representation", *Artificial Intelligence 47* (1991), 139–159.

thermodynamic level, as we detail in succeeding chapters. A developmental theory must be appropriate to the organism it serves; thus, we deliberately eschew the machine vocabulary of processing devices, programs, storage units, schemata, modules, or wiring diagrams. We substitute, instead, a vocabulary suited to a fluid, organic system, with certain thermodynamic properties." (1994, ixi)

A case Thelen and co. have extensively argued for, providing evidence for a dynamical non-representationalist explanation of cognition, is their explanation of a certain case of what they call *perseverative behaviors*: *the A-not-B error in infant development* (between the 6th-7th and 12th months).

Shapiro describes the task as follows:

"The basic form of the task is this. An infant sits on its parent's lap in front of a table. On the table are two identical cups (or boxes, or handkerchiefs), A and B. The experimenter captures the infant's attention and the infant then observes the experimenter hiding an attractive object such as a toy under A. The surface on which the cups sit is then moved to within the infant's reach, and the infant will typically reach toward A in order to retrieve the hidden object. This process is repeated several more times, with the infant finding the toy under A on each occasion. On the test trial, the experimenter shows the infant the attractive object and then, as the infant watches, places it under B. When reaching for the toy on this trial, the infant does something peculiar. Rather than reaching toward B, where it has seen the experimenter place the toy, the infant will reach toward A. The infant perseveres in reaching toward A, committing the A-not-B error." (Shapiro, 2011, p. 57)

Unlike the earlier explanation by Piaget (1954)[290], who claims that the error originates in an undeveloped or confused *object concept*, Thelen and co. suggest that no object concept, programme or agent is involved at all, but rather that the error is a behavior emergent as self-reinforcement of the already ingrained pattern the baby has already learnt to reach for A in the past, or as Shapiro puts it:

"In effect, the A-not-B error is hardly more mysterious, hardly more in need of an explanation in terms of rules and representations, than the fact that a road map is more likely to be folded along its old crease lines than new ones, or that a book is more likely to open on a favorite page than to a seldom-read one." (Shapiro, p. 61)

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[290] Piaget, Jean (1954). *The Construction of Reality in the Child.* New York: Basic Books

As will be argued later, this abolition of the necessity of an object concept in favour of emergent behavior gives a very strong basis for debate in the context of predictive processing in music, as supported by the latest Andy Clark[291] and by the latest Marc Leman[292].

B. The Watt Governor As A Model For Cognition

The philosopher and cognitive scientist Timothy van Gelder has proposed the *Watt Governor* as a prototype dynamic system, whose operating principles may be extended to cognition. His analysis of the Watt governor in support of his dynamical thesis, both ontological (cognitive agents *are* dynamical systems) and epistemological (cognitive agents are *explained better* as dynamical systems) goes as follows:

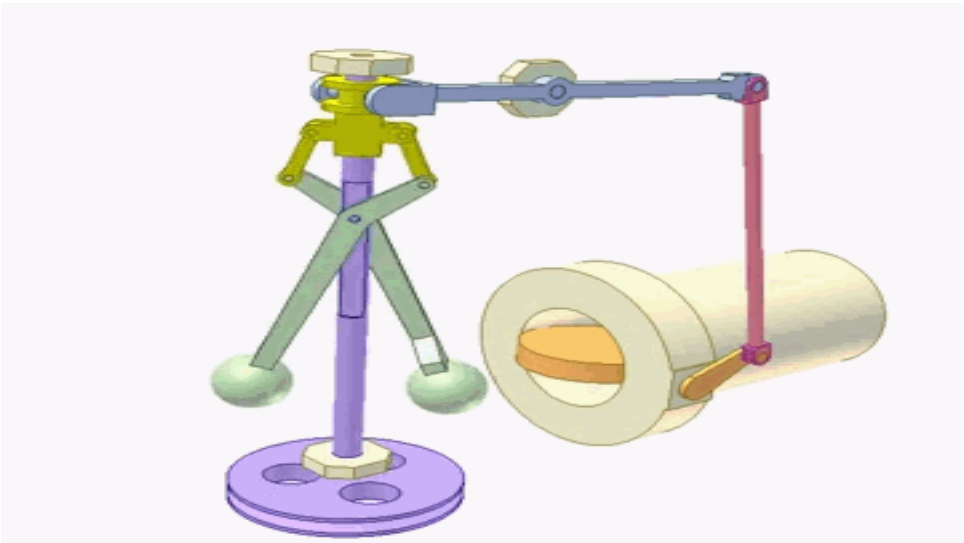

Figure 1: Watt's centrifugal governor as a prototype dynamic system

The Watt Governor is designed to control the steam flow in a machine by means of a flywheel attached to throttle valve in an inversely proportional way: Higher steam

[291] Andy Clark, *Surfing Uncertainty. Prediciton, Action and the Embodied Mind*, Oxford University Press, 2016

[292] Marc Leman, *The Expressive Moment. How Interaction (with Music) Shapes Human Empowerment*, MIT Press, 2016

flow causes the flywheel to move faster and as a result regulates the steam flow downwards through the appropriate movement of a throttle valve which closes, and vice versa, lower steam flow decreases the speed of the flywheel and opens the valve, so that more steam can increase the speed. Such a system appears then to regulate the steam flow and thus the speed of the machine automatically.

Van Gelder[293] suggests that a computationalist would try to describe the process or solve the problem of steam regulation as follows:

"1 Measure the speed of the flywheel.
2 Compare the actual speed against the desired speed.
3 If there is no discrepancy, return to step 1. Otherwise,
a measure the current steam pressure;
b calculate the desired alteration in steam pressure;
c calculate the necessary throttle valve adjustment.
4 Make the throttle valve adjustment.
Return to step 1."
(1995: 348), in Shapiro 2011, 120.

In other words, by creating an algorithm of ordered steps that are using the central representation of flywheel speed,

"it literally computes the desired change in throttle valve by manipulating symbols according to a schedule of rules. Those symbols, in the context of the device and its situation, have meaning, and the success of the governor in its task is owed to its symbol manipulations being in systematic accord with those meanings." (1995: 350) (Shapiro 2011, p. 120)

On the contrary, a dynamic description of the Governor could essentially start at any given step of the algorithm, or rather avoid altogether such a diachronic sequence of steps, since the speed of the flywall, the height of the balls and the opening of the throttle are constantly coupled and interdependent, given the steam flow. Describing the changes in all three parts of the Governor, be it the flywheel, the balls or the throttle, cannot avoid the inclusion of the other two, so that they should be described

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[293] Tim Van Gelder, "What Might Cognition Be, If Not Computation," *Journal of Philosophy* 92: 345–81, 1995

as a dynamic system of interdependent components in a constant cyclical pattern of causation and coupling.

Van Gelder claims that, for the same reasons (lack of timing partitions and interdependence of the central nervous system, the body and the environment), cognitive systems should also be described in dynamical terms. This extension is embraced and developed by the philosopher Randal Beer, who comes to apply this scheme in his dynamic description of categorical perception[294].

Van Gelder's deconstruction of the algorithmic description of the function of the Governor, or rather his demonstration of how such description is insufficient, will inform, in the next chapter, our deconstruction of an algorithmic process we have summarized as UTI, in the context of a case-study by Xenakis's *Mists*. It might equally be shown, that an algorithmic chain of actions is hardly able to describe a performer's embodied processing of very complex notational constellations, in the course of a non-linear learning trajectory.

C. The Dynamics Of Categorical Perception

Randall Beer's application of dynamical System's Theory for a directly albeit minimally cognitive task, namely categorical perception, is essential to the empirical support for the replacement hypothesis.

Beer is explicitly describing cognition as embodied and situated:

" Because a brain is embodied, it "can utilize the natural biomechanics of its body, the geometry of its sensory surfaces, and its ability to actively control these surfaces to considerably simplify many problems " (2003:211). Moreover, because bodies are situated, an agent "can utilize and manipulate the physical and functional organization of the space around it … to offload problems in its environment " (2003: 211). Embodiment and situatedness, we saw, lend themselves to a dynamical description, according to which cognitive behavior is seen as emerging from continuous interactions between brain, body, and world." (Shapiro 2011, p. 127)

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[294] Randal Beer, "The Dynamics of Active Categorical Perception in an Evolved Model Agent," Adaptive Behavior 11: 209–43, 2003

In order to harness the staggering complexity of the task of demonstrating the dynamics of cognition in a system more complex than an infant reaching for A-not-B (Thelen's case-study) or the centrifugal Governor (as the privileged Van Gelder example), and in particular in a system which replicates the tripartite structure "central nervous system-body-environment", Beer created a fully artificial agent, with a connectionist architecture for its brain, a robotic body and a controlled environment. He analyzed all

"three different levels:
(1) the entire coupled brain/body/environment system;
(2) the interaction between agent and environment that generates the observed coupled dynamics;
(3) the underlying neuronal properties responsible for the agent dynamics." (Beer 2003, 209)

"Rather than assigning representational content to neuronal states, the mathematical tools of dynamical systems theory are used to characterize the structure of the space of possible behavioral trajectories and the internal and external forces that shape the particular trajectory that unfolds explores a model agent to illustrate how the perspective and tools of dynamical systems theory can be applied to the analysis of situated, embodied agents capable of minimally cognitive behavior" (Ibid., p.210)

The agent in question is charged with the following categorical task: To be able to identify objects falling from above as "circles" or "diamonds" and act accordingly in order to catch the circles and avoid the diamonds. Part of the agent's "vision" is constituted by its ability to move horizontally in space.

The agent's "brain" consists in a *continuous-time recurrent neural network* (CTRNN) made up of seven nodes operating as "eyes", fiver interneurons, which can feed the prior states into consequent ones, and two output nodes which are "motors", effectuating movement to the left or right.

Properly evolved agents are judged on the basis of their success to catch circles or avoid diamonds, through a visual perception, which is enabled by the horizontal movement of the agent and the corresponding *scanning* of the falling object. The final evaluation shows very distinct patterns, with the task becoming typically much more difficult when the objects are starting their descent over the agent's "head".

By allowing changes in the environment of the cognizing subject, such as morphing the falling objects between a circle and a diamond or starting from various heights and positions, Beer is able to define a set of equations which describe the correlation of all those involved parameters, which are the “state variables”: height of the object as environmental state variable, the horizontal position of the agent as a body state variable, and the output of single interneurons as neural state variables.

The state space of the interactions between those variables is defined as a steady-state horizontal velocity field for both circles and diamonds, as the map of all relevant values in snapshots of the movement of the falling objects.

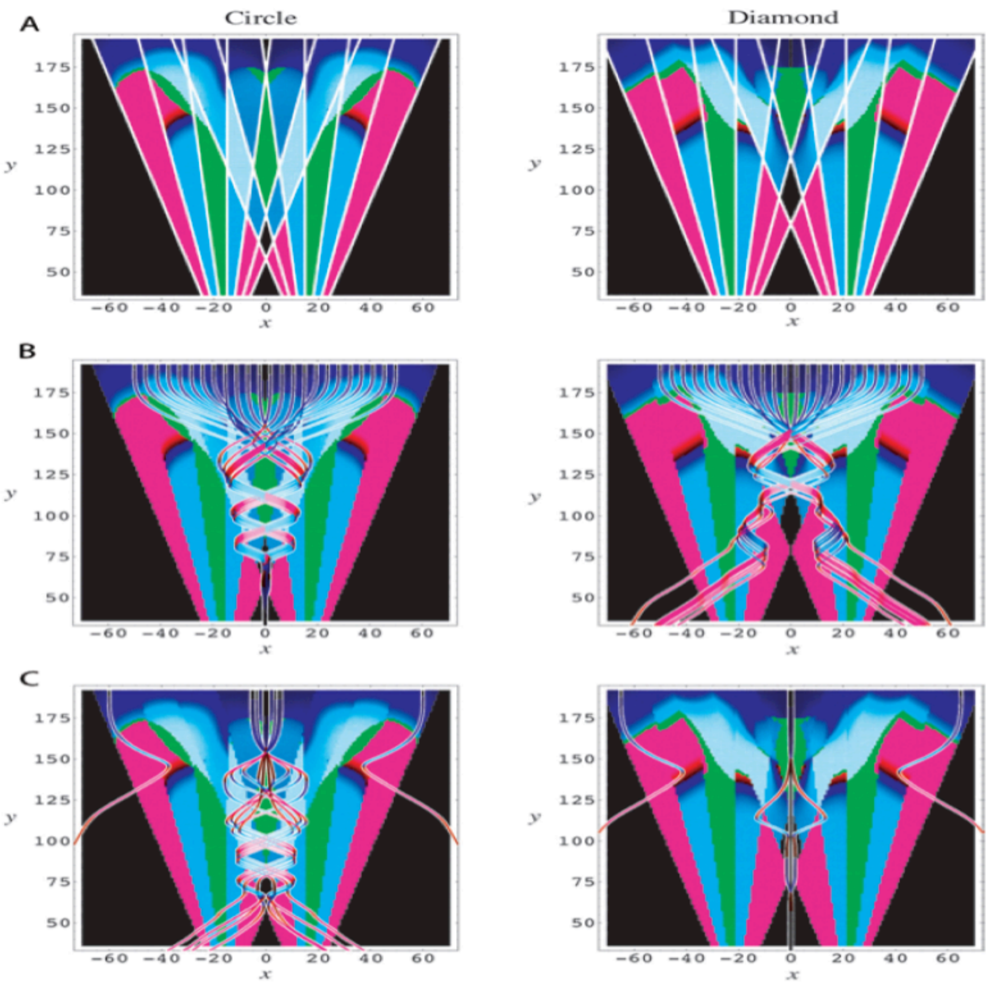

Figure 2: State-spaces for Randal Beer's robotic agent.
The differently coloured areas correspond to patterns of behavior and intensity of the artificial agent defined by a set of differential equations. From Beer 2003, p. 222

In this way, Beer is both describing and predicting the minimal cognitive task of categorical perception as embodied action in the environment. What could a state-space for the (alas, non-minimal) task of learning complex piano music look like?

D. The World Is Its Own Best Representation

One of the most easily graspable and convincing examples, providing empirical support for the dynamical hypothesis, is offered by the *subsumption architecture* by Rodney Brooks (1991): Mobile robots (mobots) achieve a satisfying navigation of their environments by replacing potential elaborate representations of those environments with layers of simple competing behaviors. Instead of the infinite computational power required for the representation of the world in all its dimensions, primitive robots demonstrate intelligent behavior through the exploration of affordances, which trigger proper responses. This behavioral overlayering is summarized under the term *subsumption architecture*. In such a creature, there is no precise dividing line between perception and cognition, or as Brooks puts it: *the world is its own best representation*.(Rowlands, 2011, p. 48), the creature is *using the world as its own model* (Brooks, 1991, p. 139, cited in Shapiro, 2011, p. 141).

Concluding this brief exposition of important empirical evidence for the replacement hypothesis, it is important to note five ideas, which differentiate embodied situated models from their computational counterparts:

1) Linear, algorithmic chains of cause and result, that is cognitive processes with defined stages, beginning-middle-end, input and output, are substituted by constant cycles of causal couplings, which capture the unique temporality and dynamicity of change in dynamical systems. Processing in real-time replaces the traditional abstraction.
2) This causal circle (rather than chain) stretches over the central nervous system, the body and the environment as coupled parameters.
3) Such descriptions evade the need for mental representability, since it is the interdependence of all involved variables which defines the outcomes.
4) Self-organisation and emergence are the key terms in describing final states, which are not the output of a linear process of cause and effect.
5) Such systems are described by non-linear differential equations, which unify

the multiplicity of phenomena and interactions in a given state-space under certain attractors and repellers.

In short: A dynamic system consists of parts that change in the course of time. Generally three steps are necessary for the description of a dynamic system, namely a) the identification of the elements or parameters that change over time b) the mapping of all possible states of the system which is designated as state-space and c) a mathematically defined rule of its evolution. Other central concepts include the idea of *emergence or self-organization* and the idea of *coupling of parameters*.

In what follows, we will review the merging of dynamical systems theory and Gibson's ecological psychology in what Anthony Chemero terms *radical embodied cognitive science* and we will argue that performance of complex piano scores can be better understood as a dynamic system. Our main contribution is the consideration of musical notation as a) *part* of a dynamic system and b) *dynamic*, transformable in and for itself, as opposed to the standard conception of notation as a "fixed in stone" container for the musical work.

3.4 Radical Embodied Cognitive Science

Anthony Chemero's radical embodied cognitive science elevates Shapiro's replacement hypothesis into the end-state of one out of two branches in the evolution of the theories of the mind – namely as the end-state of eliminativism versus representationalism. Surprisingly enough, through such re-formulation, radical embodied cognitive science finds itself standing *opposite* to the "usual" embodied cognitive science, which is rather seen as an offspring of computationalism. In that sense, radical embodied cognitive science is the direct successor of American naturalism and Gibson's ecological psychology, while

" ("normal") embodied cognitive science should be seen as a watering down of radical embodied cognitive science, and an attempt to combine a theory that is ultimately American naturalist and eliminativist in origin with the computational theory of mind." Chemero, p. 30

This constitutes a rather original statement, since the replacement hypothesis is usually viewed as some sort of anti-representationalist radicalization of computationalist embodied cognitive science.[295]

In what follows, we will review the cornerstones of radical embodied cognitive science beyond dynamic systems: The notion of direct perception; the ontological and epistemological claims, as they will applied in the embodied navigation of complex notation paradigm; and the definition and role of mental representations. Our goal is to show the possibility of a potentially complete outsourcing of the often mystified inner skills necessary for playing music, even the most complex of it, in the environment; and to show the contingency of mental representations in the act of doing so.

A.Direct Perception

The term *direct perception* is introduced by James J. Gibson as one of the three principles of his ecological psychology, outlined in his opus magnum *The ecological approach to visual perception* and summarized by Anthony Chemero (p. 98) as follows.

According to Anthony Chemero, ecological psychology commits to exactly three principles: Perception is *direct*; perception is for *action*; and perception is of *affordances*.

The first principle, which forms also the basis of my embodied navigation paradigm, claims that perception is direct. Direct perception is defined as non-inferential

[295] Interestingly enough, the very term “radical embodied cognitive science” originates in one of the “fuzzy”, according to Chemero, thinkers, who stand in an ambiguous position against computationalism, while actually embracing ideas of embodied cognition: Andy Clark, who defines it as follows:
“Thesis of Radical Embodied Cognition : Structured, symbolic, representational, and computational views of cognition are mistaken. Embodied cognition is best studied by means of noncomputational and nonrepresentational ideas and explanatory schemes, involving, e.g., the tools of Dynamical Systems theory.” (Clark 1997, 148; 2001, 129)

perception, that is as perception which does not necessitate mental computations on sensory input representations.

The second principle argues that perception is closely coupled to action in a bidirectional way, meaning both that perception guides action and that action guides perception and cognition.

The third principle introduces the concept of *affordances*, as relations between objective properties of the environment affording actions by organisms with corresponding abilities.

Thus, the ecological claim from a radical embodied cognitive view can be articulated as follows:

Organisms perceive action-oriented information in the environment and act accordingly, without the need for mental representations. Perception and action are closely coupled and can be modeled as a dynamic system.

The direct perception of music notation information becomes increasingly attractive as a model, given exactly those three principles: The avoidance of mental computations or analytic processes, the guidance of musical performance as action and the definition of notation as a set of affordances, next to the biomechanical constraints of bodies and instruments. Such a model could provide an ecological explanation of several skills, including ‘phenomenal’ sight-reading.

A difficulty raised by this anti-representational stance is of course the fact, that notational information is symbolic, that is it by default represents. In that sense, it differs by what Gibson dubs environmental information, such as the ambient optic array. The problem can be superseded by the consideration of: the material properties of notation; Rowlands’s theory of visuographic means of memory storage, after Luria and Vygotsky; established automatisms between symbols and instrumental properties, which turn notation into an extension of the instrument; the use of conceptual metaphors and image schemata. An extensive discussion of this aporia has been provided in the chapter “conceptualization”.

B. Epistemological And Ontological Claims Of Radical Embodied Cognitive Science

After Chemero's claims about cognition and cognitive systems, we articulate the following claims for musical performance from the point of view of radical embodied cognitive science:

The Ontological Claim for Musical Performance:
Musical performance is the complex dynamic interaction between agents, media and acoustical spaces. Musical performance does not in its basis necessitate human mental representations.

The Epistemological Claim for Musical Performance:
Musical Performance is better explained as a complex dynamic system which does not necessarily involve mental representations.

There is obviously a major difference between the two claims: The ontological (or metaphysical) claim is a philosophical hypothesis about the nature of cognition (or in our case musical performance). The epistemological one is a scientific hypothesis, about how we ought to research performance. The two claims are related bidirectionally: Proving the epistemological claim would be an indicator about the truth of the metaphysical one, and, inversely, if indeed the nature of musical performance is not involving representations, then there certainly must be some way to explain musical performance without them.

Now, the scope of this dissertation is to provide support for the epistemological claim, as applied to a very specific case of performance, which does have an interesting twist, as already explored in the conceptualization section of embodied cognition: The use of symbolic notation, which constitutes in itself external, not mental, representation, as part of the media available to the performance agent. We will not deal with questions of disembodied artificial agents.

So, the epistemological claim made here is reduced to the following:

The performance of complex notated piano music is better explained as a complex dynamic system not necessarily involving mental representations (radical embodied cognitive science). The coupled parts of the system include: human agents, media and acoustic spaces. The human agents in the current performer-specific study include the pianist as embodied mind, but could in principle also include composers and listeners; the media include the piano with all possible technological extensions as reviewed in the third part, and the symbolic notation, as reviewed in the current. Depending on the embodied axis involved (intra- or inter-complexity), the symbolic notation carries a variety of representations, which stand as proxies for almost all the elements of the system.

Please note the adverb *necessarily* : The above epistemological claim does not state that piano performance does not contingently produce or involve mental representations, but that it can be described and effectuated without them.

Let’s take now a closer look on some of the notions described above, starting with the following: If we are to propose a model of performative interaction with musical scores without the need for mental representations, then what exactly are those?

C. Mental Representations

This chapter has two goals: First, I will revise some theories of mental representation after Chemero’s homonymous chapter in his *Radical Embodied Cognitive Science* (Chemero 2009). Then, I will specify the notion of mental representation as it will be used in the context of embodied navigation, and in particular the radical claim that performance of complex notated piano music is in principle possible without mental representations. This does not certainly mean that mental representations / internalization do not arise during performance, it just means that they are not a necessary condition for it.

Chemero distinguishes between three types of theories of mental representation. His main criterion is the relationship between a mental representation and its target, that is the represented environmental element, in the context of dynamic systems. Each theory is simulated by a corresponding system of coupled oscillators.

Chemero describes three potential relationships between a representation and its target:

a) *Constant causality*, when both are present in the system and the target is causing the representation; after Brian Cantwell Smith (1996)[296], this is also defined as *effective tracking*.

b) *Decouplability*, when a representation can perform a function in a system even in the case of a short-term absence of the target; after Smith, this is the so-called *non-effective tracking*, in its weak version.

c) *Absence*, whereby thee target of the representation can be totally absent from the system, coinciding with the situation which Smith terms *registration*, or a strong version of decouplability between representation and its target.

A few examples to make these distinctions clear:

In the case of constant causality a.k.a. effective tracking, the agent-producer of mental representations is in continuous uninterrupted causal coupling with the target of the representation. Chemero gives an example after Caldwell:

"We can see effective tracking in the shopworn example of a frog tracking a passing fly. In terms of the physics of the situation, Smith points out, what we have is a continuously moving column of disturbance, beginning at the fly and ending at the frog. This column-shaped disturbance is just one thing, and is not separable into frog, fly, and intervening atmosphere, at least not in terms of physics." (Chemero, p. 56)

In the case of strong decouplability, or non-effective tracking, it is possible that the target which is causing the representation becomes temporarily unavailable to the representing agent:

"The frog, that is, must be able to continue to track the fly even when the light reflected from it is (temporarily) occluded." (Chemero, p.57)

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[296] Brian Cantwell Smith, *On the Origin of Objects*, Cambridge, Mass.: MIT Press, 1996

Registration finally describes a

“a stable, disconnectable internal state, one that can maintain its status as being about a particular target, even when that target is distant in space and time, and can then be reapplied to the target later.” (Chemero, p.58)

Before we see how can those three classes of representation be materialized through dynamic systems, namely coupled oscillators, it is easy to see how do these types of representation-target relationship apply in the system pianist-piano-score, and what corresponding types of performance do they describe:

a) Causal coupling describes a performance whereby both the instrument and the musical score are constantly available to the pianist, who produces representations on the fly, during the act of performance. This is the case in, say, sight-reading of an experienced player.

b) Weak decouplability would describe the situation, whereby the pianist is momentarily decoupled from the piano and / or the score, but still keeping the causal contact with them almost intact. For example, this could be the case in a conducted ensemble situation, whereby the dynamic system involves visual cues by the conductor and the co-players, so that the pianist needs to constantly switch away from the score and the keyboard. Or to the standard solo situation, where the players eyes oscillate between the score and the keyboard.

c) Registration or strong decouplability is the situation, where the pianist performs without the score and / or the instrument. This could be the case of, for example, performing by memory, mental practicing away from the instrument or performing air-gestures. In this case, both the score and the instrument are internally registered as mental states and can be recalled at will.

Chemero recognizes the first type of definition of what representation is, that is : contentful non-decouplable internal states (p. 54), as the cornerstone of many traditional theories of representation, such as Ruth Millikan's *teleological theory* of representation (Millikan, 1984).[297]

These types of representation can according to Chemero be implemented by the same oscillator model: the *Fitzhugh-Nagumo simulated neuron*, a type known as *relaxation oscillator*:

"Fitzhugh-Nagumo oscillators are a type of relaxation oscillator. When presented with an input pattern consisting of voltage pulses, a Fitzhugh-Nagumo oscillator will synchronize its firing with the pulses. If these pulses are rhythmic, the oscillator synchronizes and ''beats along'' by emitting its own pulses in tandem. A connected group of these oscillators can couple with rhythmic input patterns in ways that mirror the metrical structure of the patterns. That is, a network can distinguish weak beats from strong beats and can even represent rests using appropriate inhibitory connections. But when the driving stimulus is removed from a network, the oscillators decouple immediately and return to a quiescent state. In this way the oscillators are unable to couple with a target that is absent. In fact, they simply respond to whatever they are in constant causal contact with. That is, they respond at time t only to the input presented to them at time t." (Chemero, p. 54)

This oscillator can drive behaviour in the case where the external stimulus is constantly present and in this sense becomes a model for the first type of representations mentioned above.

This class of oscillators contrasts to *intrinsic dynamics* or *momentum oscillators*, inspired by physical systems, for example two pendulums in synch. Those oscillators don't synchronize well to a changing external signal, because of the momentum of their mass, thus they have intrinsic dynamics, deployed for cognitive tasks with a motor control component.[298]

The second and third types of representations originate in John Haugeland's "Representational Genera" (1991)[299], summarized by Andy Clark (1997) as follows :

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[297] Ruth G. Millikan, *Language, Thought, and Other Biological Categories*, Cambridge, Mass.: MIT Press. 1984

[298] We will also see these physical oscillators in our review of entrainment and sensorimotor learning.

[299] John Haugeland, Representational genera. In *Philosophy and Connectionist Theory*, ed. W. Ramsey, S. Stich, and D. Rumelhart. Hillsdale, N.J.: Erlbaum, 1991

“A system counts as representation using just in case: It must coordinate its behaviors with environmental features that are not always ‘‘reliably present to the system.’’ It copes with such cases by having something else ‘‘stand in’’ for those features and guide behavior. The ‘‘something else’’ is part of a more general representational scheme that allows the standing in to occur systematically and allows for a variety of related states.”(Clark 1997, 144)

In other words, a representation is only worth called that, when it can stand-in or replace the external stimulus, when it can be a surrogate of the stimulus.

Thus arises the strong decouplability in Smith’s *theory of registration*, whereby essentially representations are identified with long-term detailed memories, while anything else (effective and non-effective tracking) are mere *presentations*. According to Chemero, the case for strong decouplability can only be exhibited with *adaptive oscillators*, a hybrid between relaxation and physical ones:

“Much more complex adaptive oscillators are required to have representations that are strongly decouplable, to be able to represent absent features of the environment. Adaptive oscillators are hybrid oscillators that can beat along in real time to rhythmic stimuli, a task akin to tapping one’s foot along with music. In fact, adaptive oscillators have been shown to be able to beat along with noisy rhythmic signals, such as one finds with real human drummers and in the rhythms of human speech (McCauley 1996). They succeed at this task by taking desirable properties from both mass-spring oscillators and relaxation oscillators.” (Chemero, p. 58)

The weak reading of Haugeland’s thesis brings as to the second type of representations, as in for example Rick Grush’s *emulation theory of representation*[300]. Emulators are systems of prediction for the future states of the system, being updated by constant causal coupling, and in that sense a “forward model” of behavior – look at the analogy to sensorimotor learning models by Leman 2016. Andy Clark and Patricia Churchland[301] embrace the emulation theory, due to basic evidence about the ubiquity of such emulators in the central nervous system. According to Chemero though, emulators can still be simulated by relaxation neurons with the introduction of time-delays, which account for momentary decouplability and are not in that sense much different from traditional theories of representation.

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[300] Rick Grush, The emulation theory of representation: Motor control, imagery, and perception. *Behavioral and Brain Sciences*, 27, 377–442, 2004

[301] Patricia Churchland*, A Neurocomputational Perspective*. Cambridge, Mass.: MIT Press, 1989

Where does this overview of mental representation theories leave us in relation to the model of embodied navigation of complex notation? We will make a claim towards embodied and radically embodied theories of cognition. I will assume the constant causal coupling of the agent (pianist) to the environment (piano, musical score), whereby the instrument and the notation have the potential to cause momentarily or strongly decouplable mental representations (in weak embodied versions), do not though necessarily do so (in strong versions). Cases of non-effective tracking and registration will not be dealt with in our model. Actually, it is for this reason that the best candidate for exploring an embodied model with constant causal representations is: sight-reading.

My vehicle for the avoidance of the necessity of mental representation is the constant annotation or processing of music notation in real time, which is external, dynamic, real time and effectuated by physical movement, that is the movements of the pianist on the piano. The very selection of extremely complex notation is also a strategic choice: While a simple monophonic melody or polyphony or melody plus accompaniment situation can be shown to be easily mentally representable (look as an example Leimer-Gieseking's description), the sort of notations which will be looking at are simply impossible (for individuals with non-phenomenal memory) to do so.

3.5 Conclusions : Concepts For The Embodied Navigation Of Complex Notation

On the basis of radical embodied cognitive science, as well as the strands of embodied cognition summarized under the notions of *constitution*, *conceptualization* and *replacement*, we have made a series of assertions:

a) Mental representations are not necessary conditions for learning a complex piano piece, if we reformulate this learning as interaction, or as embodied navigation of the notation.
b) Intentionality is shaped dynamically on the fly by sensory input, including the score itself. After an initial spark of intentionality, a dynamic dance takes over,

with “islands” of intentionality emerging and being submerged again. Such model distances itself from the concept of a performer’s intention reproducing or aligning to the composers template of intentions that notation is assumed to be.

c) Symbolic notation is part of a dynamic system, which involves the performer’s body, the instrument and the notation (as well as other instrumentalists, instruments and parts in the case of collective music making or other systems, such as the interactive systems we will be exploring in part three).
d) Symbolic notation is an environmental structure, which for the performer features affordances, that is action-oriented information.
e) This structure is not fixed, as the material physical score is, but rather dynamically changes through the feedback of our actions.
f) This dynamic system is non-linear, which means that the interactions of its parts are described by non-linear equations, which show how the relationships between the notation, the player and the instrument will change over time.
g) In a certain sense, it is not only the performer who is playing an instrument and a notation, but also the notation is playing the performer by generating the actions that will render the acoustic result, the instrument is playing the performer through the necessary adjustments and specific proprioceptive information it invites, the acoustic space even more so, the instrument plays the notation in the sense that it might transform say unrealistic requirements or explore unintentional by the composer aspects, and so on.

The main mode of learning then is exploration and manipulation of affordances in an environment which is not exclusively physical or mental, but invariably stretches both, dissolving their distinction.

The overview of the field of embodied cognition attempted above has hopefully provided the reader with a concise group of theories, which are central in a definition of cognition beyond the computationalist model of cognition as information processing based on rules and representations. This repository of concepts and theories provides also the physical link to the exposition of the theory, or more accurately, the three versions of the theory of embodied navigation of complex notation.

Let us recapitulate the directions reviewed above as follows:

1. The efficiency claim in relation to constitution: The hypothesis, that cognition is partly constituted of manipulations of external information-bearing structures in the sense of 4E cognition (Rowlands) offers a powerful tool for the simplification of complex tasks, such as the learning of complex piano music. “In performing any given task, the more information the organism can process externally, the less information it has to process internally” (Rowlands 1999:30), which means that extreme cognitive tasks of internalization / memorization, as for example advocated by Leimer-Gieseking, can be off-loaded to the environmental structures such as the gravity, the body, the instrument and most notably for this dissertation: the musical score itself. Similar strategies are explored by Andy Clark, in a form of functionalism or smart re-designing of the environment, which allows for a Gibsonian “open-channel” or direct perception. Despite their heritage from Gibson, both Rowlands and Clark are sceptical about the incompatibility of such approaches with computationalism. We would further claim that two versions of the argument are in place: In the ontic hard version, the claim that cognitive processes consist in actions would equal versions of embodied and extended cognition, which are claiming that the neural component of cognition is shaped by the extra-neural manipulations. In the soft version, the claim that cognitive processes simply depend on environmental scaffoldings for more efficiency would equal the case for embedded or enactive cognition.
2. The performer-specific discourse claim in relation to conceptualization: Metaphorical thinking and grounded cognition resolve the emerging aporia: How can externalism be applied to an external albeit symbolic structure such as the musical score, which already represents other external structures. Image schemas and metaphorical extension are only two of the devices that have been shown to ground language in embodied experience, and there is no reason why musical notation should be an exception to this line of thinking. Moreover, Rowlands has extensively shown how memory retrieval through visuographic means equals an actual augmentation of working external memory with a simultaneous inhibition of the internalization needs. Most

importantly, the question of conceptualization reveals the possibility for the shaping of a performer-specific discourse founded on embodied experience with the instrument and the score, as opposed to the composer-oriented analytical language, which typically characterizes performers' analytical attempts and descriptions of their performance.

3. Dynamical systems theory provides powerful tools for the modeling of cognition as a dynamic dance between neural, bodily and external components, even without resort to mental representations. Such dynamicity is better captured by the mathematical tools of dynamic systems theories, the mapping of complex state-spaces, trajectories, attractors and repellers, control parameters and variables. The structuring of the dynamic performative system constitutes a challenging task, since it involves already a representational structure such as notation, so how can we claim that cognition is without representations? We can achieve that through the actual transformation of *notation itself* via movement, thus the embodied navigation paradigm.
4. All versions of embodied cognition acknowledge their owing to the Gibsonian psychology and the tripartite schema: Perception is direct; perception is for action; perception is for affordances. The ubiquity of this grounding lends to the suggested model the title of embodied navigation of a complex score, which is conceived as a series of affordances.

In what follows, we will propose three versions of the embodied navigation paradigm based on these four basic ideas, as well as three corresponding types of score annotation:

1. The soft version corresponds to the direction of embedded cognition and is satisfied with the acknowledgement of the efficiency claim: that effort can be off-loaded to external structures, by using the instrument and the body ergonomically and by annotating the score. Such annotational practices have been commonplace between performers in all times and all repertoires and are fully compatible with the computational view of the mind.

2. The hard version of embodied navigation assumes that the very learning and performing trajectory is constantly shaped by the use of external-information

bearing structures and that the concepts a performer develops are based not only on their physical experience of playing, but also on the physical experience of manipulating those structures. Embodied navigation is represented in a fully-blown restructuring of musical notation, as a multilayered tablature of things that one can do with the score based on their bodily dispositions, that is based on the notion of affordances. Such version does not necessarily do away with mental representability, but does acknowledge that the latter is primarily action-oriented.

3. In the radical version, the interaction between the internal and external elements, and most importantly with music notation, is assumed to evade the need for mental representability and could be described through the terminology of dynamic systems. In fact, such a model will be materialized in the third chapter, through the representation of interactive dynamics with the use of multimodal interactive systems, which minimize the need for mental representation by maximizing direct perception.

In the following Figures (3 to 6), you may see a juxtaposition of the three annotation types & corresponding versions of embodied navigation: The traditional form of score annotation, corresponding to the soft version of interaction with notation, by way of Yehudi Menuhin's annotated first page of J.S. Bach's Violin Sonata Nr. 2 (Figure 3); as opposed to examples of a multilayered tablature for complex music (Figure 4, hard version of navigation) and an interactive tablature based on gesture capture technologies (Figures 5, 6, radical version). These tablatures form the core of the next chapters and will be presented in depth. Their indicative presentation here serves the visualization of the distinction between the three proposed versions of embodied navigation of complex notation.

Figure 3: Yehudi Menuhin's annotation of J.S Bach's violin sonata nr. 2

a soft version of the embodied navigation paradigm

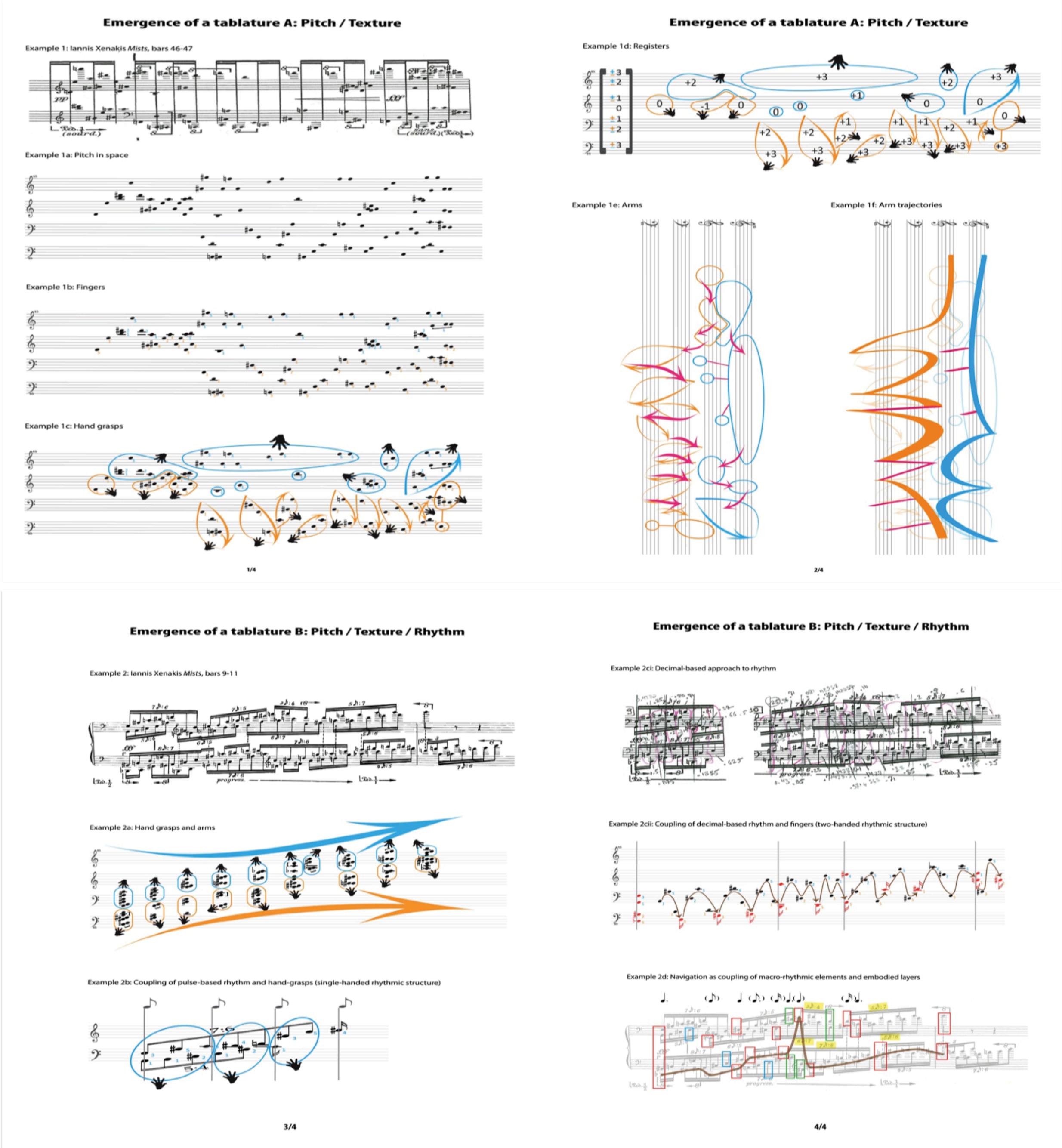
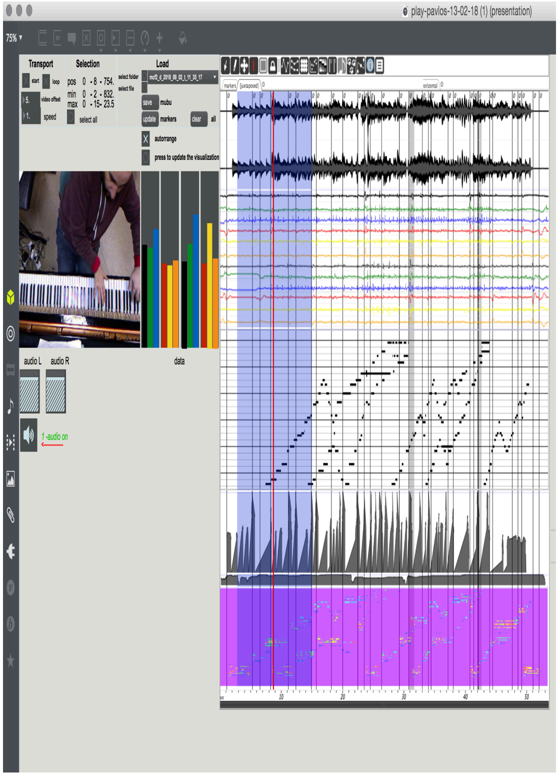
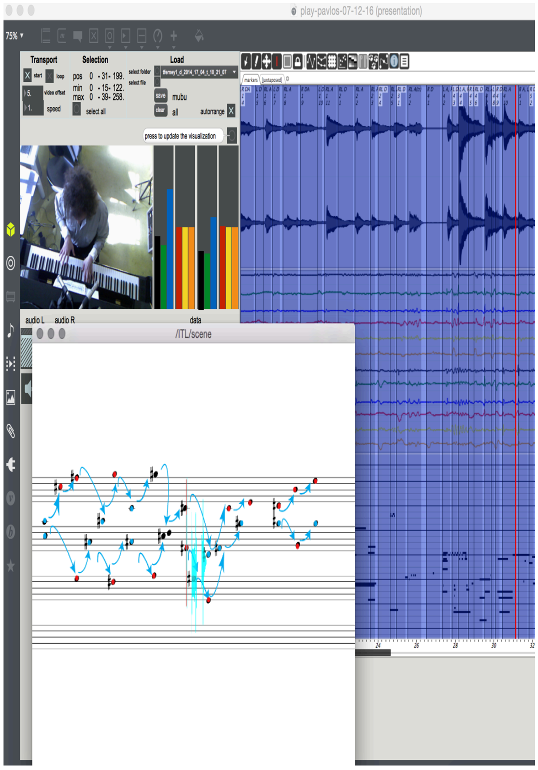


Figure 4: Multilayered tablatures and annotations on Iannis Xenakis' *Mists*

a hard version of the embodied navigation paradigm through the representation of notational affordances





Radical versions of embodied navigation through the transformation of notation into an interactive multimodal system:

Figure 5 (left): *MuBu* multimodal performance data

Figure 6 (right): *GesTcom* (Gesture Cutting through Textual Complexity) renotation and following

In comparison to the traditional UTI model, which so clearly corresponds to the algorithmic arrangement of standard cognitive science, SCS, all three versions of embodied cognition seem to allow for non-linear emergent properties in the learning process, with or without representations.

4. Embodied Navigation Of Complex Notation

The notion of embodied navigation has been developed as an alternative to internalization, manifested in the UTI paradigm of musical notation. In a nutshell, embodied navigation embraces a radical anti-representationalist dynamical stance, according to which cognition can be described as a dynamical system without the need for mental representations. It can however embrace softer versions of embodied cognition, such as embedded, embodied and extended cognition, as shown above with the differentiation of three versions of the paradigm of embodied navigation.

In our case study of complex piano performance, the radical version means that the "understanding" of a musical score by an experienced performer is direct, action-oriented and embodied understanding of affordances, without the need for internalization, memorization and mental computations. The hard version assumes a milder position, accentuating the dynamic interplay between internalization and action, while the soft version simply acknowledges the ergonomic / heuristic use of scores and instruments for what is essentially a mental cognitive task. All three versions embrace the program of a performer-specific conceptualization, based on the performer's embodied experience with musical scores and musical instruments.

At a first stage, the paradigm of embodied navigation takes the form of an external processing of the musical score through gesture and physical movement. At a second stage, the paradigm of embodied navigation manifests in or materializes as the use of customized interactive systems for learning and performance. Those systems externalize or simulate the implicit interaction dynamics of entrainment, sensorimotor prediction and expressibe alignment through multimodal feedback (Leman, 2016).

4.1 Definition of Embodied Navigation

Now let us provide a provisional definition of the embodied navigation of complex notation, emerging out of the above-mentioned epistemological claim, and briefly clarify some of the embodied cognition terminology introduced here. We do so in the form of the following five propositions:

A. Performance As Navigation In A Non-Linear State-Space Of Notational Affordances

Performance of a musical score is defined as embodied navigation in a non-linear state-space of notational affordances.

“Performance” here refers to the longitudinal learning & performing trajectory, which ranges from the first exploratory contact (‘sight-reading’) with the score up to the multiple interpretations of the musical score on stage. In collapsing “learning”, “performance” and “interpretation” under the term “navigation”, I attempt to accentuate the dynamic character of both embodied learning as performance and performance as diachronic decision-making that shapes learning.

“Affordances” refers to the notion introduced by James Gibson in his ecological approach to visual perception and further elaborated by a number of embodied cognition advocates. It signifies relations between properties of the environment and abilities of the agent, in our case properties of the score and the instrument in relation to abilities of the pianist.

A “state-space” is a term originating in dynamic systems theory and designating the mapping of all possible states of a system, which changes over time, ususally through mathematical modelling. While we will not model this state-space mathematically, we will argue that the state-space of the system body-instrument-notation is representable and navigable through other means, namely multilayered tablatures (second part) and interactive tools (third part). We coin accordingly the term “score-space” as representable by the aforementioned tablatures.

A “non-linear space” designates complex, non-hierarchical relationships between the interacting parts of a dynamic system. In this sense, it is argued that the interaction between the pianist the score and the instrument is not linearly constructed, guided or represented; but should be allowing for self-organized feedback between the score’s affordances and transformations, the agent’s actions and the instrument’s affordances. The emergent property is musical performance or interpretation of a text as interaction of the aforementioned parameters.

B. Affordances As Notations And Annotations

Affordances are representable both in the original form of the score as well as annotations of the score. Annotation enables the direct perception of affordances. Those annotations are further developed into a multilayered tablature and eventually materialized in the form of interactive systems. A multilayered tablature consists of layered representations of the notation's affordances, corresponding to embodied layers. Embodied layers do not designate parts of the body, actions or musical groupings, but rather a coupling of all that in the sense of co-articulation, as will be shortly defined. Do these annotations constitute computations? This is a good question. In fact, they are conceived as the Andy Clark and Mark Rowlands intelligent strategies of shaping the environment, which shapes the mind. The question of their mental representability and computability remains also open: They can contingently be mentally represented and thus computed, as will be shown throughout this dissertation. But this is not necessary, only contingent.

C. Touching Notation

In practice, the performer navigates the several embodied layers of the score and manipulates notation, as if it had tangible properties.The metaphor "as if it had tangible properties" hints towards the fact, that notation and instruments share common affordances and eventually notation can be viewed as an extension of the instrument. This view will be elaborated in detail in the third part of the dissertation, in the context of interactive systems theories, such as Atau Tanaka's definition of *instruments as open-ended systems*. This metaphor also hints towards a performer-specific reconfiguration or appropriation of the score, and towards the development of a performer-specific discourse and analytical language based on embodied interaction with instruments. The latter constitutes a necessity, as also stressed by Lakoff's and co. cognitive linguistics. Eventually, this metaphor will be materialized in the notion of notation as a TUI, that is a *Tangible User Interface*.

D. Mediation Between Symbolic Signification, Action-Oriented Descriptors And Physical Energy

This navigation constitutes an example of mediation between symbolic signification, action-oriented descriptors and actual physical energy. Mediation here refers to the notion elaborated by Marc Leman in his book *Embodied Music Cognition*. Mediators are transformers of physical energy into meaning and vice versa, essentially the human body and the instrument as an extension of the former. Mediation refers also to the relation between performers and listeners, effectuated according to Leman via corporeal articulations. The current dissertation aims, among other things, to the extension of this theory into the relation between composer and performers, that is towards a composer-performer communication via corporeal articulations.

Symbolic signification refers to the musical score, which acts both as an environmental structure carrying information about notation and as a proxy for all the other parts of the system, at least in traditional theoretical formulations of what a work is before the so-called performative turn in musicology.

Action-oriented descriptions is a notion by Andy Clark, equivalent to the *pushmi-pullmi* representations by Millikan[302]. It designates the mental representability of affordances.

Actual physical energy refers to both audio energy and the energy of physical movement.

E. Pianistic Gesture As Interface, Notation As Part Of A Dynamic System

Pianistic gesture acts as an interface for external notation processing and notation itself forms part of the dynamic system “body-instrument-notation”.The notion of the interface points again towards the score functioning as an extension of the musical instrument.

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[302] Millikan, R. (1995). « Pushmi-pullyu Representations ». In *Philosophical Perspectives*, 9, ed. J. Tomberlin, 185–200. Atascadero, Calif.: Ridgeview.

External notation processing is defined in contrast to internal notation processing, that is to mental representations of notation through technique.This processing becomes thus our first step towards a model of embodied navigation.

4.2 A Hands-on Example of Embodied Navigation

Let's take a look the at the following example by Iannis Xenakis's *Mists*, a solo piano piece from 1980. *Mists* will also form an extensive case study. For the moment, we use it only as a hands-on example for the clarification of concepts and terminology, which make the case for *embodied navigation* as a paradigm appropriate for the performative interaction with complex notation. Even further, the case is made for the epistemological claim: that complex performance can be explained and modeled without resort to mental representations, but rather as interaction between the pianist, the score and the instrument.

In Figure 7, you may see the original notation from Iannis Xenakis's *Mists,* bars 45 and 46. The notation represents what Xenakis calls a *stochastic cloud*, in itself an attempt of musically implementing movements similar to those of gas molecules, known as *Brownian movements*. It is a musical situation, whereby traditional notions that would otherwise allow for easy mental representability, fall short: There are no melodies, no harmonies, no rhythm other than a grid of sixteenth notes that allows for the relative placement of noteheads in the correct place, no phrases and morphological entities. What predominates is numerous stemless noteheads, without evident tonal relationship between them, superimposed on a grid of sixteenth notes. The current passage is only indicative of a rather extended musical situation, which in the Salabert edition goes on for 7 large pages. Similar writing is characteristic of Xenakis's middle period. With such a passage extended in 7 A3+ pages, it is safe to assume that most individuals would not attempt to memorize it before playing it, but would rather explore the passage on the instrument and with their hands.

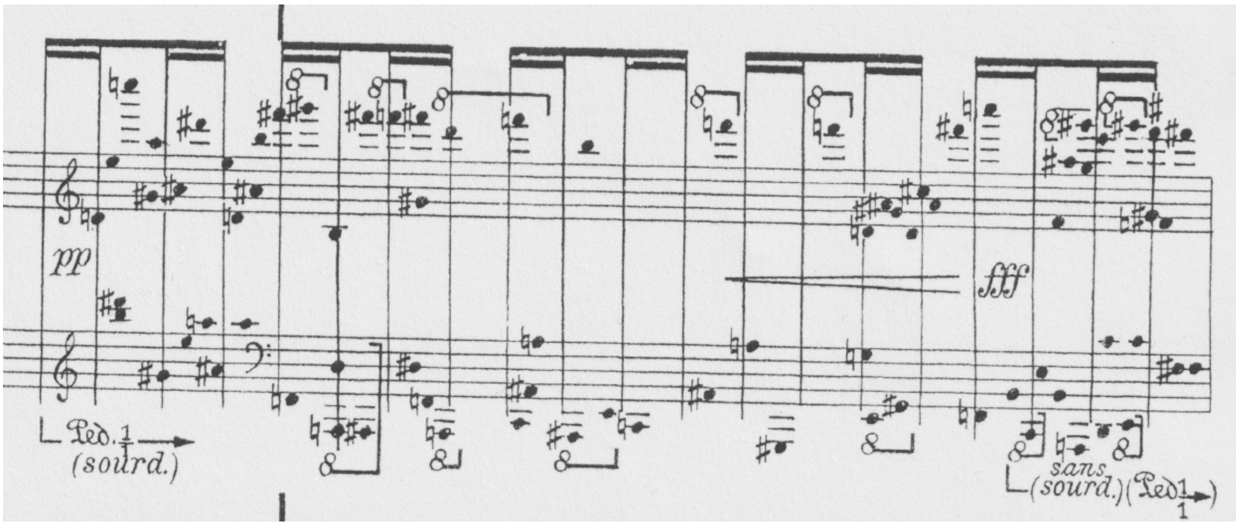

Figure 7: A stochastic cloud from Xenakis' *Mists*, bars 45-46

The concept of embodied navigation is implemented as follows: I started exploring the passage in an embodied and situated way, that is with my hands on the piano and with the musical score. My personal perception of the passage was not one of isolated individual noteheads as representations of musical pitch, that is: I do not mentally imagine or hear the pitch represented in advance. Why should I do so, since the pitch is actually layed out in front of me, in the form of piano keys connected to the sound source, piano strings? The situatedness of this notation, that is the one-to-one semantic relationship between noteheads and piano keys, given my well-developped reading skills and the resulting effortless correlation between a note on the staff and its positioning on the keyboard, allows me to *directly perceive* this notation as a set of gestural *affordances*. Those are possibilities for action in relation to the real environment of the piano keyboard and to the symbolic environment of the musical score. The symbolic environment stands as a proxy for the real environment. Given the presence of both the instrument and the notes, this action-before-perception, which drives further action, equals direct perception of gestural affordances, without the necessity of mental representation. The external representation of those perceived affordances on the music notation could yield however the following results, making the musical score even more exploitable as a resource of environmental information for further action.

Firstly, I have rewritten the passage in four staves, including only the dominant compositional parameter, which is pitch information (Figure 8). This transformation of the score aims at the avoidance of octave transposition signs, which muddle the direct perception of movement of pitch in notational space and, equivalently, movement of hands in the real keyboard space. In other words, octave transposition signs constitute an unnecessary computation, which I mentally need to implement while reading[303]. I want to get rid of that extra computation, by transforming the notation accordingly. Fast forwarding a bit to the next part, this representation in four staves is also much closer to a MIDI piano-roll representations. It will shortly be shown that this similarity could be useful for the implementation of the embodied navigation concept through interactive systems.

So, my new representation in four staves looks as follows, in Figure 8:

Figure 8: Handwritten reduced proportional representation in four staves

One could argue that this sort of representation is an accurate one-to-one representation of the layout of the keys on the piano keyboard. In other words, the transformation of the notation into four staves has revealed its affordance to be layed out on a piano keyboard, inviting my corresponding ability to play it bimanually, that is it has revealed its "keyboard-ability".

[303] Of course, in other cases, octave transposition signs might actually serve the direct perception of gestural affordances of the notation. There is no rule.

One could get even closer to this layout, by rotating the representation by 90 degrees clockwise, so that the pitch axis is now horizontal and the time axis is vertical. In this way, the pitch axis corresponds one-to-one to the pianist's perspective of the keyboard: Higher notes are laid out to the right hand and lower notes are laid out to the left hand. Thus even heightened "keyboard-ability".

Imagine now a situation, whereby each key I am playing assigns a number to the corresponding note, depending on the finger and the hand which I am using. This would result in a further transformation of the score, or annotation, as follows in Figure 9, not very differently from traditional fingering indications. In this representation, we have maximized the affordance for fingers and hand distribution ("finger-ability" and "grasp-ability", if we want to take this simplistic neologism further). Ordinal numbers one to five indicate fingering, while the hand distribution is indicated by color, blue and yellow for right and left hands respectively.

Figure 9: Reduced proportional representation in four staves and fingering: Finger-layer of the notation

The human performing mechanism for playing the piano is based on several layers of co-articulated action and several interdependent muscular groups, as will be shown in detail later. The *phenomenon of coarticulation* allows us to further transform the notation, by representing affordances about the graspability of certain groups of notes. We may also include the extension of grasp-ability in groups which cannot be grasped simultaneously as chords. Such groups still retain the fingering succession one to five, thus falling under a *hyper – grasp,* with an ambitus greater than the individual hand span. This hyper-grasp is physically enabled by the upper-arm participation, which effortlessly transposes the hand, as shown in Figure 10:

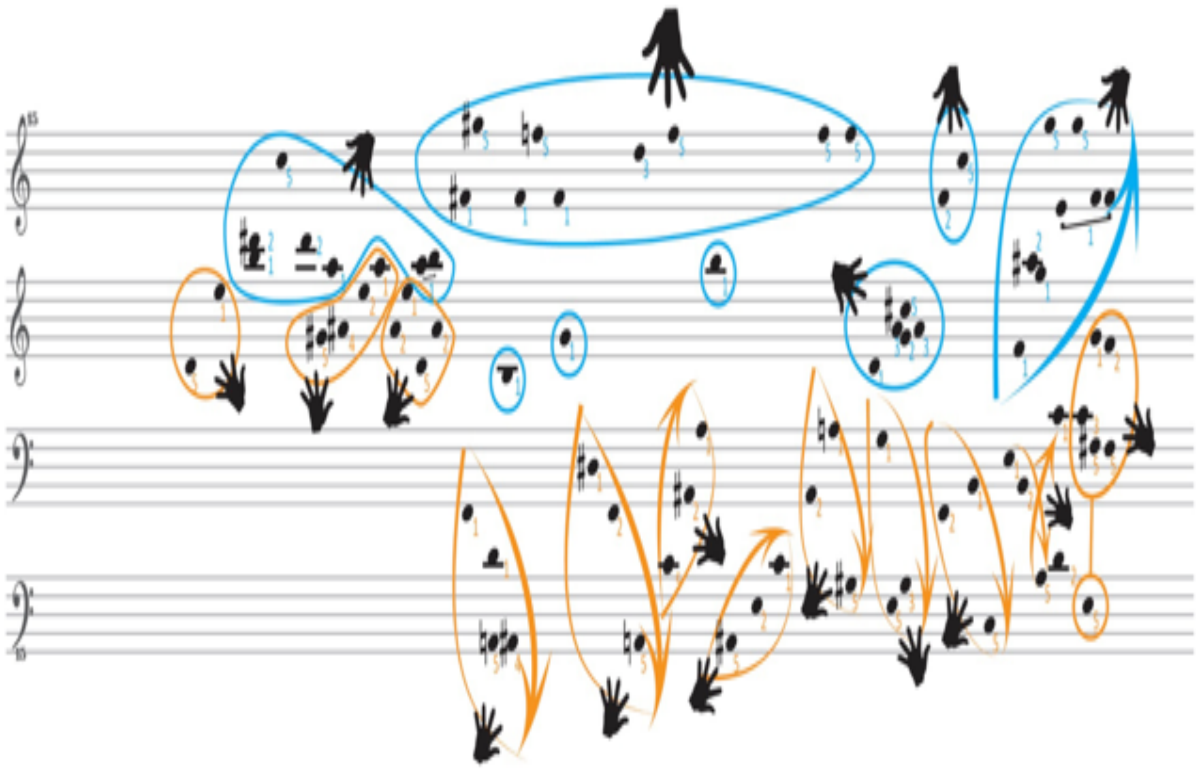

Figure 10: Reduced proportional representation in four staves and handgrasps: Grasp-layer of the notation

Closed groups in the two upper staves indicate handgrasps; closed groups with an arrow on the side in the two bottom staves indicate hyper-grasps. Individual notes in circles are “edges”, and require a rapid leap in order to be played.

This hyper-grasp entity takes us away from the finger and the grasp towards the domain of arm movements, which I depict as follows: First, by removing pitch information altogether and adding the movements that interconnect grasps in the form of arrows (Figure 11); and then, by getting rid of the grasp groups themselves, thus resulting in two linear trajectories, one for each hand (Figure 12).

Please note that this is the affordance, which we would neologize as “arm-ability” of the passage in question. Apart from the arrows that represent arm movement along the keyboard, I have also included notes that “stick out” of the linear trajectories, essentially notes that require very fast leaps and interrupt the otherwise linear trajectory of a single hand. Those notes are represented through the pink beams in Figure 12. The arm trajectories are indicated with yellow and blue for the left and right hands respectively.

Please note also that in the last figure, another feature or layer becomes directly visible and accecible to direct perception, namely the relationship between the two hands, which can
be used to further infer and represent information about body position. Thus, in the example above, it becomes clear that both hands remain in their most ergonomic areas of activity on the keyboard, without the need for hand crossings or for extreme position of both hands, for example both hands playing in the lowest or highest register at the same time, which would necessitate unbalanced body positions.

Resuming: I have depicted in the example above four types of affordances for the Xenakis passage: “keyboardability” (how the notes are laid in the leyboard), as well as “fingerability”, “graspability” and “armability”, referring to the co-articulation of embodied layers necessary to execute the passage, and with the possible extension into body position.

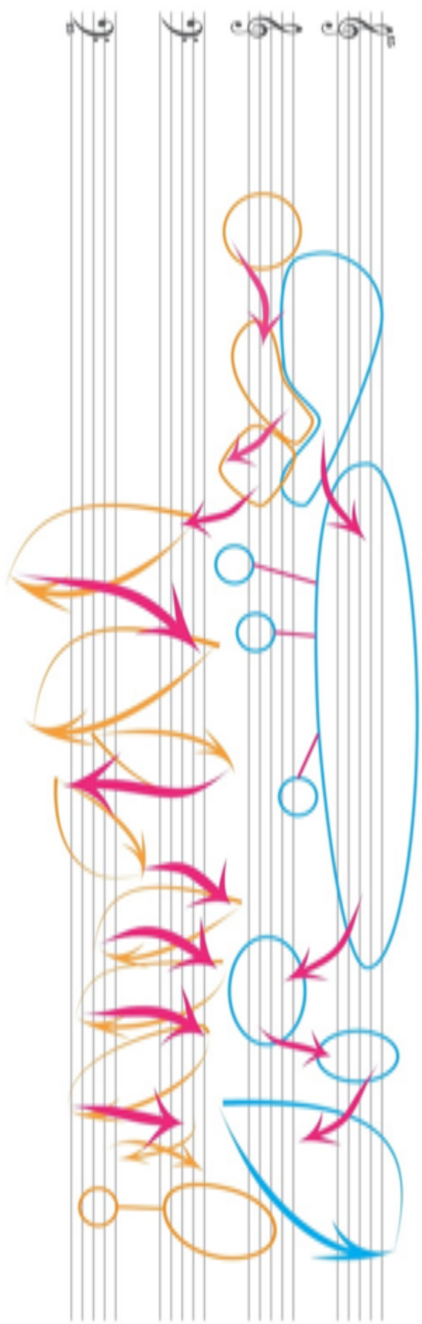

Figure 11 (left): Arm trajectories between handgrasps and rotation 90° clockwise: arm-layer Figure 12 (right): Arm trajectories in 90° clockwise withouth grasp groupings: arm-layer

The ensemble of those affordances is being resumed in the following Figure 13, which in this way acts as what I call a *multilayered tablature*, a representation of affordances for the particular passage. It is important to note, that those affordances are not hierarchically conceived. They do not represent algorithmic stages of learning or action[304]. It is imaginable for example, and this is how I often personally work, that someone identifies the arm movements through an air gesture before assigning fingers. The idea is rather, that the layout of those affordances corresponds to what in dynamic system theories would be called a *non-linear state-space of the system pianist-piano-notation*, and which changes dynamically in time. In that sense, an accurate depiction of what is really happening would be the depiction of a navigation among the several affordances, equaling a constant transformation of the notation in real time by the performing gesture.

To conclude: I have created a static representation of the dynamic process of direct perception of gestural affordances, during the first approach to the cited passage from Iannis Xenakis' *Mists*. While such representations are common, in the form of either internalization of movement patterns, or as memory aids, that is written annotations, I argue that neither internalization, nor memory aids are in principle necessary for the perception of those affordances, in the sense of Gibsons's and Chemero's models laid out above.

[304] The navigation in this multilayered tablature is non-hierarchical, but it does exhibit a linear transition from *topokinetic* to *morphokinetic* characteristics of pianistic movement (refer in the current: Gallagher, 5.2d, "an integrative theory of gesture). It also exhibits the difference between movement and stasis, in the sense of layers that feature support of the performing mechanism (grasps), and others that feature forward movement (arms).

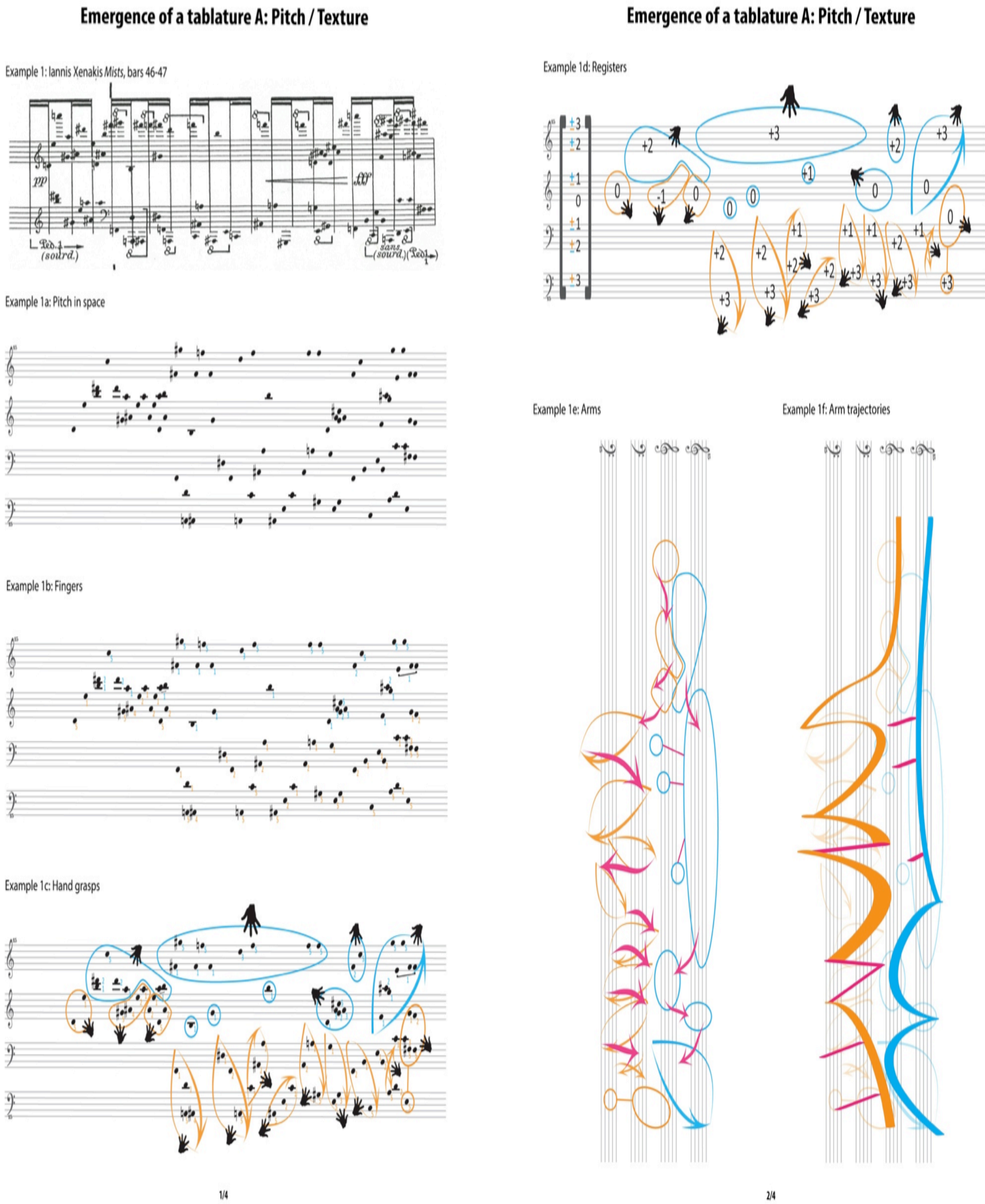

Figure 13: Multilayered tablature for Xenakis' *Mists*, bars 45-46

The example above is ideal for our purposes, due to the fact that, while exhibiting complexity in the pitch domain, it remains minimal as far as other parameters, such as rhythm, dynamics (with the exception of the crescendo by the end of the passage) and articulation are concerned.

The introduction of compositional parameters other than pitch will take us to the notion of *dynamic coupling* of more parameters shaping the performing gesture; but equally, to the notion of *expressive decoupling* of those parameters. And eventually, to a comprehensive model of communication between compositional intentionality and performative articulations under the rubric of *intentionality nodes*.

Parenthetically, and before moving on to my next example, which exhibits such parametrical couplings, I would like to flash-forward to the section on taxonomies of gesture, for example the differentiation between effective and expressive gesture. In the paradigm of embodied navigation, we posit *expressive gesture* as another layer in a rich coarticulation structure of the basic gesture, so that the above-mentioned distinction loses its power. In other words: Gesture is expressive at multiple levels, not only as a superimposition of non-effective or communicative elements on effective gesture, but in the context of the effective gesture itself, its co-articulated structure and the interaction with the multiple strata of the musical score in the form of intentionality nodes.

Before moving on to the issue of coupling co-articulated embodied layers to other parameters, I will look at the notion of coarticulation and how it has been used in recent research by Rolf Inge Godøy.

4.3 Coarticulation : The Relation Between Embodied Layers, Technical Patterns And Sound-Action Chunks.

A. Sound—Action Chunks And Technical Patterns

In this chapter, we examine how *embodied layers* differ from both the notion of *sound-action chunks,* as well as from notions of *technical patterning*. By coupling gesture and instrument to musical notation parameters, these embodied layers aim at providing a higher-order concept. This concept subsumes both technical patterns as understood in traditional piano pedagogy and coarticulation of basic actions, as understood in recent embodied cognitive science research.

B. Godøy: Coarticulation

In Godøy 2011, coarticulation is defined as follows:

> Coarticulation means the subsumption of otherwise distinct actions and sounds into more superordinate actions and sounds, entailing a contextual smearing of otherwise distinct actions and sounds, e.g. rapid playing of scales and arpeggios on the piano will necessitate finger movements included in superordinate action trajectories of the wrists, elbows, shoulders, and even whole torso, as well as entail a contextual smearing of the singular tones into superordinate contours of the scales or arpeggios.(…) One essential element of coarticulation is that it concerns both the production and the perception of sound, hence that it clearly unites sound and action into units, into what we prefer to call sound-action chunks in music. (Godøy 2011, p.2)

Coarticulation is according to Godøy a higher ordering and combination of a basic taxonomy of sound-producing actions, namely *impulsive*, *sustained* and *iterative* ones, designed after Pierre Schaeffer's typology of sound objects, in order to address the issue of sound-action chunking at different time scales. The issue of time-scaling should also be associated to issues of memory[305], which could contribute in a deeper understanding of the relation between action, sound and memory, thus also learning as internalization. For the moment, our focus will remain on the issue of association to musical notation, through the notion of embodied layers.

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[305] Snyder, Bob, "Auditory Memory: an overview", in *Music and Memory: An Introduction*, Cambridge, Massachusetts, 2000.

Table 1.1
Three Levels of Musical Experience

	Events per second	Seconds per event
	16,384	1/16,384
EVENT FUSION	8,192	1/8,192
(early processing)	4,096	1/4,096
	2,048	1/2,048
Functional units =	1,024	1/1,024
individual *events* and	512	1/512
boundaries; pitches,	256	1/256
simultaneous intervals,	128	1/128
loudness changes, etc.	64	1/64
	32	1/32
MELODIC and RHYTHMIC	16	1/16
GROUPING	8	1/8
(short-term memory)	4	1/4
Functional units =	2	1/2
patterns; rhythmic and	1	1
melodic groupings,	1/2	2
phrases.	1/4	4
	1/8	8
	1/16	16
FORM	1/32	32
(long-term memory)	1/64	1 min 4 sec
Functional units =	1/128	2 min 8 sec
large scale *constancies*;	1/256	4 min 16 sec
sections, movements,	1/512	8 min 32 sec
entire pieces.	1/1,024	17 min 4 sec
	1/2,048	34 min 8 sec
	1/4,096	1 hr 8 min 16 sec.

Figure 14: Bob Snyder, auditory memory chunks corresponding to sound-action chunks, originally in Snyder, p. 12

Please note the difference between this notion of coarticulation, as an essentially nested and "vertical" phenomenon, and the classical, horizontal definition of coarticulation as sequence of segments, summarized by Bevilacqua and co. 2016[306]:

Coarticulation relies on the existence and formalization of constitutive segments. For instance, speech is often examined as a finite number of phonological sound segments that are ordered, and which ordering is linguistic-dependent. Coarticulation can be observed and measured because the alteration of phonemes remains consistent over a large vocabulary. Considering movement, such segments become highly variable across individuals and context-dependent, making their formalization inherently more complex. Motor theorists proposed the notion of movement primitives as basic units (typically, patterns of movement kinematics) that can be sequenced to execute a complex movement. Within this framework, movement coarticulation has been linked to motor skills that involve the selection of movement primitives, their ordering and their accurate execution.

C. Sándor: Technical Patterns

In the domain of piano pedagogy, Sándor (1981) proposes the merging of technique and symbolic signification in a *visuogestural code,* after Rowlands' 2004 discussion

[306] Frédéric Bevilacqua, Baptiste Caramiaux, Jules Françoise, "Perspectives on Real-Time Computation of Movement Coarticulation", *3rd International Symposium on Movement and Computing*, Jul 2016,Thessaloniki, Greece, pp.1 - 5, 2016

visuographic memory extensions. Sándor's contribution is the development of a typology of technical patterns in relation to notation.[307] Those patterns include, in terms of Godøy's sound-action chunks, both sustained actions (legato, rotation), impulsive (staccato, free fall, thrust) and iterative ones (rotation). This code prioritizes physical motion, continuity or discontinuity of musical grouping, articulation and dynamics (in opposition to the traditional prioritization of pitch and rhythm accuracy). The user of the code can achieve a direct translation of notation into gesture, without memorizing or understanding / analyzing the musical relations, but rather through a pattern-identification and pattern-completion process. In this sense gestures, instruments and scores become interwined in a performer-specific interactive schema. For in-depth reference to Sándor's code, please refer to part two, 2.3.C. of the current.

D. Problematization Of Sound-Action Chunks And Technical Patterns In Mists

We now return to the Xenakis example above, to show how the notion of embodied layers as gestural affordances of the notation subsumes both the notion of *sound-action chunks* and the notion of *technical patterns*.

Xenakis's instruction concerning the articulation of the tones in Figure 7 is: *to be held as long as possible*. This instruction hints towards a sustaining sound result, but the very distribution of tones in the whole range of the keyboard complicates things. Legato, in the sense of the corresponding technical pattern, is impossible. There is a strong decoupling between the overall legato character of the passage and the technical means to achieve it known as legato. Figure 10, the grasp-layer of this passage, would actually include a variety of both technical patterns and sound action-chunks, already inside the smallest bits of the notation. For example, the first grasp in the right hand in Figure 10 features individual pitches, which are to be played melodically but as fast as to constitute a *grain event,*[308] rather than a melodic phrase played legato, as in a classical context. To play this bit, I am employing the following actions: A rotating movement between d#-c (fingers 2 and 5 in the RH) and

[307] Sándor 1981, "Summary of the basic technical patterns", pp. 115-140. For a review,

[308] sub-chunk level that lasts according to Godoy less than 0.5 seconds

two throwing motions (staccato) of the RH thumb for playing a and b. While this grasp could be played as an impulsive chord, the actual coarticulation inside this handgrasp does not feature an impulsive movement, but rather a mix of sustaining, impulsive and iterative movements all at once, which eventually sounding as granular. The sounding result is sustaining, but contains iterative and impulsive elements in action. Already in such a small atom of the notation, the typology becomes blended and the categories of both sound-action chunking and technical patterns complicated.

Against this event in the right hand, there are three graps in the left hand, whereby individual pitches are played similarly, but the rapid alternation of the grasps shows rather towards a succession of impulsive chords (or grasps), inside which there is the micro- articulation of flickering finger movement (again grain). The second grasp in the right hand features again a chord, this time however the three lower pitches b, g# and b sort of "stick out" of the group in the distance of two to three octaves, so that one has to interrupt the group through leaps, which are played with what Sándor would call a rotation technical pattern, due to the constant change of direction in the arm movement. Thus, we have complex actions, involving both static positioning (the chord) and impulsive leaps in a context of continuous rotation actions. It might already be clear, why a sound-action typology or a technical patterning could become here more convoluted than clarifying.

The typology of embodied layers offers a simple correlation of anatomical structures to the musical score, while not referring specifically to either actions, action-sound chunks or technical patterns. It is, as Gibson would put it, an in-between entity between subjective ability and objective features of the musical score, that guides the perception-action loop, in other words it is: affordance.

E.Hypergestures

A potentially interesting path for the mathematical formalization of the notion of embodied layers and further modeling of the embodied navigation paradigm according to Dynamic Systems Theory could be provided by Guerino Mazzola's notion of *hypergestures* and its further elaboration by Maria Mannone.

In a joint chapter[309], Mazzola and Mannone identify the ontological gap between composition and performance as a mathematical problem of "hypergestural transformation from symbolic to physical reality and vice versa". For them, the central problem of the symbolic interface is a representation of "movement at infinite physical speed, which can only approximately be played by trained musicians". Their response to this problem is the employment of mathematical tools borrowed from physical string theory:

To formally solve this divide between symbolic notation and physical realization, we introduce complex time (C-time) in music. In this way, infinite physical speed is "absorbed" by a finite imaginary speed. Gestures thus comprise thought (in imaginary time) and physical realization (in real time) as a world-sheet motion in space-time, corresponding to ideas from physical string theory. Transformation from imaginary to real time gives us a measure of artistic effort to pass from potentiality of thought to physical realization of artwork. Introducing C-time we define a musical kinematics, calculate Euler-Lagrange equations, and, for the case of the elementary gesture of a pianist's finger, solve corresponding Poisson equations that describe world-sheets which connect symbolic and physical reality. (Mannone & Mazzola, p. 137)

If the elementary gestural unit of Mannone's and Mazzola's theory is the depression and release of a singular finger, then the embodied layers introduced before are conceptualized by Mannone[310], applying Mazzola's definition to practical examples of performance, as points in the space of hypergestures:

"A gesture is formally defined as a mapping from a skeleton, that is a directed graph, into a system of continuous curves in a topological space (Mazzola and Andreatta, 2007[311]), see Figure 15 . For example, in the case of piano playing, the tridimensional space can be constituted by: length = time, depth = vertical position upon the keyboard, height = horizontal position along the keyboard. In the case of a simple skeleton constituted only by two points and an arrow connecting them, the system of curves will be simply given by a curve connecting two points in a space. When the two points are two gestures themselves, the connecting curve is a hypergesture (a gesture of gestures). A curve

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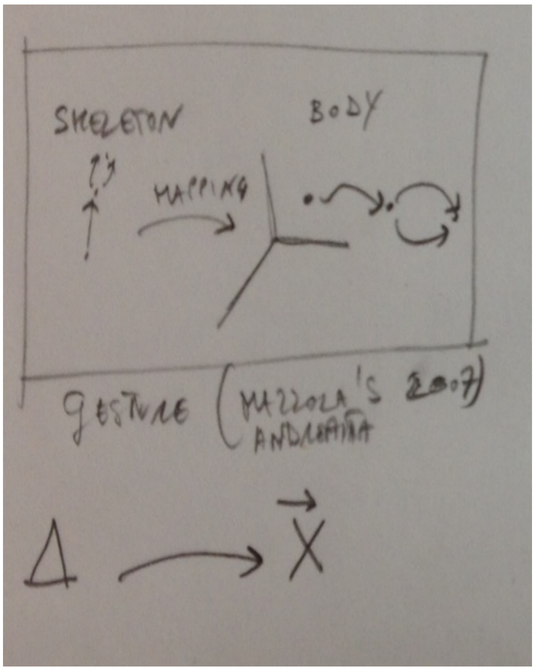
[309] Maria Mannone and Guerino Mazzola, "Hypergestures in Complex Time: Creative Performance Between Symbolic and Physical Reality", in Tom Collins, David Meredith, Anja Volk (eds.) *Mathematics and Computation in Music*, Springer 2015

[310] Mannone & Antoniadis, forthcoming

[311] Guerino Mazzola & Moreno Andreatta (2007) Diagrams, gestures and formulae in music, *Journal of Mathematics and Music: Mathematical and Computational Approaches to Music Theory, Analysis, Composition and Performance,* 1:1, 23-46, DOI: 10.1080/17459730601137716

connecting two hypergestures is a hyper-hypergesture, and so on. We thus say that a gesture is a point in the space of hypergestures. A hypergesture is a point in the space of hyper-hypergestures, and so on, see Figure 16.”



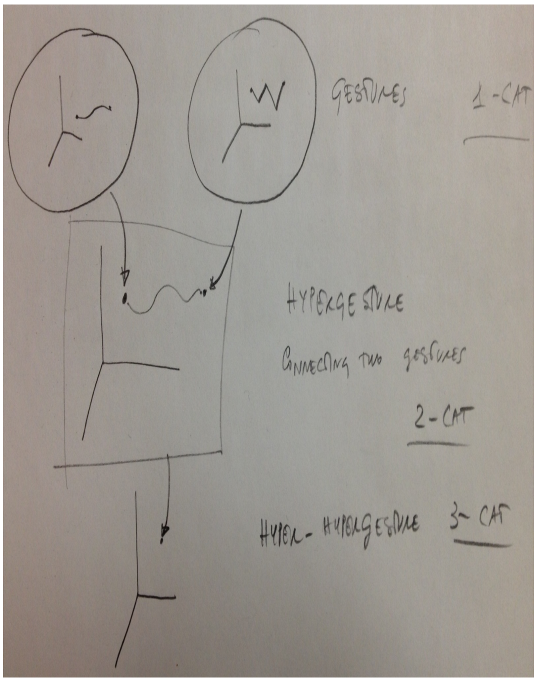


Figure 15 (left): Gesture as mapping from a skeleton into a system of continuous curves in a topological space, hand-written sketch by Maria Mannone

Figure 16 (right): Formal definition of hypergesture in a topological space, hand-written sketch by Maria Mannone

Tracing in more detail some direct applications in contemporary performance practice, Mannone writes:

“In recent studies about contemporary piano performances (Antoniadis, 2017), the hierarchy hand-grasping - arm gesture is the central key to simplifying complex scores. This hierarchy has an immediate modeling in categorical terms. Figure 17 shows a way to describe the connection between notes via hand gestures, and the connection between hand gestures via an arm gesture.”

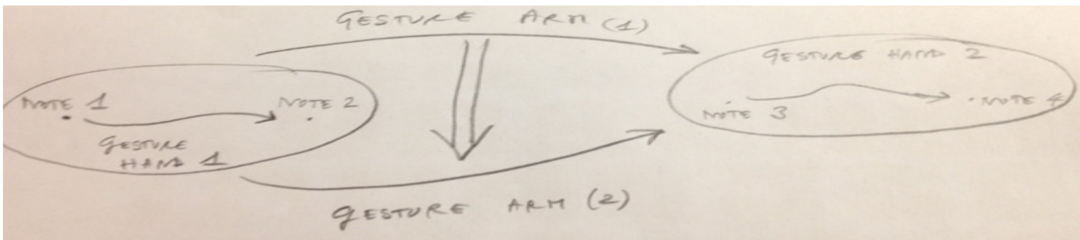
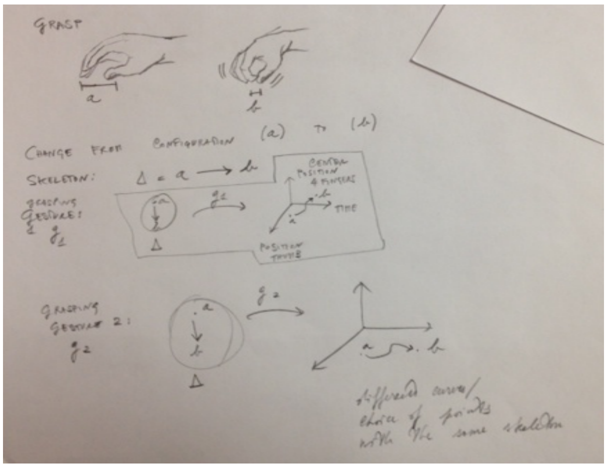


Figure 17: Grasp- and arm-layer modeled in topological space, hand-written sketch by Maria Mannone

Here, the formalism of 2-categories[312] is used (Mannone, 2018[313]).

As a more "concrete" example: we can describe the grasping gesture as a transition from a configuration "a" to a configuration "b". Given the same skeleton (two points and a connecting arrow), there are several ways to realize the same grasping movement between a and b, see Figure 18. At a higher level, there are several ways to connect two gestures. If for example, h_1 is a slower transition, and h_2 is a faster one, we can ideally transform the first into the second via an opportune acceleration operator F, see Figure 19.



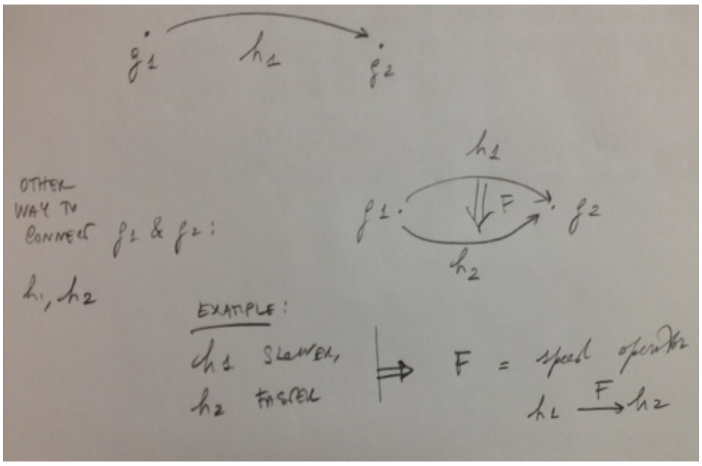


Figure 18 (left): Grasping gesture in topological space, hand-written sketch by Maria Mannone

Figure 19 (right): Speed invariance in connecting gestures, hand-written sketch by Maria Mannone

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[312] A (mathematical) category is given by objects (represented by points) and transformations between them (represented by arrows), that verify associativity and identity (S. Mac Lane, "Categories for the Working Mathematician," Springer, 1971). A category can be seen as a point, and we can define transformations between categories, creating nested structures. A 2-category, in a nutshell, is a category with arrows between arrows. As a musical example, if we describe a crescendo as an arrow connecting two loudness levels, and a comparison between two crescendo with different speeds can be formalized as an arrow between arrows (Mannone, 2018).

[313] M. Mannone, "Knots, Music and DNA". Journal of Creative Music Systems, 2 (2), 2018, http://jcms.org.uk/issues/Vol2Issue2/knots-music-and-dna/article.html accessed 30.04.2018

To complete the mathematical description, we need composition operations. In fact, we need horizontally and vertical associativity for the mathematical definition of 2-categories. The vertical composition involves hypergestures, and the horizontal composition involves concatenation of consecutive gestures, see Figure 20.

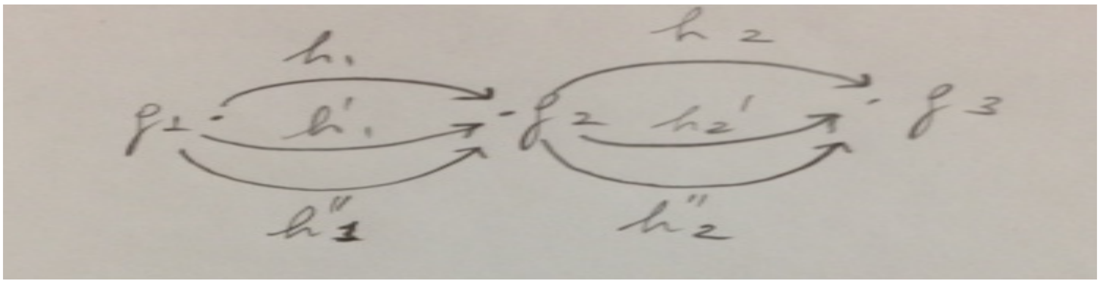

Figure 20: Vertical and horizontal coarticulation, hand-written sketch by Maria Mannone

Figure 21 shows higher level of hierarchy. We can go further with the diagram, connecting arm movements via higher hypergestures.

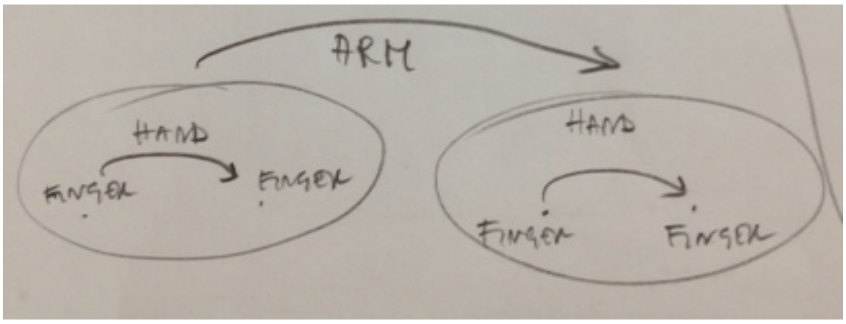

Figure 21: Higher-order concatenation of arm-gestures, hand-written sketch by Maria Mannone

While such strictly hierarchical understanding of gestures somehow defies the fluid dynamic character of real-time navigation and transformation, as folding and unfolding of hypergestures in several dimensions, the advantages of mathematical modeling and the worldsheet connection of hypergestures to complex notation might provide an exciting direction forward. More research is required for such formalization, as well as experiments with real music performances, to connect the abstract character of diagrammatic formalization with the physical parameters of sound and motion biomechanics.

4.4 An Example Of Embodied Navigation II : Expressive Coupling With Rhythm

I am coming now to the issue of *coupling of musical parameters* through a different passage from the same work, Xenakis's *Mists*, namely the bars 9-11.

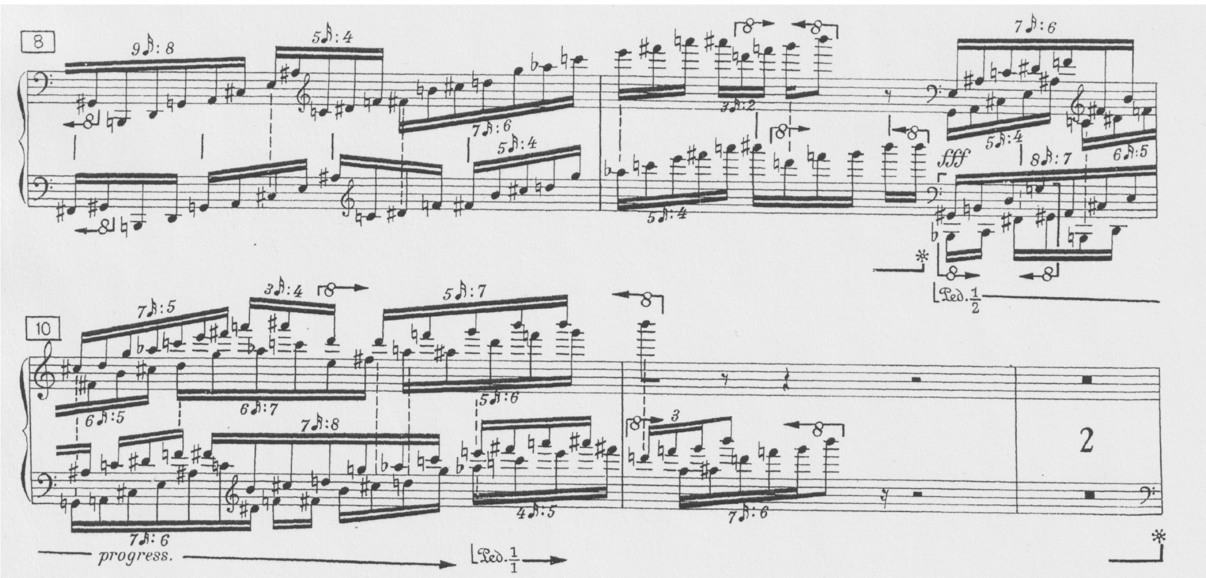

Figure 22: Iannis Xenakis Mists, bars *9-11*

While pitch information is not as dispersed and disembodied as in the first Xenakis example, the rhythmic information exhibits on the contrary staggering complexity. The passage consists of four lines, which are assigned non-coinciding polyrhythms. In such rhythms, the starting and ending points do not necessarily coincide, thus forming an interlocking mosaic of polyrhythms at different nodes. Facilitating the case for direct perception, Xenakis does mostly indicate coincidences of voices, that is simultaneous attacks in different voices, via dashed vertical lines; he also indicates the first eighth note beat with a bold vertical line between the two staves, and eventually, on closer observation, assigns a line of continuous sixteenth notes distributed among the voices, thus allowing for a steady eighth beat pulse, as shown in the following example:

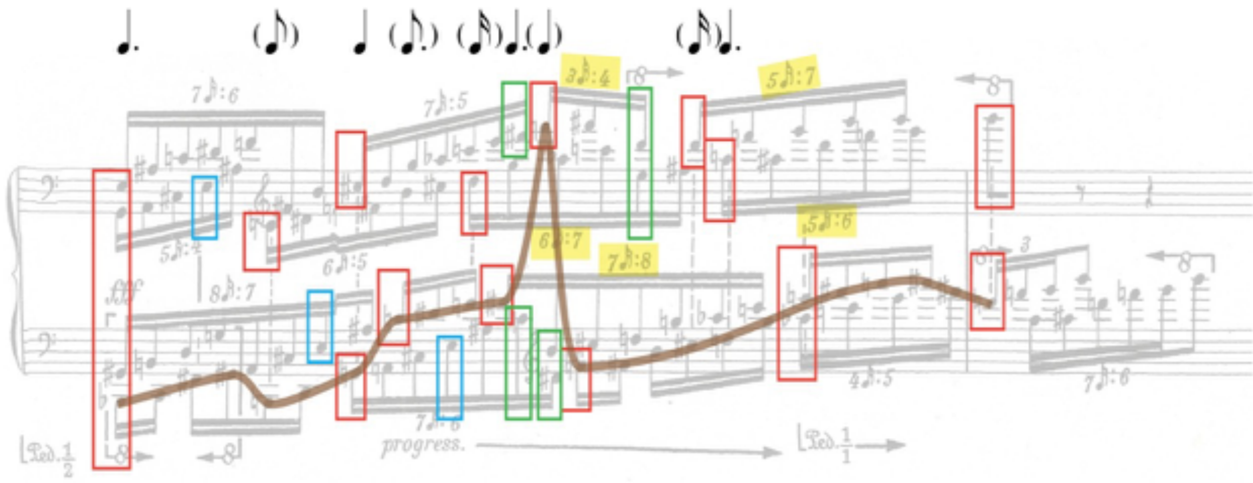

Figure 23: Macrostructural/ arm-layer features: The brown line indicates continuous sixteenth notes. Red boxes indicate the beginning of a new tuplet and often coincide with Xenakis' dashed lines.

I will argue that the execution of this incomprehensible, uninternalizably complex rhythm, can be seen as the *expressive alignment* between two coarticulation layers, namely the gestural layer corresponding to pitch and layers corresponding to mediation techniques for tackling the rhythmical complexity.

First, let me show the tablature, featuring the grasp- and arm-layers for bars 9-11:

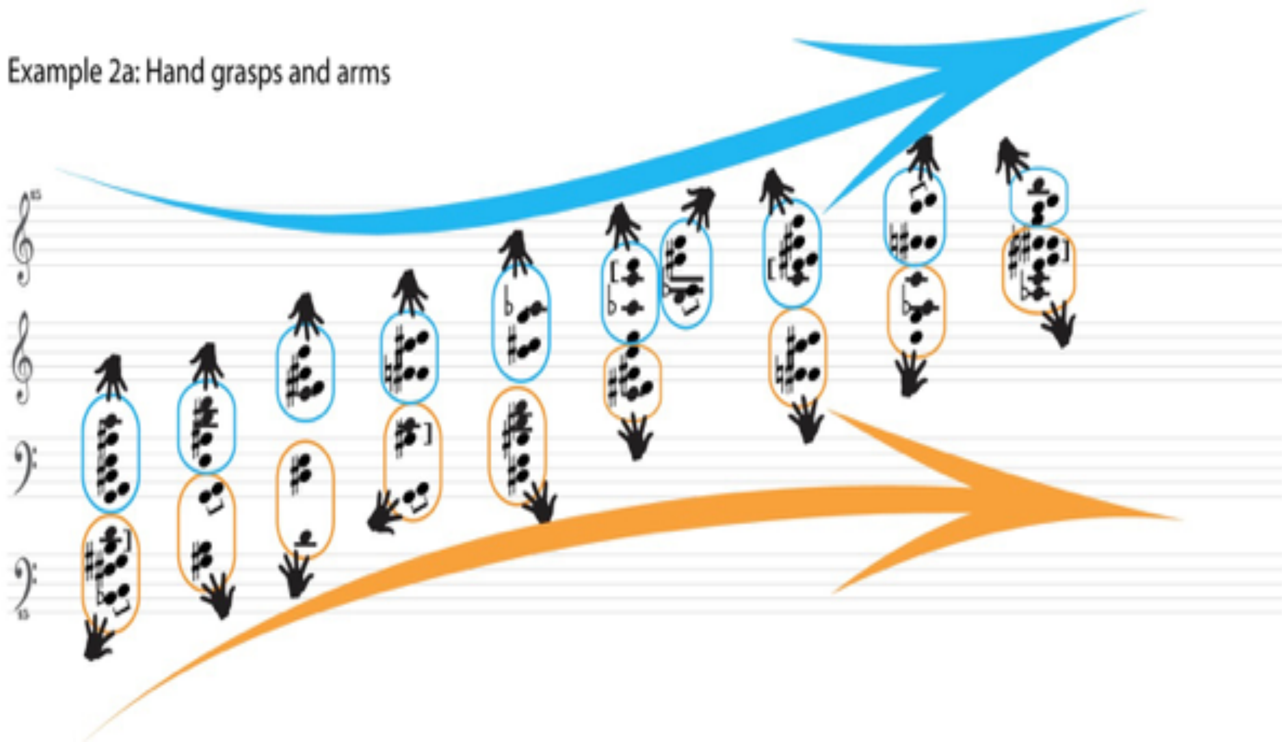

Figure 24: Grasp- and arm-layer for *Mists*, bars 9-11

The choreography is much simpler than in the first stochastic example. It namely consists of a single homodirectional movement of the arms, which stretches over the whole keyboard, from bottom to top, and which is articulated in a number of mostly very manageable grasps . These are manageable in the sense, that they mostly can be played simultaneously as chords. This gestural template is now to be further coarticulated by the elements of rhythm as will be shown in what follows.

First a note on why the rhythmic notation is incomprehensible: In simple rhythmic tasks, for example the execution of three notes over two for a given duration, the task can be modeled and mentally rehearsed via the least common multiple of the two rhythms. In such simple example, the shared duration will be subdivided in 3*2=6 parts, so that the 3 attacks fall on 1, 3 and 5, while the 2 attacks played against them are falling on 1 and 4 of a common stream of sextuplets. In other words, there is a perfect match between the two patterns, which allows us to mentally represent and potentially internalize the task, and then perform it.

Let's come now to the task of the first two upper tuplets, a 7:6 tuplet played against a 5:4 tuplet, what we defined as a non-coinciding rhythm. In this case,we need to imagine the two figures extended, so that they occupy the same duration, given by the least common multiple of their denominators: that means 12 sixteenths for 6 and 4 respectively. Thus, the tuplet can be thought of as a 14:12 against a 15:12, that is as a 14:15, numbers always referring to number of sixteenth notes.

Further clarification of this metric relationship through the technique of least common multiple is deemed to fail, since this would give a 14*15=210 subdivision, which is too large to be humanly computed in real time for each note. In other words, we have no way of *understanding* the proper placement of each note in relation to the other, in the same way we did with the 3:2.

A. Mediation Techniques

Franklin Cox suggests in Cox 2002 that the way to tackle such incomprehensible tasks is through *mediation techniques*: the use of external mechanisms, which allow for an approximate but satisfying performance of the rhythm.

I will show three varieties of mediation techniques, and will also mention a fourth one, which I will though not exhibit, since it requires internalization and is thus not appropriate for my case.

The first technique is the *approximate even distribution of the notes of the tuplet between the eighth note beats*. Please note that the two tuplets in question, 7:6 against 5:4, correspond, not accidentally, to the unit which we called a hand grasp, and in particular to a succession of three of those grasps, as shown in the following figure:

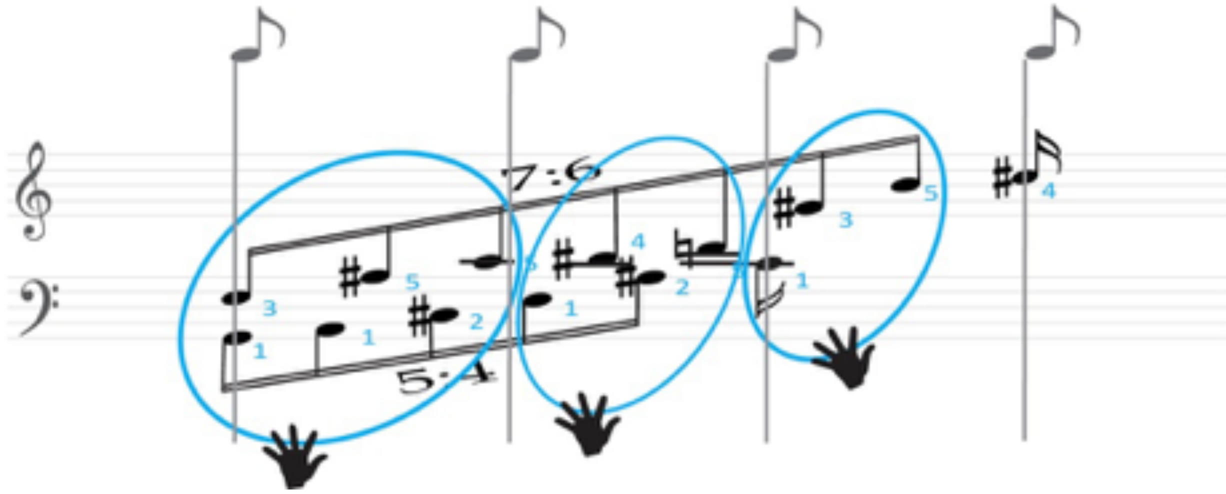

Figure 25: Coupling of grasp-layer to the eighth-note beat

The definition of the grasp layer and the addition of the eighth beat as part of the coarticulation of the passage allow for a pretty easy distribution of individual notes, that is fingers, around the beats. This coupling of pulse-based rhythm with the grasp layer corresponds to ideas of expressive aligning and/or entrainment as reviewed by Leman 2016. Please note that this coarticulation structure is already expressive, in the sense of a flexible embodied action in several layers over a steady beat. *Expressive gesture* is *no*t an added layer but rather a property emerging out of the interaction of those four embodied layers: fingers, grasps, arm movement and eighth note beat.

It is important to note, that both structures can be perceived directly from the score, the hand grasps through the exploratory activity of finger-assignment, the eighth beat through the continuous sixteenth notes, so that no further annotation is needed and of course no further mental representability. The player can certainly always annotate the score adding eighth note beams, in which case the beat coarticulation becomes visible and thus expendable as an environmental structure for direct perception. Note also how neatly do the following entities couple together: the first grasp with the first beat, then the second with the second, only the thumb arriving slightly after the beat, then the third with a new grasp. The complex polyrhythm can in this way be regarded as an expressive inflation of a much simpler structure of grasp sequence, triggering expressive alignment without the need for mental representations.

This first mediation technique seems ideal for one-handed structures. The addition of the left hand and its corresponding polyrhythms presents us with a different order of complexity, whereby, due to the polyphonic requirement, four voices instead of two, the distribution of notes between beats is rendered more complicated and unstable. In this case, I introduce a second mediating technique, namely the correct placement in the beat: For each note, and thus finger, the correct position is explicitly computed in the form of a decimal number, which shows its position in the beat, as in Figure 26:

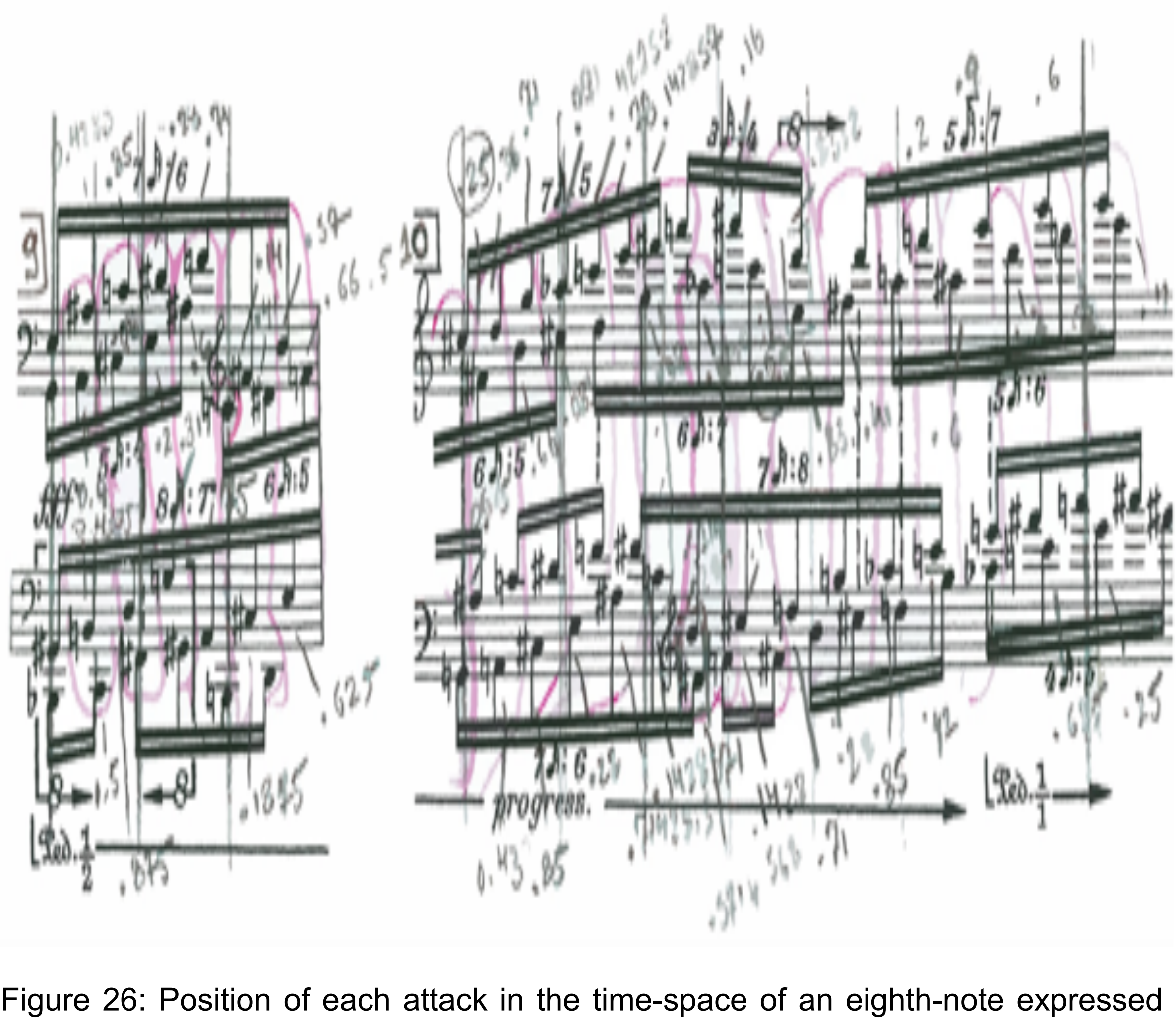

Figure 26: Position of each attack in the time-space of an eighth-note expressed in decimals. Hand-written annotation.

Eventually, one can represent the exact succession of fingers as indicated in the following example, without even anymore depending on the beat for the correct placement, as in Figure 27:

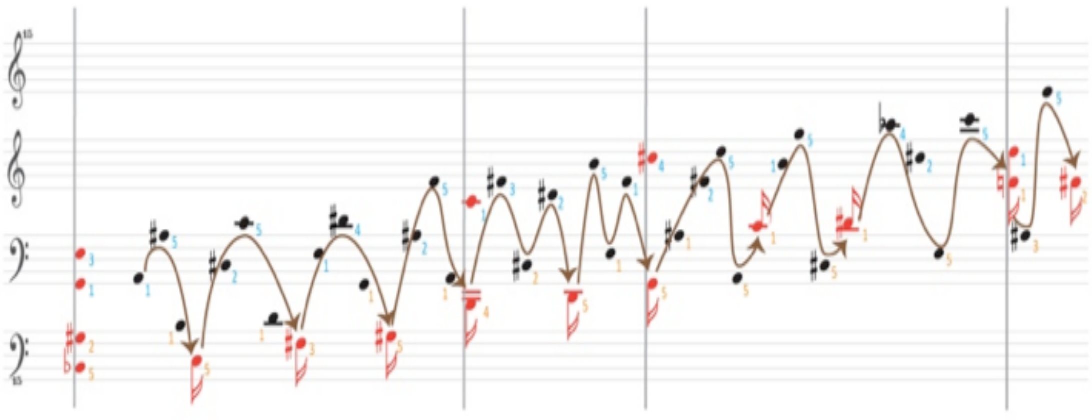

Figure 27: Coupling of finger-layer and decimal technique as a series of attacks

The comparison of this figure to the pulse-based Figure 25 exhibits the following paradox: Essentially, neither of the two techniques is in itself sufficient for a perfect execution of the passage as written. A constant shift of attention between, firstly the correct order of the notes/fingers/attacks and, secondly, the even distribution of the different tuplets in relation to beats, is required for a satisfactory performance. But since the decimal technique corresponds to control of the finger layer while the pulse-based one on the control of the grasp layer, the passage requires the navigation, or oscillation, between those two layers. In other words, embodiment in the form of coarticulation becomes crucial for the understanding of the passage *after* it has been played, in the sense of an exploratory activity.

In the last example, I have indicated several macrorhythmic elements which further coarticulate the basic gestural templates for the duration of the whole passage, or in terms of macro-structure. In red boxes, I indicate the beginning of new tuplets, corresponding to new metronomic speeds[314]. Blue boxes indicate the canonical

[314] In his 2002 essay, Cox speaks of the practice known as *re-tempoing* as one of the mediation techniques, whereby complex relationships to beats are transformed into complex tempi-relationships, given an internalized repertoire of tempi.

introduction of the same pitch material, essentially non-octave scales, which constitute the main material of this passage. The continuous brown line indicates the continuous sixteenth notes, which we have already indicated as an alignment thread for the complex rhythm. The green boxes show simultaneous attacks, which are not indicated by Xenakis with dashed lines; the highlighted ratios indicate rhythms which are slower, in contrast to the initial rhythms which are faster than the main beat. The passage is thus split in two, whereby the first half features a type of structural acceleration, whereas the second structural deceleration. We have eventually notated a guiding beat pattern, which I was using at the time I learnt the piece, as simplification of all those complex trajectories.

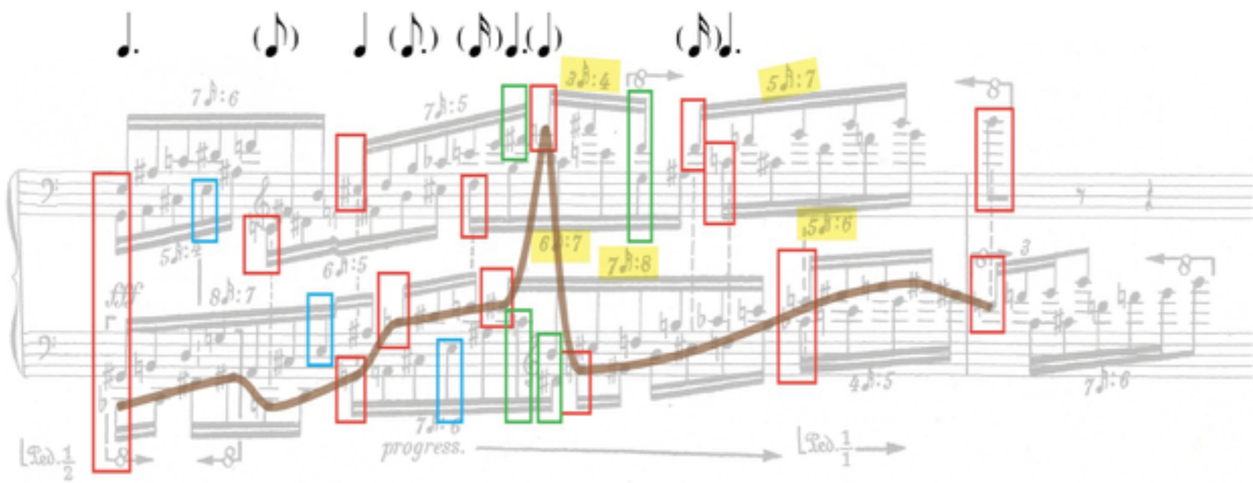

Figure 28: Coupling of arm-layer and macro-structural features

While arguably some of these elements require elementary computations, most of them are directly observable / perceivable as affordances of the passage and are very neatly coupled with the gestural template. In that sense, the multilayered embodied structure is rendered visible and performable through external annotation, even without internalizing anything at all.

Please note that, through coupling and expressive alignment, the multilayered structure allows for prioritization, interpretative choices in the form of interaction and eventually relatively effortless performance without internalization.

4.5 Intentionality Nodes

A. From The Coupling Rhythm-Gesture Towards A Network Of Multiparametrical Couplings

The generalization of coupling compositional parameters to coarticulated embodied layers can be generalized and extended. Other parameters, such as dynamics, articulation, pedaling, timbre, extended techniques, harmonic structure and phrase structure,etc., can be correlated to embodied layers, creating a dense network of expressive factors over a basic gestural ground or template defined by pitch. Such factors diachronically shape performative gesture and their relevant 'weights' constitute what traditionally would be called interpretation. This relation is now represented as interaction between coarticulated layers.

Such proliferation of information poses problems of complexity and representation and urges us to introduce the notion of *intentionality nodes*.

The first component of the term, intentionality, hints at the fact that such parameters embody compositional intentionality through performative action. Given the fact, that in the context of intra- and inter-complexity intentionality is diffused and hardly realizable in its totality, the different 'weights' of individual parameters manifested in physical movement give an accurate blueprint of performers' prioritization processes. Such prioritization processes stand firmly at the core of what is traditionally called interpretation, only that now they constitute and are constituted by physical movement, thus providing mediation between physical energy and meaning, and a plausible theory of interpretation and expression as interaction.

The second component, nodes of different weights, is inspired by connectionist architectures, with the further aim of implementing the paradigm of embodied navigation as a neural network. This implementation has not been achieved in the current thesis. As will be shown in detail in the third part, this complex network of intentionality nodes is absorbed into the gestural template and considerably simplified through performative embodiment.

In the following example (Figure 29) from Mark Andre's piano work *Contrapunctus*, I have represented intentionality nodes with different symbols against a gestural ground of handgrasps represented by blue ellipses (left). I have then correlated those with multimodal data recorded with *MuBu* for Max (right), a technology to be explored in the third part of the Dissertation.

As shown in the legend, red frames indicate simultaneous attacks, brown beams indicate beats, purple polygons indicate rests, orange rectangles a change in articulation, green stars a change in dynamics, green arrows a continuous change in dynamics, blue ovals a modulation in speed (corresponding in the various nested tuplets of the musical example) and pink numbers the exact decimal position of a single note in the beat. In that sense, each single note can be seen as the node of several parametric layers and correspondingly indicated, with some notes being the meeting points of more parameters than others, as indicated in the example.

In the right side of the example, I have used this notation of musical parameters to annotate the sound and gesture recording of the musical score in the left.

For the moment, it suffices to stress how the notion of intentionality nodes allows to organize, represent and correlate multiple strata of compositional intentionality into a singular expressive gesture. The actual navigation of such strata will be effectuated with the use of the *motionfollower*, as will be shown in part three of the current.

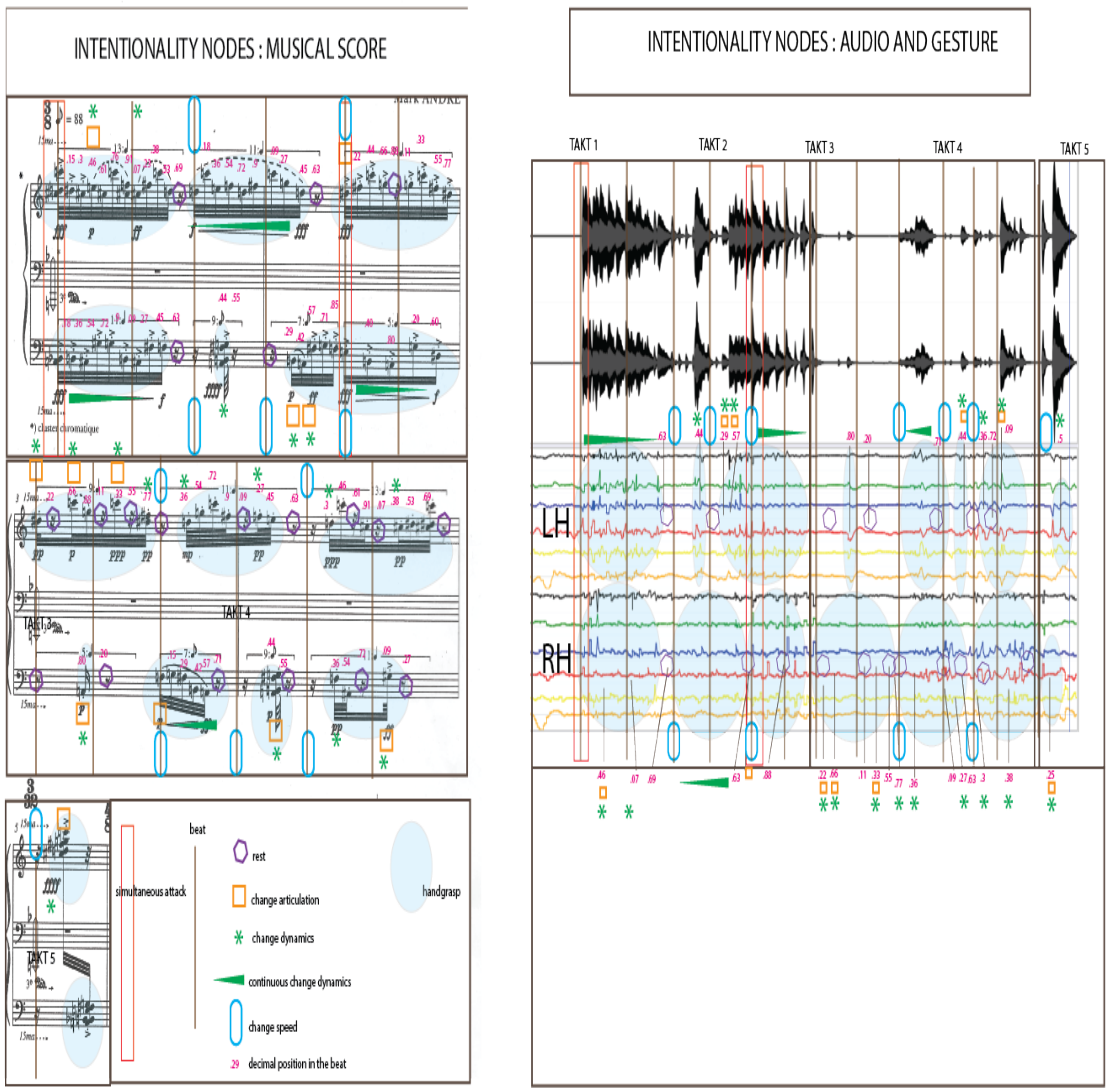

Figure 29: Intentionality nodes identified on the score (left) and on a representation of multimodal data (right) in Mark Andre's *Contrapunctus*, bars 1-5. The data shown on the lefts are from 3D accelerometers and 3D gyroscopes worn on the wrists

The notion of multiple symbolic layers interacting towards a single aggregate of gesture and sound can generally be represented in terms of a connectionist architecture as follows in Figure 30: Compositional parameters are represented by one node each in the input layer, their interaction represented by the hidden layer of intentionality nodes, which produces the output layers of gesture and sound.

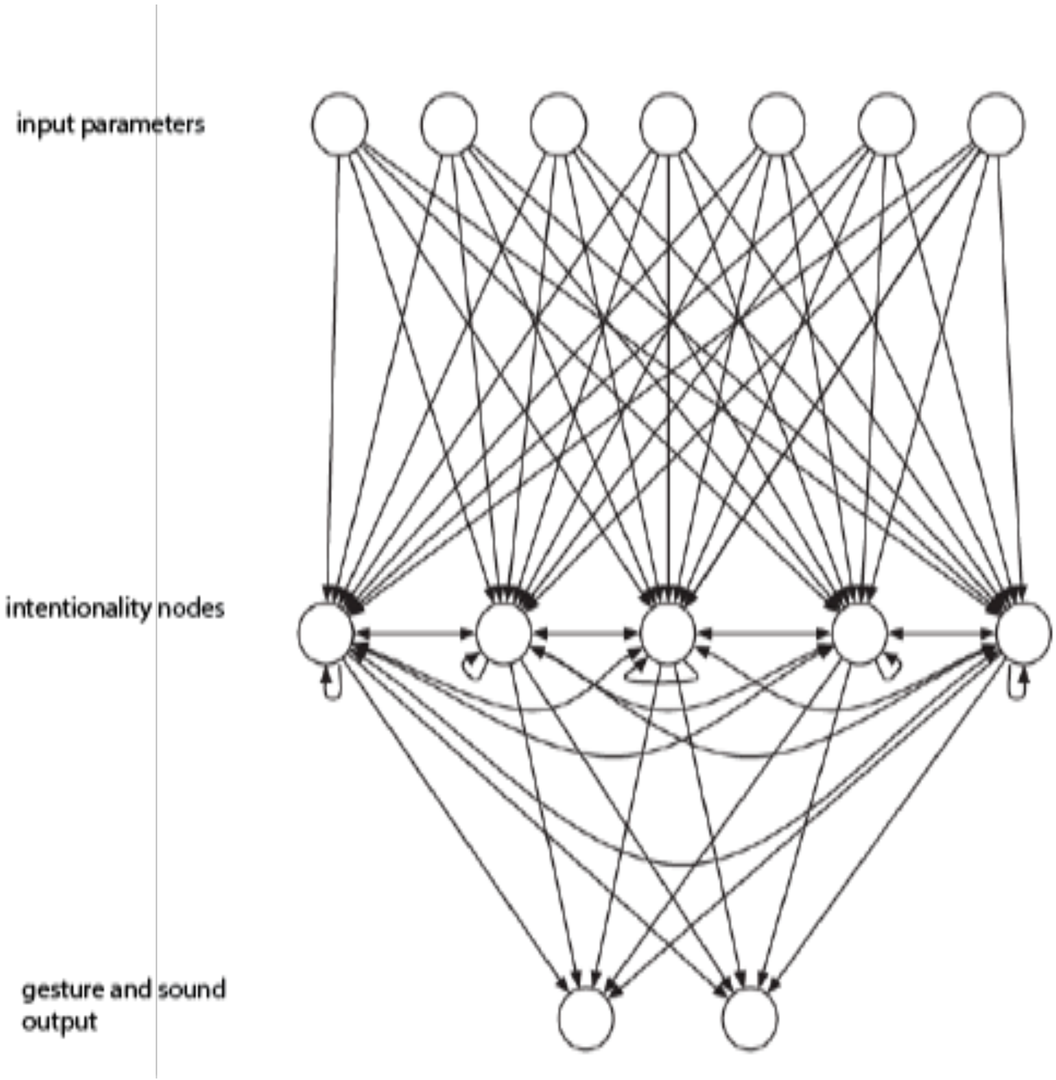

Figure 30: Intentionality nodes as middle layer of a connectionist architecture, with input compositional and output performative parameters

B. The State Space Of A Single Note

The following thought experiment could be used in order to further define the notion of affordances, dynamic systems and intentionality nodes in relation to music notation.

Imagine a notated single notehead with no information other than pitch being represented.

In this case, it is safe to assume that such symbolic representation affords a maximum of options, or a complex state-space, in relation to the other parameters. The pitch, and thus the position in the instrument, is locked, but: musical parameters such as duration, dynamics, articulation and timbre are free, and so is the variety of the corresponding coarticulated actions.With which finger, with what participation of lower, upper arm or which motion, with what character etc. this note will be played remains open. Imagine this variety of possible options as representable in a singular space, according to the parameters discussed above. This would be the state-space for the interaction with a single notehead.

The addition of symbolic information about this one tone and its integration in multiple parametrical and morphological structures by adding other notes has a double effect: On the one hand, it delimits the possible interpretations, the possible interactions with the tone ; but on the other hand, it augments them, due to the tone's recontextualization in multiple parametrical strata which invite prioritization.

C.Ontogenesis Of A Performance

Embodied navigation takes place not in the abstract, but rather in what we call a *score-space*, represented through the tablatures shown before. However, such tablatures can hardly represent the longitudinal process of the navigational act. As already stated, research in cognitive linguistics suggests that the metaphorical language is structural for our conceptualization. It hints at the grounding of musical phenomena in basic embodied structures, which derive from recurring physical experiences, especially the experience of our own bodies. But the score-space is far from only metaphorical: One moves along the score which constitutes a physical space – both of the score and through its symbolic representation of the keyboard. The score-space designates the *folding* and *unfolding* of the keyboard space through embodied layers of coarticulation. And all that during a diachronic trajectory, which leads from the practice room to the performing stage.

In this sense, the concept of a score-space derives from the bodily experience of the performer with the medium of notation, from the very first moment she engages with a work, through the learning process and through the various performances; in a nutshell: through the ontogenesis, the growing of the performance. In contrast to a conceptualization of the learning process as an algorithm with input and output, or the conceptualization of the performance as a linear reproduction of the notated material, the concept of a score-space enables the formulation of the movement of the performer in space and time as navigation. The temporality and spatiality of this engagement seldom correspond to the time-line of the real-time performance: Two extreme cases of such linear engagement would be either an algorithmic build-up of a piece note to note (as in Leimer-Gieseking) or a unique run through the piece for the first time (sight-reading). However, the engagement with complex pieces after 1945 bears a more complex time-morphology: Quasi-chaotic, flexible drifts for familiarization with the global aspects of the piece; resistance because of the high viscosity of the polyphonic textures; "surgical" static decoding of complex rhythms; anxious formulation of fragile lines; setbacks in vicious circles; and doubtful premieres because of a minimum of preparation time.

This multiplicity of performative experience urged Danae Stefanou and me to define four dimensions, or grades of continuity and discontinuity, pertaining to this score-space (Stefanou-Antoniadis, 2009, pp. 83-84)[315]:

(1) The *assemblage-view,* as an outside-of-time, highly personalized gestural template, which is produced through the first *scanning* of the piece.

(2) The *forward-moving stratification*, as the establishment of lines of continuity in this template.

(3) The *resistance to the flow*, as the projection of discontinuities in the template.

(4) The *line of flight*, as the real-time passage through these dimensions, that is, a singular performance.

We are not talking here about stages of learning or rehearsal hierarchies, since these dimensions are not self-contained. They are rather recursively interconnected,

[315] Danae Stefanou, Pavlos Antoniadis, «Inter-structures: Rethinking continuity in post-1945 piano repertoire», JIMS Online Journal (Spring 2009) http://musicstudies.org/wp-content/uploads/2017/01/Stefanou_JIMS_0932105.pdf accessed 11.05.2018

through perpetual movement and translocation. We therefore assume a multiplicity of structural planes and entry points to the structure.

Dimension / Trope 1: "Assemblage-view"

As a first dimension in this navigation, we suggest the grasping of the amorphous whole of the score-space, as an assemblage of temporarily convenient physical localizations, positions and movements. Their function is to penetrate through textual complexities and resistances, as if through a rainforest. The vantage points offered here are physical (stressing the direct, intuitive, corporeal manifestation and choreography); psychological (avoiding the danger of some kind of paralyzing effect of the textual complexities and keeping the forward drive); and an indispensable, even if vague, familiarization with the global aspects of the work from the very beginning of the learning process. However, this familiarization is very far removed from traditional performance accounts privileging the visual, two-dimensional apprehension of the score into a neat and complete mental image (e.g. Cone 1968[316], Gieseking & Leimer 1972), as well as from more recent textually driven paradigms of the score-as-script (e.g. Cook 2001[317]) that consider mental study away from the keyboard as a first-step in the preparation of any performance (e.g. Hill 2002[318]). Our main divergence from such models, is that this "assemblage-view" favours a physical, three-dimensional consideration of the score not as a visual object to be sonically reproduced, but as a space to move into.

Dimension / Trope 2: "Forward-moving stratification"

The second dimension is constituted through the assignment of territorial strata and the channelling of the performative flow along these lines. These are groupings of all kinds: Explicitly notated, implicitly discoverable, or based on physical parameters such as gesture, energy distribution, tension and release principles etc. They operate on all different levels of the musical form. Directionality and hierarchies may result,

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[316] Cone, Edward. T. (1968). *Musical Form and Musical Performance.* New York: Norton.

[317] Cook, Nicholas (2001). "Between process and product: music and/as performance," *Music Theory Online*7.2(http://mto.societymusictheory.org/issues/mto.01.7.2/mto.01.7.2.cook_frames.html accessed 7 March 09)

[318] Hill, P.(2002). "From score to sound" in J. Rink (ed.), *Musical Performance: A guide to understanding* (Cambridge: C.U.P), pp.129-43.

but fragmentation and discontinuity, plus conflicts of different strata and compositional structural planes, can equally well be the case.

Dimension / Trope 3: "Resistance to the Flow "

The third navigational dimension entails resistance to the flow. This involves the microscopic, "hieroglyphic" treatment of sounds and sound events as autonomous objects to be sculpted on a vertical plane and re-situated in the performer's body (in line with Artaud's "affective athleticism"), as well as in the actual performance space. This is a moment-specific process that relies on non-continuity or non-memory, in Tudor's sense as revised in part one. The compositional ways to sabotage continuity are of course highly specific to particular works, but the common denominator for the performer is, once again, the physicality inherent in the projection of discontinuities. The latter quality could very easily become absorbed or 'smoothened' within the organic continuity of conventional instrumental gesture, a feature often stressed in mainstream conservatory education and institutionalized performances of radical music (Pace 2008[319]).

Dimension / Trope 4: "Line of Flight"

The actual performance, then, constitutes the fourth dimension, as a Deleuzian *line of flight* along the timeline and across the score-space defined by the other three tropes, re-defining it and de-territorializing it. A performance is no longer a pre-constructed object to be presented with various degrees of perfection, but part of a perpetual movement, an irreversible and unrepeatable process, where continuity and discontinuity have been treated as dialectical and superimposed planes, allowing for great flexibility of future performances. In this sense, the navigation is no less performance than the performance itself, and interpretation is nothing more than the set of unique qualities that define this navigation (like speed, regularity, directionality, focus etc.). In this light, new understandings can also be forged with regard to Deleuze & Guattari's take on the music of Boulez, summarized as "the pure act of the drawing of a diagonal across the vertical and the horizontal" (Deleuze & Guattari

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[319] Pace, Ian (2008). "Complexity as Imaginative Stimulant / Making Possible the Irrational", lectures at the Orpheus Institute.

1980, p. 477-8). The diagonal, here, is not simply a compositional gesture, but a performative one.

One could thus represent navigation in a four-dimensional score-space as follows:

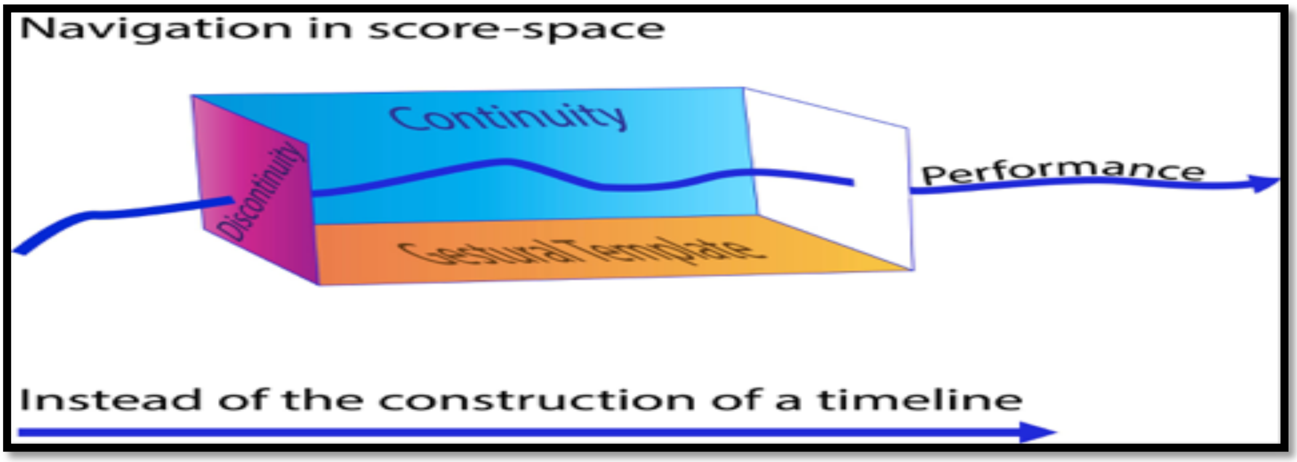

Figure 31: Schematic representation of embodied navigation in a four-dimensional score-space, in lieu of a linear reproduction model

The gestural template is formed by the embodied layers, whose parametrical shaping is occurring along lines of continuity and discontinuity in the learning trajectory. This interplay is shaping the score-space. A singular performance constitutes the passage through that diachronic space. The differentiation from the reproduction model of a singular timeline is presented in Figure 31.

Embodied Navigation is an extension of physical movement, a higher-order movement in a diachronic trajectory along a multi-dimensional state space. Embodied navigation means the perpetual movement in-between embodied structures of the immobile score-space. This movement produces a new and infinitely malleable space. The movement functions between learning and performance, between detailed and global aspects and between the continuity of performance and the resistance of decoding. The qualities of this navigation -its directionality, its speed, its viscosity etc. -define, what can sound from the initial incomprehensible and/or unplayable image. Interpretation is then this diachronic movement, instead of the repetition of a frozen sound-image.

We have defined embodied navigation of complex notation as higher-order physical movement in a state-space shaped by notational and instrumental affordances. In that sense, it is important to stress that embodied navigation is not a metaphor for virtual movement inside a musical score, but rather the *temporal extension* of the notion of physical movement in the physical space of the instrument as articulated by the affordances of the musical score – what we have termed the score-space of the instrument. Navigation takes place in multiple time-scales as ontogenesis of the performance, similar to the development of a living organism, from the first stages of learning up to the multiple performances, which are traditionally termed "interpretations". Similarly to navigation defined as non-metaphorical movement, the score-space is *not* a metaphorical space where virtual movement would take place, but rather the dynamic, in-time articulation of the fixed physical spaces of instruments and musical scores by physical movement.

4.6 Conclusion : Multiple Taxonomies Of Notational Affordances For Embodied Navigation

As becomes clear from the Xenakis examples above, gestural affordances of the score are defined at a first stage as correlations between notated pitch, keyboard loci and coarticulated embodied layers, and at a second stage, as the further coupling of those layers to other musical parameters –here complex rhythm-, which further coarticulate and modulate gesture along lines of continuity and discontinuity. The coupling to more compositional parameters creates a dense network of intentionality nodes as shown in the Mark Andre figure (Figure 29).

The model of the Xenakis example in 4.4 is represented in the following taxonomy (Figure 32):

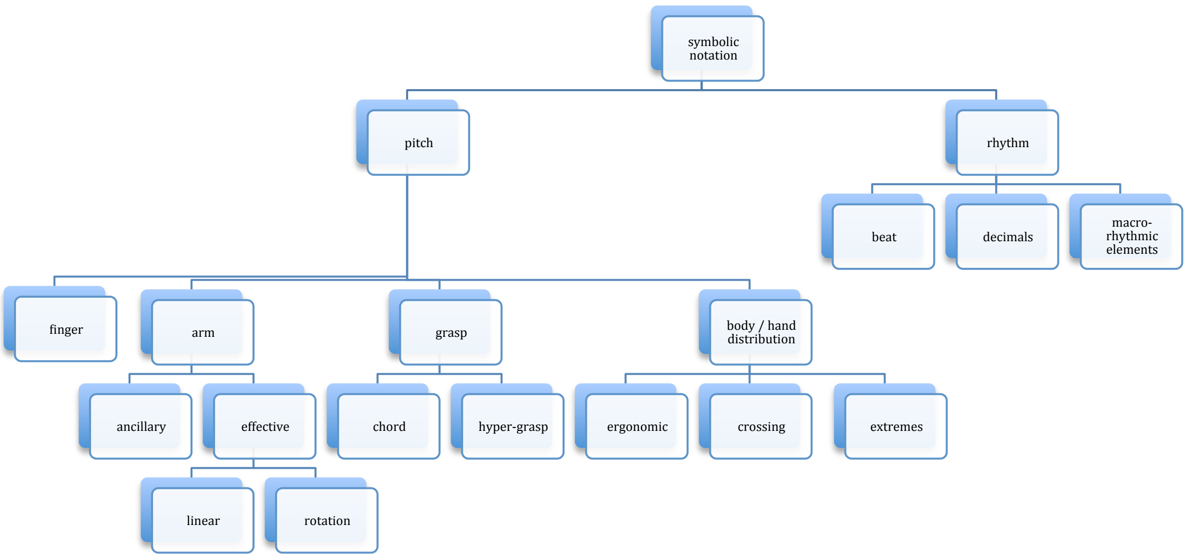

Figure 32: Taxonomy of notation-gesture correlations based on embodied layers

Pitch formations are correlated to embodied layers and are coupled to rhythmic elements.

The parameter of pitch is organized in four interdependent, concatenated and nested embodied layers: finger, hand-grasp, arm movements and hand distribution, with corresponding body positions (for short : body).

The finger layer is identical to traditional fingering, with an one-to one correspondence to the notated pitch.

The grasp layer describes formations of pitch that can be grasped, either simultaneously as chords or consequently as melodies. In the case that this succession of fingers exceeds the individual hand-span, an element of arm movement and hand displacement is introduced, for which we have coined the term hyper grasp.

The arm layer consists of movements which are either ancillary, that is connective movements to displace the hands to a different region of the keyboard without playing, or effective, whereby the arm movement involves the attack of keys and probably also intermediate keys. In the latter case, the distinction from a hyper- or quasi-grasps becomes fuzzy or even obsolete. Eventually, those arm movements can be either linear, in the sense of a smooth displacement along the keyboard as traditionally in scales and arpeggios, or rotational, for effective changes of direction in the keyboard space.

The body layer describes the relationship between the two hands and the corresponding body positions as ergonomic (a relatively balanced position where both hands are active in their most ergonomic respective areas, the left hand below the middle c and the right hand above that); crossing (whereby one hand is leaping over the other) and extreme (whereby both hands play in the outer extremes of the instrument, necessitating a forward movement of the torso). Body positions can be represented by the distance between the two linear trajectories curves as in the Xenakis arm layer figures (Figures 11, 12).

The parameter of rhythm is organized along mediation techniques for complex rhythm in: beats, decimals and macrorhythmic elements. As was shown above, beats couple neatly with grasps, decimals with fingers and the macrorhythmic elements with arm movements, even though these articulations are characteristic of only this particular example. Alternative couplings and decouplings can be conceived of, and are indeed the case in most piano music.

To give another toy example, let us imagine the scale of C-major played by the right hand in one octave with the traditional fingering of 12312345 ascending. In this case, the decoupling, which constitutes one of the basic problems of piano technique, is the desired continuity of the scale versus its non-symmetrical partitioning in two groups (123, 12345), which essentially correspond to two different hand positions or grasps. If we imagine a grouping every four notes, then it becomes clear that the change of position occurs after the passage of the thumb, thus making the decoupling between the pitch and the rhythm pattern obvious. If we add dynamics and articulation and all, we can imagine several possibilities for decoupling, which make the navigational model palpable even for such a simple example.

In the above description, the parameter of pitch has a pronounced position: It is assumed to be the parameter *par excellence,* which defines embodied layers and a unique feature of rhythm, namely beat, is expressively aligned to it. Other entry points and prioritizations, in terms of movement in space and time, are certainmy conceivable.

The taxonomy above is reflecting my personal prioritization processes. The embodied navigation paradigm is designed however for a multiplicity of taxonomies pertaining to individual differences, so that one could conceive of the affordances in terms of, for example technical patterns, as the ones described by Gyorgy Sándor, or sound-action chunks, as described by Rolf Inge Godøy, or any other potential taxonomy that correlates notation, gesture and sound.

A. Sándor Taxonomy

A different taxonomy from the point of view of traditional piano pedagogy is proposed by György Sándor. Sándor suggests that the application of five basic technical formulas or motion patterns, which are not identical to musical patterns (=decoupling), suffice, alone or in combination, for the translation of notation into motion. He defines the formulas as: Free Fall, Five Fingers (scales/arpeggios), Rotation, Staccato and Thrust. He correlates them to pitch formations, tempo, energy source (gravity or muscles), articulation and dynamics, and adjusts them through piano topography (white or black keys, extremities or centre of the keyboard).

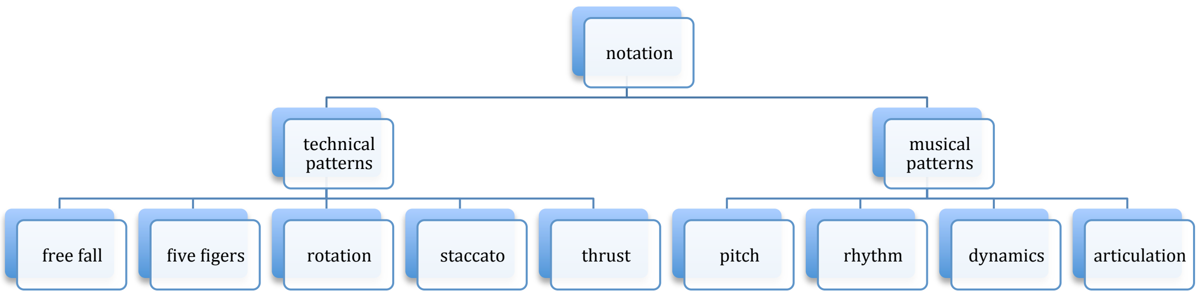

Figure 33: Correlations of notation and gesture based on Sándors taxonomy of piano technique.

Please note that in Sándor's taxonomy in Figure 33, musical patterns refer to the mainstream repertoire and are easily identified and correlated to technical patterns.

They also refer to the concrete actions that need to take place. Coarticulation is already incorporated or learnt in these technical schemas, rather than explored, as is the case in the embodied navigation model.

B. Godøy Taxonomy

From the point of view of embodied music cognition, Godøy's taxonomy of musical actions and sound-action chunks could offer a different vantage point for the application of the embodied navigation model. As shown before in the context of the Xenakis' example, the correlation of these features to complex notation is far from simple. Symbolic information on the musical score might necessitate a complex amalgam of several types of features. On the other hand, the advantage of such typology would be the potential extension of the embodied navigation model beyond piano-specific gestures. In that sense, it could serve the extension of the embodied navigation paradigm to other instruments, through the coarticulation and sonic features' link to symbolic notation.

In Figure 34, you may see an overview of Godøy's basic analytical categories. Sound-action chunks are defined as to their relation to basic sound production, after Schaeffer's notion of *objet sonore*; as to the blending of these categories in the sense of phase transitions and co-articulations; and as to their temporal characteristics.

In Figure 35, you may see Godøy's typology of music-related actions as to their functionality, reflecting other proposed taxonomies of gesture revised in 5.2 of the current part.

Similarly, and as already shown in the examples mentioned above, the creative spontaneous blending of those taxonomies is never out of the question, *as far as it serves the direct perception of affordances for action*. Even a singular finger event, such as a sustained note, can be defined according to the mode of touch employed and the coarticulation, that is corresponding wrist, lower, upper arm and shoulder or even body participation required to play the note.

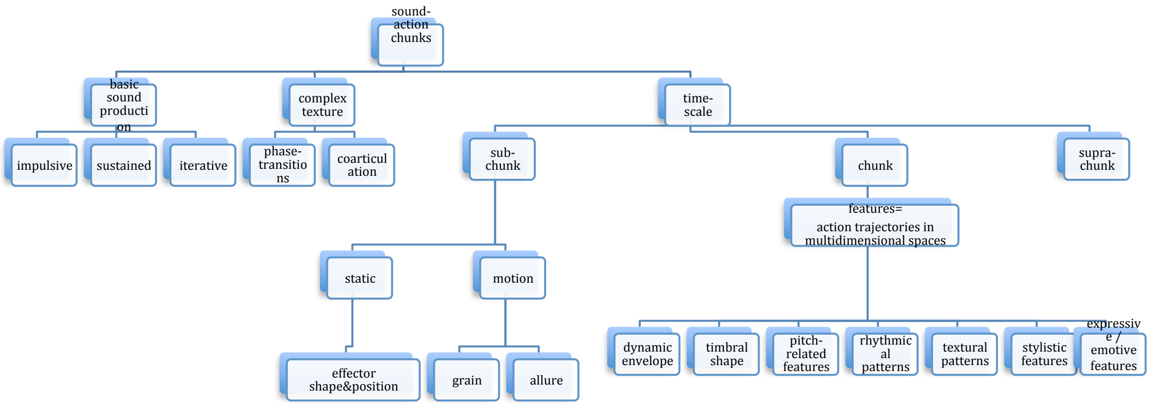

Figure 34: Taxonomy of coarticulation features according to the theory of sound-action chunks by Rolf-Inge Godøy. There is no correlation to music notation.

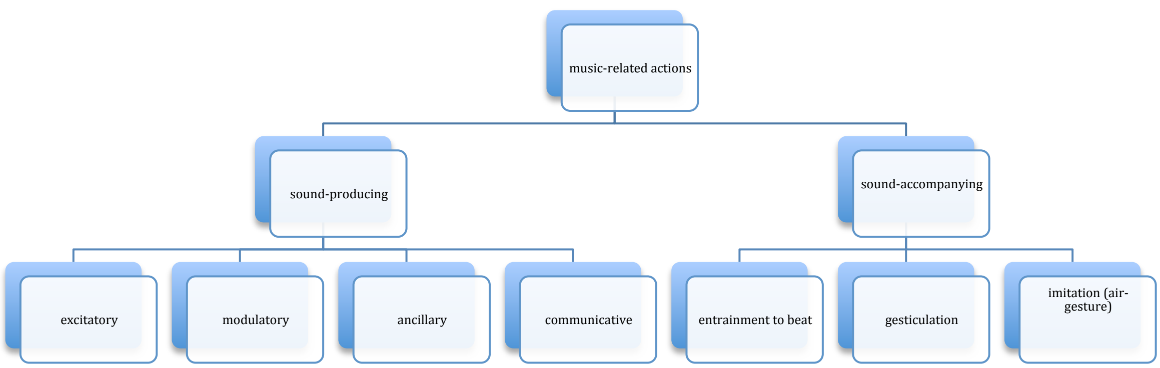

Figure 35: Basic typology of gestures accoring to function by Godøy

The following figure (Figure 36) represents a potential interactive schema between the taxonomies explored above: Embodied layers of the score are entrained to an external beat and modulated by dynamics and articulation in expressive alignment to the score. These embodied layers crystallize in concrete technical patterns, which give rise to complex sound-action chunks. The sound-action chunks operate at several time-scales, corresponding to different structural levels of the score and indicating different rates of continuity and discontinuity, eventually of change in time. Crucially, this embodied environmental information can be fed back into the notation and transform it.

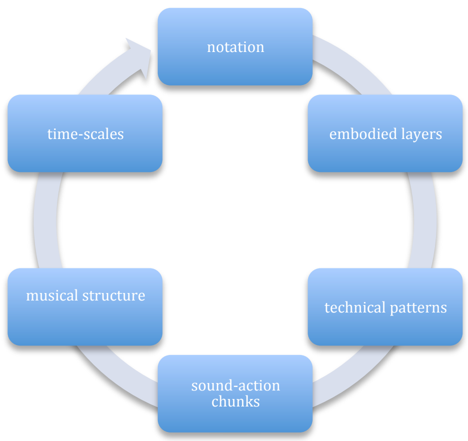

Figure 36: Interactive schema for multiple typologies in relation to notation

A comparison of the embodied layers to other taxonomies, shows that they are far from being incompatible: This taxonomy offers the highest possible resolution to complex phenomena of coarticulation in relation to notation. Concrete actions and sound results, in the sense both of traditional technical patterns and of sound-action chunks, as well as structural properties and different time scales, can be subordinated to embodied layers, creating trajectories in multidimensional spaces as shown above. The embodied layers function, so to speak, as an interface between the notation and its physical realization.

Please note the return to notation as central to an embodied cognitive turn, in the sense that notation is being processed or transformed during the navigation process into the units described above. One can zoom in or out of notation, and at the same time in and out of musical structure and time-scales on the basis of gestural primitives, regardless of the degree of complexity.

Please also note, that the openness of a coarticulation architecture allows for the integration of further layers pertaining to the second (electronics) and third (performativity) axes of embodiment, as will be shown in selected case studies.

In a nutshell : embodied navigation is the process of direct perception of notational affordances that guides coarticulation into action-sound chunks at different time and structure scales. It is also the actual trajectory in a multi-layered, multidimensional state-space of interaction possibilities. This motion reflects and represents the longitudinal development of interpretation as interaction between notation, gesture and sound.

5. Embodied Navigation Of Complex Piano Notation And Embodied Music Cognition

5.1 Embodied Navigation And Sensorimotor Prediction

The epistemological claim for embodied navigation, namely that "musical performance is better explained as a complex dynamic system which does not *necessarily* involve mental representations", seems to be, albeit superficially, at odds with latest evidence on the dynamics of expressive interactions, and in particular with the notion of *sensorimotor prediction*.

Before introducing those theories and examining their relationship to a radical model of embodied navigation, it is important to, once again, underline the contingent character of the above mentioned proposition. In other words, the fact that mental representations are not a *necessary* part of a music performing dynamic system obviously does not mean that mental representations are not *existing* or even *desirable*. It only means that, in the case of extremely complex music, reliance on mental representations as a prerequisite to performing presents certain disadvantages in terms of cognitive workload, which can be outsourced to the environment, in part or in whole. But mental representations can potentially be part of the game and stand in for various parts of the system, in the sense of the mental representations as reviewed before.

Let us now review some theories of sensorimotor prediction.

A. Predictive Models

In chapter 6 of his latest (2016) book *The Expressive Moment: How Interaction (with Music) Shapes Human Empowerment*, Marc Leman argues that sensorimotor prediction is one of the cornerstones of what he calls the *dynamics of expressive interaction* (the other two being entrainment and expressive alignment, to which chapters 5 and 7 respectively of the book are being dedicated). In the context of the embodied navigation paradigm, while entrainment and expressive alignment seem to be harmoniously co-existing with notions of expressive (de)coupling of parametrical layers in relation to a gestural template, the notion of sensorimotor prediction raises some questions. We address those, being fully aware that the embodied navigation addresses higher-level and longitudinal processes, in comparison to sensorimotor prediction that addresses interaction at a "molecular" level.

The theory of expressive prediction according to Leman "is based on the idea that the human brain is a predictive machine that forms beliefs through sensory interaction with the environment" (p. 124). In its basic form, the prediction model posits that motor commands by a performing subject are inextricably associated with sensory expectations, namely expectations about the kinesthetic / proprioceptive outcome of the movement (internal expectation), the sensory outcome of the action, and the potential perception of other external or environment stimuli (external expectations). Those expectations seem to work part and parcel with the commands in both directions, so that either a motor command generates the expectation of a desired output and / or, vice versa, the expectation generates the relevant command. If the first component of this prediction model is the close relation between motor commands and expectations, then the second component addresses the comparison between the actual perceived outcome, or external simulation, to the expected one. Thus, a trumpeter who has used his lips and fingers to produce an expected pitch might for different reasons have failed to do so. The perception of the difference between the expected and perceived output is termed *prediction error*. This error allows then for a third stage in the sensorimotor prediction loop, namely the updating of the system of expectations and motor commands, so as to minimize the prediction error and fit it to the real outcomes.

Other important features of such predictive models include:

a) the fact that they allow for internal simulation of the expected outcome during the execution of the action, so that a motor command can be intentionally guided without the need of sensory feedback or continuous sensory monitoring, which is far too slow and cognitively charging.

b) the fact that they are forward-looking, again in relation to the limitations imposed by feedback models
c) the fact that they can be inverse, in the sense that expectations for the sensory outcome drive the actual commands. This variety is called *ideomotor theory* (Hommel 2013[320]) and posits intentionality at the core of musical performance.

B. An Example Of Predictive Model For Musical Performance

An ideal example for the application of the expressive prediction theory to musical performance is provided in Leman, p. 134, summarized by the author as follows:

"The procedure works as follows: First, the notes are re-conceptualized as a scale using a chunking process. Second, the scale chunk is handled as an object concept. Third, the object concept activates a motor command involving an inverse predictive model. This sets the readiness for action, and initiates the action at the time of the action execution. Fourth, the motor command is executed using a forward predictive model that simulates the action to produce expected sensory outcomes. Fifth, the produced sensory outcomes are checked whenever that is possible. The prediction error may be used as sensory feedback to adjust the ongoing predictions. Note that predictions allow for a parallel processing of action and perception. Thus, at the start, the musician will imagine the D major scale. This imagery prepares for a performance of the first four notes. Then, while playing these notes, the musician imagines the E-flat major scale, which prepares for the performance of the first four notes of the E-flat scale just as the D major sequence is completed, and so on. The thought experiment suggests that interaction with music can indeed be broken down into a range of cognitive processes, including chunking, imagery, action intention, action execution, and the use of auditory and kinesthetic feedback. In short, the theory of predictive processing offers an understanding of processes in music playing, and it may be instructive as a cognitive model for music education" Leman 2016, p. 139

Here are some preliminary observations about Leman's suggested model in the context of embodied navigation of complex notation exposed before:

Firstly, the simplicity of the musical material being chunked here, namely parts of major diatonic scales, does allow for the rapid conceptualization – objectification – internalization and subsequent imaging of the desired action and sensory output. But what would happen in the case of even slightly more complex musical material, such

[320] Hommel, B. , "Ideomotor action control : On the perceptual grounding of voluntary actions and agents", in *Action Science : Foundations of an Emerging Discipline*, W. Prinz, M. Beisert, and A. Herwig, MIT Press, 2013

as the example of Xenakis' *Mists* reviewed above, whereby multiple strata of parametrical information need to be organized in intentionality nodes networks? The sheer complexity, both qualitative and quantitative of the material, makes the application of predictive models hard from a computational point of view.

Second, interactive aesthetics in many strands of post-1950 composition are programmatically aiming at unpredictability. The best example would be Klaus Karl Hübler's or Wieland Hoban's layers of independent actions, with the intentionality of an indeterminate sound result. How would predictive models be applied in such cases ?

Third, the process is being presented in strict algorithmic fashion, with the only exception being the feedback loops allowed in terms of error prediction. Such linearity seems to be at odds with the claim for musical performance as a non-linear system of interactions between the embodied mind, the notation and the instrument. The non-linearity, we claim, aims at explaining the *emergence* of intentionality, before it is fully at work in predictive models triggering actions; or, to use Merleau-Ponty's terms: It aims to "slacken the intentional threads which attach us to the world and thus bring them to our notice"[321] (Merleau-Ponty 1962, p. xiii).

Fourth, at the core of this model stands the brain's ability to imagine and simulate actions and outcomes, based on previous learning. The compatibility of computational and embodied variants of cognition, such as also advocated by Clark and Rowlands, allows for a smoother integration of such models in embodied cognition debates. However, the radical embodied stance criticizes such models as lapses towards a representationalist view of cognition. The question being raised is: Would prediction be possible without mental representations? A positive answer to this question would allow for a smooth integration of predictive models in the program of radical embodied cognition. Positive answers to this question have actually been proposed. An example is the question around the *optic flow* and its sufficiency to guide action, as opposed to its reliance on *extra-retinal information* or *efference*

[321] Merleau-Ponty, M. 1962. *Phenomenology of Perception*, London: Routledge & Paul.

copies, which equal mental representations. For an overview, refer to Chemero 2009, p. 126.

Fifth, such models are claimed to allow for generalization at the level of expression:

"Note also that what is said here about note chunks can also be applied in more detail at the level of expression. We are then speaking about articulations of notes, co-articulations and about the articulation of expression arcs that control the timing, dynamics and the articulation of larger sequences of notes". Leman 2016, p. 139.

However, the passage from a cognitively manageable amount of information to the complex nested information, which we have claimed as "the level of expression", is not further analyzed. How is this passage effected? Linearly or non-linearly? The level of expression has already been shown, so is our thesis, as an emergent property out of interactions, rather than an independent layer on top of some 'basic' sensorimotor learning.

It is exactly music of staggering notational complexity and navigational aesthetic intent that questions predictive models. At the same time, such music invites alternatives based on the notion of direct perception and embodied cognition.

Even in the case of music not that complex, a main line of criticism from the point of view of radical embodied science is expressed by the following passage by Thelen, questioning particularly Piaget's *object-concept* cited by Leman:

"We propose here a radical departure from current cognitive theory. Although behavior and development appear structured, there are no structures. Although behavior and development appear rule-driven, there are no rules. There is complexity. There is a multiple, parallel, and continuously dynamic interplay of perception and action, and a system that, by its thermodynamic nature, seeks certain stable solutions. These solutions emerge from relations, not from design. When the elements of such complex systems cooperate, they give rise to behavior with a unitary character, and thus to the illusion of structure. But the order is always executory, rather than rule-driven, allowing for the enormous sensitivity and flexibility of behavior to organize and regroup around task and context." (Thelen 1994, xix)

Another model for the assessment of why predictive models are not fit to describe complex dynamic processes, such as the performance of a complex musical score, has been provided by Van Gelder's critique of computational approaches to the Watt Governor.

Remember a supposed computational approach to the Governor, which very much resembles Leman's account in that it chunks the process into algorithmic steps:

1 Measure the speed of the flywheel.
2 Compare the actual speed against the desired speed.
3 If there is no discrepancy, return to step 1. Otherwise,
a measure the current steam pressure;
b calculate the desired alteration in steam pressure;
c calculate the necessary throttle valve adjustment.
4 Make the throttle valve adjustment.
Return to step 1.
(1995: 348), in Shapiro 2011, 120.

Van Gelder proposes a comprehensive dynamic description which could essentially start at any given step of the algorithm, or rather avoid altogether such a diachronic sequence of steps, since the speed of the flywall, the height of the balls and the opening of the throttle are constantly coupled and interdependent, given the steal flow. In the same vein, given the first sparkle of intentionality or motivation of the performer to engage with a complex musical notation, all linearly arranged elements of the system that Leman provides us with, that is chunking, imagery, action intention, action execution, and the use of auditory and kinesthetic feedback, would be deconstructed into a self-organized performing system. In such system, motor commands would, for example, appear to alter or even shape the very *chunking* and *object concepts*. And this notwithstanding that, in the hard model of embodied navigation, such object-concepts aka mental representations are judged as contingent in the first place.

C.Are Predictive Models Incompatible With The Notion Of Embodied Navigation ?

Let's review some of the ideas that both models can share.

First, the idea of chunking. While the chunking process in Leman's predictive model is supposed to be an objectification / conceptualization of musical material on the basis of existent patterns (scales), the embodied navigation model suggests multiple chunkings at multiple hierarchical levels of movement co-articulation, based on notational affordances. In that sense, chunking of action-oriented descriptors appears to be a useful heuristic for the management of cognitive overload.

Second, the idea of an algorithmic sequence with environmental feedback loops seems counterintuitive to the idea of navigation along and between several dimensions or strata of chunks. However, the scenario of learning that we defined as 'resistance to the flow' / refinement towards perfection, can indeed profit from a strong predictive model. Still, such model aims clearly at an understanding of interpretation as reproduction rather than as 'line of flight' through a state-space longitudinally formed.

Third, the idea of intentionality cannot be evaded through a navigational model, since motor commands at the lowest physiological level do have incontestable intentional beginnings. The question is rather *which* out of multiple intentions codified in a complex score is driving those motor commands and how is the choice to be made? Or whether (as we claim) embodiment navigates and assembles these fragmented intentions, without necessarily unifying them into a singular concept driving performance. There has been enough evidence in part one to show that, the type of intentionality associated with music notation is often misleading, since most often contemporary scores codify both sensory outputs and motor commands alike in a symbolic way. In that sense, symbolic notation allows for multiple possible entry points and fosters exploration rather than prediction, at least in some stages of the learning process.

Fourth, as will be shown in part three, the very basis of interactive systems materializing the embodied navigation paradigm ar*e effectively based on prediction*, in the form of probabilistic architectures (*Hidden Markov Models*). The question here is rather, to what extent are the states and layers of such models equivalent to objects or mental representations. At the user level, those systems are clearly based on interaction dynamics of entrainment and alignment, and such dynamics have been shown to be able to evade representation. Please refer to 3.4c on mental representations for an overview of mental representations as simulated by dynamic systems.

Concluding: This chapter remains open-ended as to the compatibility of a model of embodied navigation with sensorimotor predictions. Computational limitations, interactive aesthetics bordering on indeterminacy, arguments from phenomenology and radical embodied cognition, and musical expression, all raise questions concerning the nature of intentionality, mental representations and linearity in predictive models. At the same time, there are notions that show towards potential compatibilities: The notion of action-oriented chunking; performance scenarios that tend towards a *reproduction* rather than a *navigation* model; the distinction between the intentionality of motor commands and intentionality in higher-order processes of learning and performance; and eventually the Bayesian architecture of interactive systems themselves, show towards potential compatibilities.

5.2 Embodied Navigation And Gesture

A. Introduction : Embodied Navigation Is Movement, Not Gesture.

We have defined embodied navigation of complex notation as higher-order physical movement in a state-space shaped by notational and instrumental affordances. In that sense, it is important to stress that embodied navigation is not a metaphor for virtual movement inside a musical score, but rather the extension of the notion of physical movement in the physical space of the instrument as articulated by the affordances of the musical score – what we have termed as the score-space. Navigation takes place in multiple time-scales as ontogenesis of the performance, similar to the development of a living organism, from the first stages of learning up to the multiple performances which are traditionally termed “interpretations”. Similarly to navigation defined as non-metaphorical movement, the score-space is *not* a metaphorical space where virtual movement would take place, but rather the dynamic, in-time articulation of the fixed physical spaces of instruments and musical scores by physical movement.

The selection of the term “movement” for embodied navigation is intentionally preferred to the use of the term “gesture”. Understanding this choice of terms begs a review of literature on musical gestures, drawing upon two basic distinctions:

1. The distinction between gesture and physical movement and
2. The distinction between physical / performative musical gesture and virtual / compositional musical gesture.

Both distinctions seem, in our mind, to perpetuate the Cartesian gap between body and mind, despite the fact that gesture is canonically theorized as a hybrid, in-between category between body and mind.

In this chapter we will advocate not for gesture but for real bodily movement as the basis of all cognitive phenomena, in a sort of “reverse cartesianism” which acknowledges the primacy of movement; for movement instead of gesture, as the basis of a radical embodied cognitive science, which avoids altogether the linguistic implications of gesture. We need a model which breaks away from the linguistic aspects of gesture into the pre-linguistic ground of the “expressive moment” (Leman 2016, Gallagher 2005). In line with embodied navigation, movement will be shown to transcend the canonical distinctions of musical gestures (for example, into effective, ancillary, expressive, communicative etc.) and manifest as a real medium of notational information processing, effectively the “corporeal subtext” (Zenck 2014), upon which all musical phenomena are grounded.

B. Definitions Of Gesture

We have shown (parts one and two) how the model of embodied navigation rethinks the UTI (understanding-technique-interpretation) or Frank Cox’s 2002 hmmpp (high-modernist model of performance-practice) paradigm of musical performance. In the current chapter, I will try to show how it rethinks state-of-the art typologies of musical gesture and / or movement. My review of these typologies is drawing from Alexander

Refsum Jensenius' 2010[322] excellent overview of musical gesture taxonomies and relevant research questions, as well as from Shaun Gallagher's 2005 discussion on body image as opposed to body schema and on his integrative theory of gesture. We then address the ensuing issues in relation to the proposed paradigm of embodied navigation. The model of embodied navigation extends and at the same time questions current typologies and distinctions of gesture and movement, by privileging movement and by dissolving the distinction between, for example, effective and expressive gestures. Let us take a closer look at those typologies.

In Jensenious et al. 2010, (as well as in the Jensenious 2017[323]) Jensenious draws attention to the inflated and often confusing use of the term "gesture" for music-related movement, while at the same time acknowledging that the ubiquity of its use reflects its role as a hybrid between physical movement and meaning:

> Given the different contexts in which gestures appear, and their close relationship to movement and meaning, one may be tempted to say that the notion of gesture is too broad, ill-defined, and perhaps too vague. Yet the use of this notion is very convenient in modern music research because it builds a bridge between movement and meaning. A closer look at the term "gesture" reveals its potential as a core notion that provides access to central issues in action / perception processes and in mind / environment interactions. (Jensenious 2010, p. 12)

One main methodological distinction to be made is between the notion of gesture as opposed to movement. The authors argue that:

> The main reason for doing this is that the notion of gesture somehow blurs the distinction between movement and meaning. Movement denotes physical displacement of an object in space, whereas meaning denotes the mental activation of an experience. The notion of gesture somehow covers both aspects and therefore bypasses the Cartesian divide between matter and mind. (Jensenious 2010, p. 13)

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[322] Alexander Refsum Jensenius, Marcelo M. Wanderley, Rolf Inge Godoy, and Marc Leman, "Musical Gestures : Concepts and Methods in Research", in Leman, Godoy (ed.) *Musical Gestures : Sound, Movement and Meaning*, Rootledge : 2010

[323] Alexander Refsum Jensenius, "2014: To Gesture or Not? An Analysis of Terminology in NIME Proceedings 2001–2013", in Alexander Refsum Jensenius and Michael J. Lyons (eds.) *A NIME Reader : Fifteen Years of New Interfaces for Musical Expression*, Springer : 2017

A first remark as to the assertion, that the notion of gesture bypasses the Cartesian divide between matter and mind, should already be uttered here: As has been seen in the overview of the field of embodied cognition above, the very acknowledgement of the hybrid nature of gesture seems to be a truism that even traditional cognitivists would have no reason to dispute. It is rather the dynamic interaction between the mental and the physical and the shaping of the mental by the physical, which needs to be addressed. In this sense, and under certain strands of embodied cognition, physical movement could be seen as already cognitive proper, in that it carries information about a certain dynamic situation in the environment. Thus, it could even be claimed, that it is by terminologically staying closer to the notion of movement, albeit a richer definition of movement which does not denigrate it into a lower status, that one could avoid the Cartesian gap, which is eventually rather perpetuated through the hybrid formation of the concept of gesture.

We will claim that, from a radical non-representational embodied perspective identical to Shapiro's replacement hypothesis, this "blurring" (negative connotation) or "blending" (positive connotation) of the boundary between physical movement and meaning, or between mind and matter, actually creates more problems than the ones it attempts to address: It often results in artificial distinctions and typologies of movement and it tends to denigrate physical movement, constituting what the philosopher Mark Rowlands would call a Cartesian fallback position (Rowlands 2010). On the contrary, as has been shown with the model of embodied navigation exposed above, movement, both as the phenomenological movement coarticulating embodied layers of the music notation, as well as the diachronic navigation in the score-space, forms an indispensable part of the cognitive processes involved in performing, even without the need for mental representations.

Drawing from Zhao (2001) [324] and McNeil (2000)[325] in linguistics, Jensenious adopts their tripartite distinction of gesture as communication, control and metaphor as follows:

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[324] Zhao, L., *Synthesis and Acquisition of Laban Movement Analysis Qualitative Parameters for Communicative Gestures*, PhD thesis, CIS, University of Pennsylvania, Philadelphia, PA.

[325] McNeill, D. (ed.) (2000). *Language and Gesture*. Cambridge: Cambridge University Press

(1) Communication is involved when gestures work as vehicles of meaning in social interaction. This use of the term is common in linguistics, behavioral psychology, and social anthropology.
(2) Control is involved when gestures work as elements of a system, such as in the control of computational and interactive systems. This is common in the fields of human-computer interaction (HCI), computer music, and similar areas.
(3) Metaphor is involved when gestures work as concepts that project physical movement, sound, or other types of perception to cultural topics. This use of the term is common in cognitive science, psychology, musicology, and other fields. (Jensenious 2010, p. 14).

The case for gesture as communication is made through the research of the coupling between bodily movement and speech. In that sense, gestures are "visible actions as utterance" (Kendon 2004)[326], an essential non-reducible part of speech. McNeil (1992)[327] further articulates gestural functions drawing from Ekman's and Friesen's (1969)[328] taxonomy into:

a) iconic gestures (as representation of objects and actions)
b) *metaphorics*, similarly to *iconics* but with a higher degree of abstraction
c) beats, as the gestural punctuation of a narrative
d) *deictics*, as pointing gestures and
e) emblems, as stereotypical patterns acquiring meaning by convention (for example, the OK sign).

According to McNeil, the relationship of gesture to speech is *co-articulatory or co-expressive* (Jensenius 2010, p. 15) and ranges along the so-called *Kendon continuum* (Kendon 1982), from gesticulation (which features the co-existence of speech and gesture) through emblems (whereby speech is optional) to pantomime and sign-language (as forms with an obligatory absence of speech). In that sense,

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[326] Kendon, A. (2004). *Gesture: Visible Action as Utterance.* Cambridge: Cambridge University Press.
[327] McNeill, D. (1992). *Hand and Mind: What Gestures Reveal About Thought*. Chicago, IL: University of Chicago Press.
[328] Ekman, P. and Friesen, W. V. (1969). *The repertoire of nonverbal behavior: categories, origins, usage, and coding. Semiotics*, 1,49-98.

gesture cannot refer to movement *per se*, but rather to to its intended or perceived linguistic meaning.

A more liberal definition of gesture is not restricted in its linguistic communicative aspect but rather considers it as "any movement or change in position of a body segment" (Feyereisen and de Lannoy, 1991, p. 3, in Jensenious 2010, p.15). Such broad definition finds good use in the recent research in the field of human computer interaction and makes a case for gesture as control movement. In contrast to the first wave of interaction as command-lines and singular presses of keyd, HCI nowadays acknowledges the rich potential of embodied and affective computing through the development of sensors-based techniques. The notion of *Expressive gesture* (Camurri 2001)[329] is in that respect an interesting development towards the extraction of expressive features out of spatio-temporal rather than linguistic or denotative characteristics of the musical act. Gesture is in other words observable and objective.

In the computer music literature, Cadoz (1988, p. 64)[330] considers as gesture all non-vocal sound-producing physical behavior, while for Miranda and Wanderley (2006, 5)[331] "gesture is used in a broad sense to mean any human action used to generate sounds. The term refers to actions such as grasping, manipulation, and non-contact movements, as well as to general voluntary body movements." Another important distinction is the one between manipulative and empty-handed gestures, the former based on are based on physical contact, or what may also be called ergotic, haptic, or instrumental contact, in contrast to semaphoric, free semiotic or naked gestures (Miranda and Wanderley 2006).

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[329] Camurri, A., De Poli, G., Leman, M., and Volpe, G. (2001). A multi-layered conceptual framework for expressive gesture applications. In *Proceedings of the International MOSART Workshop*, November 2001. Barcelona, Spain.

[330] Cadoz, C. (1988). Instrumental gesture and musical composition. In *Proceedings of the 1998 International Computer Music Conference.* The Hague, TheNetherlands, 60-73.

[331] Miranda, E. R. and Wanderley, M. M. (2006). *New Digital Musical Instruments: Control and Interaction Beyond the Keyboard*. Middleton, WI: A-R Editions, Inc.

The latter distinction shows already towards the blurring of those categorizations: Are there really control gestures which are purely functional and with no embedded or constructed communicative meaning?

In the rich field of musical gesture defined as metaphor originating in the experience of physical movement, Jensenious cites important work by Métois (1997,16)[332], Middleton (1993)[333], Todd (1995, 1941)[334], Hatten (2003)[335], Delalande (1988)[336] and Gritten and King (2006)[337]. The common ground of all those writers is, that the intentional, communicative and meaning-bearing components of physical gestures can become somehow abstracted from its purely physical component and encoded in musical notation and musical sound alone as musical gestures, which then become proxies for their absent and contingent physical co-articulation, evoking it but not necessitating it. The relation of such considerations to cognitive linguistics, as explored in the Conceptualization Hypothesis of the current, and in particular in relation to metaphor theory as explored by Bob Snyder and Lawrence Zbikowski, is significant.

From the overview of gesture studies presented above, it becomes clear that there is whatsoever no definition of gesture which is not considering it as a hybrid between physical and mental phenomena. It is this fuzziness, which makes Jensenious claim that

> The main advantage of using the term gesture is that it surpasses the Cartesian divide between physics and the mind. As mentioned above, we may think of movement as the changing of a physical

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[332] Metois, E. (1997). *Musical Sound Information: Musical Gestures and Embedding Synthesis*. PhD thesis, Massachusetts Institute of Technology.

[333] Middleton, R. (1993). Popular music analysis and musicology: bridging the gap. *Popular Music*, 12(2), 177-190.

[334] Todd, N. P. M. (1995). The kinematics of musical expression. *The Journal of the Acoustical Society of America*, 97(3), 1940-1949.

[335] Hatten, R. S. (2003). Musical gesture: Theory and interpretation. course notes, Indiana University. http://www.indiana.edu<deanfac/blfal03/mus/must561-9824.html (accessed 1 June 2007).

[336] Delalande, F. (1988). *La gestique de Gould: Clements pour une sémiologie du geste musical*. In G. Guertin (ed.), Glenn Gould Pluriel. Quebec: Louise Courteau, 85-1 11.

[337] Gritten, A. and King, E., (eds.) (2006). *Music and Gesture*. Aldershot, UK: Ashgate.

position of a body part or an object, which can be objectively measured. The notion of gesture goes beyond this purely physical aspect in that it involves an action as a movement unit, or a chunk, which may be planned, goal-directed, and perceived as a holistic entity (Buxton 1986[338], in Jensenious 2010 p. 19).

One could argue though for exactly the opposite: namely, that it is the very fuzziness of the term gesture which will make us prefer the more general term movement, accepting as a given that physical movement already embodies cognitive characteristics.

C. Concepts For The Study Of Musical Gestures

In the fourth section of the above mentioned chapter, Jensenious et al. 2010 offer several important concepts for the study of a. spatial and b. functional aspects of musical gestures. Interestingly enough, the temporal aspects do not feature as a separate field of study, even though they are mentioned in the introduction to the section (p.19) as parts of a subjective phenomenological level of gesture typologies.

As far as the spatial aspects of gesture are concerned, Jensenious et al. provide important grounding concepts, such as the scene of the gesture / performance, the performer's positions and several performance spaces. The scene is defined by the limits between performers and spectators, mostly as a social convention rather than as a purely physical space (which it obviously also is). Body positions pertain to the distinction between the preparation, performance and release of actions, again theatrical conventions which frame a performance in time, trigger audience expectations and assume concrete physical forms. Performance spaces refer rather to frames of action defined from the point of view of the performer's embodiment. Such is the Laban concept of the *kinesphere*, as the frame which defines the possibilities and constraints of a body in a given point in space, as well as spaces for the different functional characteristics of gestures, when those are spatially defined. Thus, in the case of piano performance, Jensenious uses frames for the distinction between sound-producing gestures on the keyboard, sound-modifying gestures in

[338] Buxton, W. (1986). Chunking and phrasing and the design of human-computer dialogues. In H.-J. Kugler (ed.), *Information Processing 86, Proceedings of the IFIP 10th World Computer Congress*. Dublin, Ireland, 475-480

the pedals and ancillary, sound-accompanying, communicative or expressive gestures in the body core. In the context of gesture's spaces, Jensenious lists also characteristics of a rather temporal nature, such as the syntactical articulation of sound-producing gestures in preparation-action-release phases, with reference to Leman's equivalent characterization of actions as bell-shaped, consisting of the same tripartite structure of prefix-excitation-suffix; as well as phenomena of co-articulation in the sense of Godøy, which Jensenious refers to as "nested gestures". From the last two concepts, that is the biomechanical arc of a gesture and its nested nature, it becomes already clear that a purely spatial understanding of gestures as frozen movements, without taking into account their temporal evolution, might present methodological problems – an issue which becomes central in Bevilacqua et al.'s approach to gesture modeling.[339]

From a functional point of view, Jensenious et al. affirm a rather canonical distinction of gestures into sound-producing, communicative, sound-facilitating and sound-accompanying, drawing on previous work by Gibet (1987)[340], Cadoz (1988)[341], Delalande (1988):

a) Sound-producing gestures are those that effectively produce sound. They can be further subdivided into gestures of excitation and modification. Sound-producing gestures are called instrumental gestures in (Cadoz 1988) and effective gestures in (Delalande 1988).
b) Communicative gestures are intended mainly for communication. As will be discussed later in this chapter such movements can be subdivided into performer-performer or performer-perceiver types of communication. Communicative gestures are called semiotic gestures in (Cadoz and Wanderley 2000). Several of these can also be considered gestures in the way Kendon (2004) and McNeill (1992) use the term.
c) Sound-facilitating gestures support the sound-producing gestures in various ways. As will be

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[339] Bevilacqua F., Schnell N., Rasamimanana N., Zamborlin B., Guedy F. (2011) 'Online Gesture Analysis and Control of Audio Processing'. In: Solis, J. & Ng. K. (Eds.) *Musical Robots and Interactive Multimodal Systems.* Berlin Heidelberg: Springer-Verlag

[340] Gibet, S. (1987). *Codage, Représentation et Traitement du Geste Instrumental: Application a la Synthése de Sons Musicaux par Simulation de Mécanismes Instrumentaux*. PhD thesis, Institut National Polytechnique de Grenoble.

[341] Cadoz, C. (1988). Instrumental gesture and musical composition. *In Proceedings of the 1998 International Computer Music Conference*. The Hague, The Netherlands, 60-73.

discussed and exemplified in a later section, such gestures can be subdivided into support, phrasing, and entrained gestures. Sound-facilitating gestures are called accompanying gestures in (Delalande 1988), non-obvious performer gestures in (Wanderley 1999), and ancillary gestures in (Wanderley and Depalle 2004).
d) Sound-accompanying gestures are not involved in the sound production itself, but follow the music. They can be sound-tracing, i.e. following the contour of sonic elements (Godary et al. 2006a), or they can mimic the sound-producing gestures (Godsy et al. 2006b). Jensenious 2010, p. 23-24

Importantly enough, Jensenious et al. stress the potential hybrid functionality of a given gesture, and employ an interesting visualization based on dimension spaces.

From the point of view of embodied navigation, several points can be made in relation to Jensenious' concepts as summarized above.

Firstly, temporal characteristics of physical movement in the typologies in question seem to refer to closed gestures (*prefix-excitation-suffix* structure), or nested gestures in relation to spatial features. Such questions will be dealt with in detail in part three and in particular in the context of gesture modeling as conducted by the ISMM team at IRCAM. At this instance, an open-ended conception of gestures as *multidimensional temporal profiles* allows for the creation of interactive systems that compute gesture dynamically.

Second, the hybrid functionality of musical gestures brings us in principle to the same ontological and epistemological aporia as the hybrid definition of gesture overall: Phenomena that are dynamically connected and indissolubly inter-related, such as, for example, the performance of a chord on the piano employing the technique of free fall (Sándor), should be described through abstractions (in terms of a dimensional space grasping sound-facilitating, sound-producing and communicative / expressive gesture). Amalgamations of features or functions without organic relationship might become methodologically more of a burden rather than illuminating, when their interaction is not meticulously analyzed.

Third, while intentionality forms an integral part of this hybrid definition of gesture as "thinking movement", the interplay of intentionality and action in more complex forms, such as when intentionality is driven by a musical score, remain unexplored.

The model of embodied navigation as physical movement in a score-space attempts to give an answer to these three aporias. Firstly, by focusing on the dynamic, in-time aspects of the player's embodied interaction with the instrument and the score. Second, through the consideration of physical movements as already encoding and revealing cognitive characteristics and performing cognitive functions. Third, through the organic emergence of complex physical movements as interaction between several co-articulated embodied layers with the compositional parameters of the musical notation.

In terms of Jensenious's typology, the focus of the embodied navigation paradigm lies in effective gestures and ancillary ones, only that those are already perceived as expressive in their interaction with and calibration from the musical text. There is no expression as an independent layer added to some basic gestures with communicative intention, but rather emergent expression through dynamic interaction between notation, body and instrument.

An open question concerning embodied navigation in relation to the reviewed gesture taxonomies could be the following: Would exploratory physical movements triggered by a musical score with a loosely-defined intentionality qualify as a different functional type of gesture, possibly a "score-annotation" gesture or a "notation / inormation-processing" gesture?

D. An Integrative Theory Of Gesture

The aporias cited above (hybrid nature of gesture as bridging the mental and the physical and its functional compartmentalization and fragmentation) are addressed by Shaun Gallagher's integrative theory of gesture and distinction between *body image* and *body schema*.[342] His theory is being developed through the merging of two families of gesture theories (motor and communicative) and experimentally confirmed through the study of a deafferented subject, Ian Waterman, who is, despite his lack of proprioception and occasionally vision, able to gesticulate.

[342] Shaun Gallagher, *How the Body Shapes the Mind*, Oxford University Press, 2005

First, we will define and clarify body schema as opposed to body image. Here is Gallagher’s extended definition:

“I defined body image as a (sometimes conscious) system of perceptions, attitudes, beliefs, and dispositions pertaining to one's own body. It can be characterized as involving at least three aspects: body percept, body concept, and body affect. Body schema, in contrast, is a system of sensory-motor processes that constantly regulate posture and movement—processes that function without reflective awareness or the necessity of perceptual monitoring. Body schemas can also be thought of as a collection of sensory-motor interactions that individually define a specific movement or posture, including elementary (relatively defined) movements, such as the rotation of a wrist within a larger movement or the movement of hand to mouth.”

If the body image is conceptually distinct from the body schema, then an account of the body image is not equivalent to an account of the body schema. I have suggested through a phenomenological analysis that the two concepts can be kept distinct, that the terminology does not have to be confused, and that such distinctions are clarifying rather than confusing.

Following this central distinction, we can outline several important facts.

First, to the extent that I become perceptually aware of my body, as something in my peripheral field or as something attended to, then I have an occurrent body percept. Although I may not be conscious of certain beliefs or attitudes that I have concerning my body, in principle I should be able to bring such beliefs and attitudes to consciousness. In contrast, I have suggested that the body schema is always something *in excess of* that of which I can be conscious. Even if I become conscious of certain aspects of my posture and movement, the body schema continues to function in a non-conscious way, maintaining balance and enabling movement.

Second, the body image normally involves a personal-level experience of the body that involves a sense of ownership for the body. The body schema, however, functions beneath the level of personal life. Even in pathologies where there is a failure in regard to a sense of ownership, the body schema may continue to function in its anonymous way, that is, in its ordinary, non-conscious way of dealing with its environment.

Third, the body image involves an abstract and partial representation of the body in so far as one's perception, thought, and emotional evaluation can attend to only one part or area or aspect of the body at a time. Thus, one's body appears in consciousness with certain parts emphasized or singled out. The body schema, on the other hand, functions in a more integrated and holistic way. A slight change in posture involves a global adjustment across a large number of muscle systems.

Fourth, the body, as it appears in consciousness, normally appears as clearly differentiated from its environment. In contrast, the body schema functions in an integrated way with its environment, even to the extent that it frequently incorporates into itself pieces of the environment that would not be considered part of one's body image.

Fifth, consciousness of action tends to be specified in the pragmatic meaning of the intentional task, rather than in terms of a body percept that, depending on circumstances, might involve the perception of muscles stretching, limbs bending or unbending, walking, reaching, standing, or sitting. This means that the body is normally and to some degree experientially transparent, that it effaces itself in its projects. The prenoetic functions of the body schema tend to be subsumed into larger intentional activities. Body-schematic processes are ordered according to the intention of the actor rather than in terms of muscles or neuronal signals. (Gallagher, 38)

This distinction becomes the vehicle for the articulation of an integrative theory of gesture, which brings together the two big families of motor and communicative theories of gesture, identifying the type of movement that gesture involves as irreducible to movement controlled exclusively by body-schema or body –image processes.

Four types of movements constitute Gallagher’s continuum between physical and semantic properties, the latter reserved only for the term gesture proper:

1) Reflex movement, such as the babkin reflex or sneeze, features automatic motor programs.
2) Locomotive movement, such as walking and sitting, is controlled by body schema[343]
3) Instrumental movement, such as reaching and grasping, is again controlled by the body schema.
4) While the expressive movement, such as pointing and gesturing, is controlled by cognitive-semantic and communication requirements.

Thus, an integrative theory understands gesture (movement type four) to be 1) embodied (constrained and enabled by motoric possibilities of the body schema); 2)

[343] (but can be controlled by body image in Ian Waterman, a deafferented subject who has lost proprioception and controls movement through seeing).

communicative (pragmatically intersubjective); 3) cognitive (contributing to the accomplishment of thought, shaping the mind, intra-subjective).

While Gallagher concurs with McNeil, that ‘Gestures are not just movements and can never be fully explained in purely kinesic terms. They are not just arms waving in the air, but symbols that exhibit meanings in their own right (McNeil: 1992, 105) or ‘Gesture and language are one system’ p.2, he argues at the same time that sufficient motor control or constraints are equally important and that gesture can never transcend embodiment.

Instead of asserting a fuzzy border between cognitive and physical characteristics, Gallagher achieves a very precise anatomy of gesturing through the description of four different aspects of expressive movement:

- The initiation of the gesture (generally unconscious but inhibitable) as cognitive and communicative.
- The launching and timing as cognitive and communicative.
- Morphokinetic semantics as cognitive and communicative.
- But topokinetic properties as controlled by body schema and proprioception.

Concluding, the reason that we are using the term “movement” rather than “gesture” is that body schematic (as opposed to body image) properties seem to be the least common denominator in Gallagher’s integrative theory of gesture. Movement is present in a spectrum from reflex to expressive through locomotive and instrumental, with an increased accentuation of cognitive (meaning linguistic as thought-shaping) and communicative characteristics as we approach the expressive end. The same movement is described as a shift from topokinetic (body schema, proprioceptive) to morphokinetic (body image, visual) characteristics. Embodied navigation explores the whole range of topokinetic and morphokinetic, as well as motor, cognitive and communicative features. One may navigate, so to speak, between morphokinetic and topokinetic features. Notation in itself amalgamates several of those characteristics: Thus, the note-to-note resolution integrates the topokinetic precision of musical gestures (movements), while linguistic formations, such as musical phrases, take as to the morphokinetic aspects, which should be associated to the arm-layer, with the grasp and quasi-grasp layers functioning as intermediates to this movement.

The last word on body schema as environmental interaction belongs to Gibson:

"One might say that the body schema is not something entirely in-itself; through its posture and motor activity the body defines its behavioral space and environment under constraints defined by environmental affordances." (Gibson 1979) (p. 37),

Those affordances we have defined both as physical (instrument, biomechanical constraints) and as symbolic (notation).

5.3 Embodied Navigation And Corporeal Articulations

A. Embodied Mediation

The current chapter engages in more detail with Leman's earlier notion of corporeal articulations in his *Embodied music cognition and mediation technology*. Its objectives are:

1) To clarify his definitions of first-, second- and third-person descriptions
2) To use these definitions for our methodological passage from static representations in the form of multilayered tablatures into the use of multimodal interactive systems, equaling a passage from first-person to third-person descriptions
3) To show his theory of communication based on corporeal articulations, extended from the performer-listener bipole to the composer-performer relation

The relationship between mind and matter has been one of the recurring themes of philosophical and musicological research alike. However, it should be noted that this mediation from physical energy to meaning has traditionally mostly referred to the perception of music by listeners. The case for performers of notated music remains under-represented. In particular, those performers often start with a symbolic score as proxy of encoded sonic output (descriptive notation) and less so, physical actions and realities –gestures, movements, instruments (prescriptive notation), which they are expected to interpret and to intentionally invest before the praxis of performance. The body as a mediator between codified meanings in the form of music notation and the actual physical energy of the performance, *pre-compositionally* as *corporeal subtext* (Zenck), as well as *post-compositionally*, as the performer's embodied navigation of the text, has not been adequately researched in terms of embodied cognition.

One of the main questions of this chapter is: In the case of composer-performer communication, can the body be seen as mediator in the same or in a similar way, as in the performer-listener communication?

Leman's point of departure is the gap between existent mediation technologies, which transmit encoded physical energy, and human modes of signification. Leman has described a two-way embodied mediation between physical energy and abstract meaning:

> It is based on a hypothesis about the nature of musical communication, which is supposed to be rooted in a particular relationship between musical experience (mind) and sound energy (matter). In this mind / matter relationship, the human body can be seen as a biologically designed mediator that transfers physical energy up to a level of action-oriented meanings, to a mental level in which experiences, values, and intentions form the basic components of music signification. The reverse process is also possible: that the human body transfers an idea, or mental representation, into a material or energetic form. This two-way mediation process is largely constrained by body movements, which are assumed to play a central role in all musical activities. The embodied music cognition approach assumes that the (musical) mind results from this embodied interaction with music. The approach can be considered an extension of, or perhaps an alternative to, the classical (disembodied) music cognition approach. (Leman 2008, xiii).

We focus on the performer-specific side of this communication model (from meaning to physical energy), with the significant twist that we are talking not of mental representations, but rather of symbolic representations in the form of notation. In other words, we are talking about a model of composer-performer communication, as mediation between symbolic signification and physical energy, through performative corporeal articulations. Rather than mere mediators, we also adopt a radical embodied cognitive science position, whereby the body is *constituent* of the cognitive process of understanding the symbolic signification, in the form of its diachronic manipulation (or external processing) through physical movement and gesture. Our model of embodied interaction with complex notation extends Leman's model to the mediation technology of musical notation, through augmented and interactive notations and musical representations (part three) : How could the medium of notation a) encode rather than represent physical energy and b) be interactively manipulated through the body, offering an example of action-oriented mediation between composers, performers and listeners. After his distinction between description and experience, part of the goal of this PhD is the transformation of the score from a symbolic mediator into an actual physical mediator.

The embodied navigation model as exposed above is the outcome of artistic or practice-led research, fueled by self-reflection and theories in cognitive science. The proposed outcome in the form of a tablature might be seen as the equivalent of a state-space in a dynamic system, cannot though capture the dynamic nature of the process of learning and its longitudinal quality. One could claim that such representations are not much different from performer's annotations, in their subjective / implicit- becoming - objective / explicit character. In that sense, they are similar to first-person descriptions and that is a methodological problem. We tackle this problem through our resorting to third person descriptions, via the use of multimodal data for action, action measurement, and action-based descriptors.

To sum up, moving sonic forms *and symbolic forms alike* may be captured by corporeal articulations (movements and / or gestures). This realization may form the basis of a kind of universal music description that is of interest to music mediation technology.

b. Descriptions

Performer-specific embodied interaction with complex musical scores has moved on from the initial stage of subjective first-person descriptions (in the form of abstract understanding as the basis of a UTI model), to measurement-based third person descriptions (to be presented in part three, as the basis of a TUI model), via second-person descriptions in the form of an external processing of the notation, that is in the form of multilayered tablatures.

Here is a further clarification of the notions of first-, second- and third-person descriptions by Marc Leman:

“The **first-person descriptions** in musicology draw upon interpretations of intentions attributed to music, such as an attribution of ‘‘inner victory of the spirit’’ to a passage in Beethoven’s Piano Sonata in A. This attribution is possible because the information picked up from physical energy is used to define properties of objects that are relevant in view of the subject’s action-oriented bias. Thus, moving sonic forms receive the status of actions to which intentionality can be attributed. Interpretation aims at finding the source of the attributed intention. In doing this, it often puts intentions in a historical and cultural framework. Through the lens of subjective interpretation, personally experienced intentions enter into the domain of a linguistic-based description of the world. Thus, music description acquires the status of a meaningful but personal narrative which other people can understand because they share similar interpretations of the environment. The description results from a subjective interpretation. It is both intention-based and symbolic / linguistic. In contrast, **third-person descriptions** are about repeatable measurements of phenomena. These measurements, in principle, can be obtained by any observer, or can be made by a machine or with the help of a machine. By putting knowledge of human information processing mechanisms, as well as knowledge of user conventions, into a machine it is possible to measure high-level structural and semantic properties directly from physical energy such as pitch, loudness, tempo, and particular affects such as ‘‘sad’’ or ‘‘happy’’. In addition, subjective involvement with music can be observed from the third-person viewpoint. For example, a subject’s movement of arms and legs in response to music, or brain activity, can be recorded and further analyzed from a third-person perspective.

Second-person descriptions are used to show, express, and articulate the private experience from one subject to another. They imply a ‘‘me-to-you’’ relationship. Both subjects have a disposition to show, express, and articulate music, and therefore can understand the experience on the basis of such a shared expression. It is like a doctor who asks a patient to describe what he or she feels. The nonverbal and verbal articulations of the patient express what is perceived and experienced. Based on that information, the doctor should be able to make a correct diagnosis. The patient’s articulations should avoid interpretations and associations. At the lowest level, the articulations can be related to bodily behavior which the doctor observes. At the highest level, they may involve verbal descriptions of corporeal feelings. Second-person descriptions reflect involvement with physical energy in a context of intersubjective communication. Yet, in being subjective, these descriptions can be elusive and bound to a number of subjective factors. Note that second-person descriptions comprise nonverbal articulations as well as verbal descriptions. Verbal descriptions of observed states of the human body involve self-observation and sometimes interpretation, and in that sense they may come close to first-person descriptions. Indeed, it may be possible to consider a continuum of steps from low-level corporeal articulations, to vocal utterances, to high-level conceptualized self-observations, and, finally, to interpretations which relate bodily behavior to cultural topics. In my definition, only the latter would be considered genuine first-person descriptions. Clearly, not all verbal descriptions rely on hermeneutic interpretations. There is sufficient room for considering a self-contained category of nonverbal as well as verbal descriptions that have their origin in corporeal articulations rather than in cultural associations. The intimate nature of these descriptions is in agreement with a social context where two subjects interact; hence the name ''second-person description.'' (Leman 2008, pp. 79-82)

Interestingly enough, the tripartite schema presented by Leman –an abstracted subjective interpretation of intentionality, communicated via intersubjective descriptions mixing verbal and corporeal articulations, ending up in objectively codified sound energy- reflects pretty neatly the classical Understanding – Technique – Interpretation paradigm of piano performance as well, even if in some sort of reverse order : The subjective interpretation occupies in the latter rather the end phase of a communication chain, whose starting point is the supposed objectified nature of the musical score to be transparently interpreted or understood. In Leman, the process is considered as a two-way mediation, including both top-down (subjective) and bottom-up (objective) descriptions. The transition is effectuated through the body-mediator, on the basis of performer's intentionality and expressive goals. For an application of this two-way mediation process in contemporary piano performance, please refer to Caruso 2016[344].

In our revision of the UTI towards a Tangible User Interface (TUI) model of communication, interpretation and intentionality *emerge* as first-person descriptions in the course of embodied interaction with the elements of the performing system, bodies, instruments and notations, codified in intersubjective, second-person descriptions and objectifiable in the form of third-person discriptions. As it will be shown in part three, the crucial transformation which facilitates such understanding is the conceptual and physical merging of notation and instrument.

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[344] Giusy Caruso, Esther Coorevits, Luc Nijs & Marc Leman (2016): Gestures in Contemporary Music Performance: A Method to Assist the Performer's Artistic Process, *Contemporary Music Review*, December 2016 http://dx.doi.org/10.1080/07494467.2016.1257292 accessed 05.05.2018

One of the great advantages of Leman's notion of several levels of description remains its ubiquity in describing both a UTI as well as a TUI model of interpretation or interaction respectively.

PART THREE:
EMBODIED NAVIGATION OF COMPLEX PIANO NOTATION THROUGH INTERACTIVE SYSTEMS

1.Abstract

If the first part of this dissertation exposed the reasons, the “why” for revising the model of interaction with complex notation, and the second proposed a new model, the “what” of embodied interaction with complex notation, then the third part will introduce the technological implementation of notation as gesturally controlled interface, or: the “how” can an embodied model of interaction with notation be materialized and externalized through new interactive technologies.

In the second part, we introduced the notion of embodied navigation, as a paradigm of embodied interaction with musical notation. Instead of mentally understanding and then physically executing, the performer is assumed to be constantly processing notation through bodily movement in an expressive and dynamic way. We represented this model and process by means of static multilayered tablatures, which consist of different embodied layers of action coarticulation.

Two are the central aporias with means of representation of embodied navigation: First, the very fact that they are static, while describing a highly dynamic and longitudinal phenomenon of navigation in a state-space of interpretational possibilities. Second, the fact that they constitute subjective, second-person descriptions from the performer’s point of view. In that sense, they don’t differ substantially from ancient annotational practices of performers, which in themselves reflect and codify this constant form of notational processing.

The introduction of interactive multimodal systems for the embodied and expressive navigation of complex notation has then two objectives: First, to provide live, dynamic representations of the paradigm of embodied navigation; second, to attempt bridging the methodological gap between artistic practice and scientific research, by employing objective data and third-person descriptions. The field of interaction will address a significant set of questions, such as: To what extent can notation be regarded as an extension of the instrument and an extension of the human body;

why is difficulty important as an expressive factor; and what can we learn about traditional performance from the field of Music Interaction.

A third reason for using and developing appropriate interactive systems for the embodied navigation of complex notation is the amalgamation of notation and instrument into a single interface. Such a project is drawing from the modern conception of instruments as extendable, transparent and open-ended interfaces. If symbolic notation can be considered as an integral part of the instrument and vice versa, then we need to find ways to materialize this integration and transfer knowledge from the field of Human Computer Interaction and instrument building (a.k.a *New Interfaces for Musical Expression*) into the domain of musical notation and representation. This conception of notation as instrument opens up the way to the integration of several theoretical strands, concerning the interaction between humans and instruments and between human and machines, into the field of interaction between humans and notation. Humans may interact with notation in an embodied way, either in its traditional form, or in technologically enhanced, extended and augmented forms based on sensor-based interactive systems. Interestingly enough, such extendability opens up possibilities for embodied interaction with symbolic systems beyond music notation, the foundations and implications of which were analyzed in part two, “The Conceptualization Hypothesis”.

The intra-complexity of music notation offers a very nice example of such potential transfer of knowledge from HCI. To the question (and often criticism) “why should music notation be that hard?”, one may seek answers in music HCI, which accentuate not usability and efficiency but rather appropriate degrees of difficulty for longitudinal engagement and flow.

Another dichotomy that comes into play concerns the traditional as opposed to technologically enhanced forms of notation, similar to the dichotomy between acoustic, digital and augmented instruments. In the same vein, we could consider traditional notations as well as notations specifically made for new instruments, and eventually augmented notations.

The scope of this dissertation remains mostly limited to the interaction between a soloist and the very interface of notation. However, the guidelines and systems presented below could be adapted to the interaction among more players, conductor and players, and eventually listeners and players.

Finally, the field of interactive systems introduces wholy new means and concepts related to the interaction dynamics with a musical score, namely expressive alignment, entrainment and sensorimotor prediction, as reviewed by Marc Leman in his latest book *The Expressive Moment*.

Concluding, the objectives of this part then are:

1. To show the necessity of interactive systems for the materialization of the paradigm of embodied navigation.
2. To show the development and usage of such systems.
3. To show their integration in the context of a wider field of interaction, which refers both to musicology and to creative practice.

The third part will be articulated as follows:

Firstly, I will present an overview of the field, including the distinction between musical interactions in general, often overlapping with embodied cognition, and human-machine interaction.

Second, I will look at work, both creative / compositional and musicological, which is relevant to my project, before investigating the specific methodologies and tools having been developed at IRCAM and eventually their applications in my own work.

Third, a customized technology based on the notion of embodied navigation will be introduced: *GesTCom* (Gesture Cutting through textual complexity).

While the construction of interactive music systems and digital instruments stands at the centre of Musical Interaction and HCI, the analysis of traditional music performance is also important. The current project bridges both objectives, in the sense that it does develops a new interactive system, *GestCom*, for the analysis of the performance of very complex, albeit mostly traditional, notation.

On a final note, please be attentive to the ambivalence of *interaction* referring both to Music Interaction as:

“Music and Human-Computer Interaction” : Music Interaction encompasses the design, refinement, evaluation, analysis and use of interactive systems that involve computer technology for any kind of musical activity, and in particular, scientific research on any aspect of this topic. Music Interaction typically involves collaboration between researchers, interaction designers and musicians, with individuals often able to play more than one of these roles.” after Holland & Co.;

and “Music Interaction”, in the sense of the expressive dynamics of entrainment, alignment and sensorimotor prediction, after Leman.

2. Introduction

This introductory section addresses the distinction between music interaction (MI) and music human-computer interaction (MHCI). While those two fields are in effect communicating vessels, obviousy heavily overlapping and mutually influencing each other, it is necessary to address the scope of each and assess their respective relevance for our project.

2.1 What Is Music Interaction. Distinctions Between MI And MCHI.

The word *interaction* signifies the dynamic reciprocal relationship between two agents. Taking into consideration the diversity of roles, materials, genres and social contexts that music-making encompasses, it is easy to acknowledge the breadth of the field studying music interactions and known as Music Interaction (abbreviated to MI). Thus, one may talk of MI research in activities as distant as that of a digital luthier, an algorave[345] practitioner, a classical pianist or a listener of folk music; in group musicianship as well as in solo performance; with or without machines; stretching over the whole range of musical materials as understood in Western art music and in other traditions and practices. It is in fact hard to imagine any musical activities at all, which would not feature interaction of some sort. From a dynamic systems perspective, interaction in music is ubiquitous.

The focus on music interaction has however been a relatively recent trend in musicology and one directly linked to the digitalization of culture. Thus, for Holland and co. (2013)[346],

Music Interaction refers to “Music and Human-Computer Interaction”. Music Interaction encompasses the design, refinement, evaluation, analysis and use of interactive systems that involve computer

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[345] An algorave is an event where people dance to music generated from algorithms, often using live coding techniques, and short for "algorithmic rave".

[346] Simon Holland, Katie Wiwlkie, Paul Mulholland, Allan Seago (eds.), *Music and Human-Computer Interaction*, Springer-Verlag, London, 2013

technology for any kind of musical activity, and in particular, scientific research on any aspect of this topic. Music Interaction typically involves collaboration between researchers, interaction designers and musicians, with individuals often able to play more than one of these roles. (Holland, 2013, p.5)

Interestingly enough, developments in the very field of HCI seem to have often been driven by considerations for music applications, as vividly demonstrated in the work of the pioneer interaction designer Bill Buxton. Buxton influenced considerably the move from the early command line interfaces towards gestural interaction with the computer, as documented in Buxton 1979[347] and recognized music as a prime field for studying human-computer interaction:

One thing that I want to emphasize is that the real objective of the system's designers was to study human-computer interaction, not to make a music system. The key insight of Ken Pulfer, who spearheaded the music project, was that to do this effectively he needed to work with users in some rich and potent application domain. And he further realized that music was a perfect candidate. Musicians had specialized skills, were highly creative, what they did could be generalized to other professions, and perhaps most of all – unlike doctors, lawyers and other "serious" professions – they would be willing to do serious work on a flaky system at all hours of the day and night. (Buxton 2008, cited in Holland 2013, p.3)

The mutual influence of MI and HCI and their practical merging into the field of MCHI should not lead us believe, either that MCHI deals only with digital musical practices, or that MI is in fact identical to MCHI.

As to the first point: While a significant portion of MCHI research is indeed oriented towards the development of new interactive music practices, based on new systems and interfaces, there is an equally significant portion of systems designed for the study of traditional musical performance and interactions. The first direction could actually be identified with the NIME community, a

[347] Buxton,W., Sniderman, R., Reeves, W., Patel, S., & Baecker, R. (1979). "The evolution of the SSSP score editing tools. " *Computer Music Journal*, 3(4), 14–25C60.

"musical and instrument-building tradition concerned with gesture" that "goes beyond enhancing traditional instrument performance practice to looking at new paradigms for instrumental performance" (Tanaka, p. 234)[348]

The second direction of MCHI would rather feature a much broader study of interaction, including the study and modeling of musical gesture in general[349] and the study of traditional music practices[350], but always on the basis of new technologies.

As to the second point: Marc Leman proposes a different basis for music interaction, terming it rather *expressive interaction*, which does also incorporate the use of customized interactive systems, but has a much broader field of applications:

"With this book I propose a general framework for understanding expressive interactions. The focus is on the dynamic, fast, pre-reflective processes that form the basis for successful interaction with music. Examples of such interactions are playing music, dancing in synchrony with music, listening to music, and many other forms of interaction that have now become possible thanks to the new interactive technologies: running or jogging with music, using music as biofeedback for sensorimotor rehabilitation, and so on". p. 1, Leman 2016

Dovetailing with his famous music embodied cognition, Leman proposes an embodied understanding of expressive interactions with music, which is not limited to cognitive processing.

While the goal-directed dynamics of interaction remain cornerstone in the form of mind-state construction, comprehension of ongoing processes as intended goals and assessment of states in terms of future rewards (p.1), Leman's contribution "relies on ongoing, pre-reflective, back and forth *corporeal articulations* that mark and

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348 Atau Tanaka, "Sensor-based Musical Instruments and Interactive Music", in Dean 2009, pp. 233-257

349 Featuring, for example, Godøy's theory on *sound-action chunks* or Bevilacqua's modeling of musical gestures through the *gesture following* paradigm, as will be explored shortly.

350 Indicatively : Andrew McPherson and Youngmoo Kim, "Piano Technique as a Case Study in Expressive Gestural interaction", in Holland 2013 ; Diana S. Young, "Capturing Bowing Gesture : Interpreting individual technique" in Jorge Solis, Kia Ng 2011, Baptiste Caramiaux, Marcelo Wanderley, Frédéric Bevilacqua, "Segmenting and Parsing Instrumentalists' Gestures", in J. New Music Research vol. 41, no 1, pp. 13-29, 2012

constitute the interaction" (p.3). In other words, Leman places the epicentre of expressive interaction "upon process that allow the ongoing flow of the interaction in terms of expressive signs", while fully embracing the understanding of interaction in terms of intention models.

The issue of intention models in music is however heavily criticised by a significant number of recent research, especially when longitudinal studies of long-term engagement with music, such as the learning of a new musical instrument, are concerned. Articulating a significant difference between the general HCI and HCI in music, McDermott et al argue that music is an *autotelic activity*, whereby rather than efficiency in achieving goals, what counts long-termly is engagement and flow[351]. As a result, a multi-dimensional notion of diachronically shifting difficulty becomes often more important than the easiness of use, which often features in general interaction studies.

The same breadth of a working definition for interaction is finally shared by the ISMM team at IRCAM, under the auspices of which this project is conducted. It includes research and development on interactive music systems, gesture and sound modeling, interactive music synthesis, gesture capture systems and motion interfaces. The applications cover the performing arts but also the audio industry, sound design, gaming, and emerging applications such as rehabilitation with auditory feedback. The team has an obvious strong focus on MCHI through the development of customized hardware and software for music interaction, such as the *R-IoT* sensor & the *Modular Musical Objects*[352], or the *MuBu,* the *Gesture Follower*[353] , the *Collaborative Situated Media*[354] etc. At the same time, there is an equally strong interest in the conceptual frameworks that guide interaction, such as embodied cognition, collaborative aspects of interaction, conceptual metaphor and gesture design, so as to justify a footing on MI as well.

351 James McDermott, Toby Gifford, Anders Bouwer, and Mark Wagy, "Should Music Interaction Be Easy?" in Holland 2013, p. 30 citing Csikszentmihalyi, M. (1991). Flow: The psychology of optimal experience. New York: Harper Collins.

352 http://ismm.ircam.fr/devices/ accessed 28.04.2018

353 http://ismm.ircam.fr/category/software/ accessed 28.04.2018

354 http://cosima.ircam.fr/page/2/

In a nutshell: The distinction between MI and MCHI is pertinent in the field and very much so for the current dissertation. MI is characterized by the study of almost every aspect of music-making, often but not necessarily and only contingenty with the use of dedicated technologies, while MCHI is focusing on both the development of new musical interfaces and practices, as well as the research on traditional practices through new tools. If the second part of this thesis was exactly the exploration of MI in the form of a model of embodied interaction with complex notation, then this chapter opens up to MCHI through the exploration of systems dedicated to the analysis of embodied navigation. Interestingly enough, the *GesTCom* prototype bridges both directions of MCHI, because it is a new interface used for the analysis of traditional music performance, albeit in the under-researched field of complex piano music.

For the scope of our research, we understand interaction in both senses: As scientific enquiry and analysis of the performance on the traditional acoustic instrument, and as the design of new interactive systems, which materialize the model of embodied navigation. The significant twist in this research is that we focus on notation as part of the instrument, eventually as part of the dynamic system notation-body-instrument, so that the notion of interaction in this thesis could be reformulated as: *The study of the expressive dynamics between body-instrument-symbolic representations, with and without the use of interactive systems.*

2.2 The Amalgamation Of Notation And Instrument [355]

The hybridization of notation and instrument can be considered as a cognitive movement from representation to enaction. Features of such hybridization are latent in every notation, as a mix of descriptive and prescriptive functions. Current advances in the fields of computer music representation (interactive scores, International Conference on Technologies for Music Notation and Representation (TENOR) and New Interfaces for Musical Expression (NIME)), with predecessors in

[355] This chapter was initially presented in a reduced form as a paper in the proceedings of TENOR 2015 under the title “notation as instrument : from representation to enaction”, in collaboration with Eric Maestri :
http://tenor2015.tenor-conference.org/TENOR2015-Proceedings.pdf accessed 12.04.2018

graphic and action-oriented scores, are turning notation into a *shared multimodal platform between composer and performer*, liquidizing the limit between notation and instrument. We will briefly present this dynamic rapport between scores and interfaces (haptic interactions, post-Klaus K. Hübler tablature notations of decoupled action-structures) in the light of several theoretical models (enaction defined as navigation of affordances from the field of embodied and extended cognition, Leman's action-reaction cycle extended from instrument-making into notation, Veitl's conception of software as tablature, Atau Tanaka's definition of instruments as open-ended systems, Rasmussen's model of information-processing). We are following an explicit line from new interfaces involving notation back to graphic and action-oriented scores, considering them in the theoretical framework of enaction.

A. Ontology Of Notation Today

In an extension of its primordial role as recording of musical praxis and mnemotechnics, music notation today is still assuming the central position in the sophisticated communicative chain of conception, composition, performance and reception. This role persists despite the 'performative turn' in musicology, which advocates the multiple nature of the musical work of art beyond an *Urtext* and into performances, recordings and improvisations[356] ; and despite the problematizations in view of music's medial extension, paradigmatically in early electronic music[357]. The role of notation today could be described as one of *attracting* compositional activity and *releasing* performing activity. All compositional activity is aiming at the generation of notation, all performing activity is itself generated by notation, thus a linear model of musical communication, with notation in the centre as a mediator between composers and performers.

Interestingly enough, the linear nature of this arrangement is perplexed by the omnipresence of performance inside composition and vice versa: From a composer's perspective, notation attempts to codify a future presence of performing bodies and

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[356] N. Cook, *Beyond the Score: Music as Performance*. Oxford University Press, 2014; A. Arbo and M. Ruta, *Ontologie Musicale*, Paris, Hermann, 2014.

[357] C. Seeger, "Prescriptive and Descriptive Music Writing", *The musical Quarterly*, 44, 2, 1958, 184-195.

instruments *in virtue of* their real absence in the act of composition; and from a performer's perspective, this set of virtual presences in the form of notation has to be deconstructed (traditionally through the understanding of the notation and of the composer's intention) and reconstructed in material presences: movement and sound.

Alternatively to this ambivalent communicative chain, notation can be viewed as equal constitutive part in a self–organized, feedback-loop dynamic system, in a formulation originating in the field of 4E cognition. At its current state of development, notation can be thought of and further developed into a shared multimodal platform for both composers and performers in the form of a tablature and / or interface, that is: in the form of an instrument.

We will explore different manifestations of such hybridization, starting with a straight-forward one, Tomás and Kaltenbrunner *Tangible Scores*.

B.Tomás-Kaltenbrunner Tangible Score

The question of an inherent (in-the-instrument) score frames in new terms the problem of interaction design and affordance exploration of instruments and notations alike.

The problem of a differentiation between scores and interfaces is largely debated in the NIME community. A NIME designer develops a notation system that is inherent to the instrument. The designer thus cancels the difference between music composer and instrument maker: the instrument *is* the score. The definition is compatible with Atau Tanaka's definition of instruments as *open-ended systems*, whose architecture includes a structural-compositional layer, next to the input and output systems, mapping algorithms and sound synthesis systems[358].

The example provided by the *Tangible Score* highlights very well this particular evolution. Tomas and Kaltenbrunner claim that different layers, namely the

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[358] A. Tanaka, "Sensor-based Instruments and Interactive Music" pp. 233-255 in R. Dean, *The Oxford Handbook of Computer Music*. Oxford University Press, 2009

instrument and the score, accompany the interaction between the composer and the performer. However, the evolution of electronic instruments implies a radical change in this perspective: The construction of the instrument is not only an instrument-maker realization, but it becomes an act of composing. *Inherent scores* are in this sense an expansion of what an instrument normally is: These instruments expand and reinforce their affordances, acting themselves as objects of the musical composition. The instrument implies gestures and sounds, exploding in a multiplicity of instrumental *morphophoric elements* in the sense of Marie-Elisabeth Duchez:

"The notion herein referred to as morphophoric - or form-bearing - element, has always and unfailingly guided musical action, that is to say strategies of production (inspiration, invention, representation, execution) and reception (listening, memorization). But this essential guidance is first of all only a more or less conscious, empirical practice based on immediate perception. Its efficiency, therefore, though direct and reliable, is limited, and it corresponds to what are generally called "primitive", orally-transmitted musics" [359] Duchez 1989, p. 199

C. Graphic Scores As Proto-Inherent Scores

Tomás and Kaltenbrunner trace back the development of the notion of inherent scores in the 1960s, and in particular in graphic scores. The NIME designer programs the affordances, exactly as a graphic score would in the 50s or 60s merely represent them. These scores are interfaces of interaction with the instruments: The sound result is open, but conducted by the graphic constructions prescribed by the score. *Inherent scores* are similar to *graphic scores*, despite the fact that the first are sound-producing and performable, while the latter are only representational. As remembered by Tomás and Kaltenbrunner :

[…] performing became the creative exploration in freedom of the musical affordances, musical reactions or acoustic relations to the physical space performed, *without the need of any kind of musical notation*. NIME Proceedings 2014, p. 610, my italics

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[359] M.E. Duchez, "An Historical and Epistemological approach to the Musical Notion of "form bearing" element", *Contemporary Music Review*, 4:1, 199-212.

In this sense, inherent scores are evolutions of graphic scores, conceived as musical interfaces. Composers design the instrument, after Lachenman's motto: "*Komponieren heißt: ein Instrument bauen*". (Composition is, to build an instrument)

The *tangible score* is the result of a compositional process that enacts gestures and strategies:

We define a tangible score as the physical layer that is incorporated into the configuration of a digital instrument with the intention of conducting the tactile gestures and movements. Ibid., p. 610

Thus, the tangible score influences and orients the process of enactment of the instrument: it affords tactile gestures and movements. In this sense, this instrument embodies gestural scores.

It needs however to be stressed, that Tomás and Kaltenbrunner focus mainly on the physical interaction, avoiding the problem of the acoustic one. For them, *tangible score*,

"as a traditional score, encodes a musical intention and delegates the decoding part to other agents". p. 610

That is partially true: a traditional score implies sounds that a gestural one does not. The score of a violin sonata is an encoding of the compositional intention via the gestures, that leaves the decoding to the performer agent. However, we must remark that we cannot program differently the sound of a violin. In this sense the *tangible score* is not exactly traditional, but rather an exciting new extension of traditional possibilities. Each instrument has compositional constraints, but, until now, instruments are the result of historical and intersubjective evolution based on fundamental morphophoric elements – like pitches -; the *tangible score*, as mosts of NIMEs, is designed on open morphophoric elements, that can be chosen by the composer or the performer, inventing in that manner different possible arrangements of *the score*.

D. Action-Based Scores

The relationship between notation and instrument, conceived as a trigger of imagined and real gestures, emerges in various works since the 60s. The sonic invention of contemporary music restored the problem of notation, multiplying the number of possible morphophoric elements that inform the composition. Our aim is to remember here three examples that seem to highlight the problem in a historically ordered way.

One important composer that conceives composing as instrument-making is Helmut Lachenmann. In a certain perspective the work of the German composer is inspired by phenomenology and primitivism, and more directly by the references to Schaeffer's *musique concrète* (see also part one). Lachenmann defined his music as *musique concrète instrumentale*. However, behind this intriguing definition, the composer is not making instruments, but was rather exploring new possibilities that were at the time still strongly idiomatic. In *Pression*, a renowned piece for solo cello, the composer invents new sounds and new writing for the cello. In this piece composed in 1969, the composer prescribes the cellist to play in unorthodox manners, precisely notating the gestures and the instrumental parts that must be activated by the performer's gesture.The composer explores the instrument, exactly as the *tangible score* must be explored by the performer.

A milestone in subsequent developments towards the representation of independently organized, or decoupled, actions towards indeterminate sound results is offered by the work of the recently deceased (March 2018) Klaus Karl Hübler, and in particular in his article “Expanding String Technique”[360]. There, Hübler soughts to present a completely new perspective on the instrument, through an expansion of sound and technique that has its roots in the specific resources of the instrument and its manner of performance.

Hübler influenced the next generation of composers, such as Aaron Cassidy, who is known for his original approach to the notation problem. Cassidy's scores invest deeply in the notion of musical gesture. Following the examples of Hübler, Barrett and Ferneyhough, Cassidy works on the notion of *instrumental decoupling*: a separation of the various activities of instrumental sound production. The work of Cassidy expands the approach that we highlighted in Lachenmann: Not only is there

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[360] K. K. Hübler, “Expanding String Technique”, pp. 233-244 in CS Mahnkopf, F.Cox, W. Schurig *Polyphony and Complexity*, Wolke Verlag, 2002.

an exploration of instrumental affordances, but even an exploration of the performer's bodily affordances. Therefore the instrument and the score are means of representation and at the same time stimulation of the gestural content of the player's activity: Physicality is conceived in material terms. In his *Second String Quartet*, Cassidy resumes the gestural parameters to a unique staff, making an evolution in relation with previous work. The score has the role of being the interface for instrumental and physical enactement of the global musical body – the performer and the instrument. In this sense, the score acts as a state space of gestural affordances. The relationship with sound, being open, reveals an element shared with the *tangible score*: The graphics afford gestures on a known instrument, the string quartet, and the performer interacts with the sounds creating the acoustic output, that is not written in the score. In a similar manner the *tangible score* affords gestures creating open sounds possibilities. On the contrary, Lachenmann indicates precisely the sound results.

In all three examples, the score stands in the centre of the relationship between gesture and sound, being an abstract symbolic interface for physical movement, even if with different degrees of sonic prescription.

E. Efforts Of Projection In Time

We are arguing that scores and instruments seem to share a common essence. If scores are, or might be, abstract symbolic interfaces, and instrument concrete ones, we highlight how the recent evolution of new musical interfaces seems to make fuzzy the limit between them.

Scores and instruments not only pragmatically converge today in multimodal interfaces, but they do have a common essence characterized by the typology of intentionality, based on the effort of projection of the maker: composition of scores or construction of instruments are forms of projection in time, based on enactive experience.

The making of musical instruments involves action and perception; it also involves the understanding of the action-relevant value of sounds, the judgment of these sounds in view of musical ideals, and shaping physical environment that produces sound: projections of movements in virtue of the absence of physical presence.The composer, the performer and the instrument-maker project the sound-object in time: They must project their subjective experience in an intersubjective dimension. Projection is expectation of reality based on past experience. The action-reaction cycle proposed by Marc Leman as a paradigm for instrument making (and more widely, for music making and perception), frames theoretically, for us, this concept. If the process of instrument-making, described by Leman as the synergic relationship between "Play, Listen, Judge and Change" is true, then the process of composition can be equally described. In fact

> While a musical instrument is being built, a set of action-reaction cycles, which may occur on different time scales and perhaps in hierarchical order, transforms matter and energy into a cultural artefact for making music [Leman, 2007: 52][361]

There are forms of projections through writing that evolve in technology. Performers and composers are entailed in a similar form of projection, characterized by a different degree of distance from the gestural and sonic output. The projection is the conception of a process of accumulation of experience that comes to define the good shape of the instrument and of the score. Leman underlines the process as the *Ratchet Effect*:

> […] the actual process of instrument-making (ontogenesis) and the history of how an instrument evolves (phylogenesis) can be seen as the result of a repeated cycling of Play, Listen, Judge, Change. The action-reaction cycling is a dynamic model with the capacity to subsume a cumulative process similar to a ratchet effect [Leman, 2007: 54]

In our opinion, we can extend this model from instrument to notation, assuming that in both of them perception induces intentionality and anticipation: The world is conceived from the viewpoint of action and prediction rather than merely based on the construction of *Gestalts.*

[361] M. Leman, *Embodied Music Cognition and Mediation Technology*, MIT Press, Cambridge, 2007.

Scores are the result of a ratchet effect, in the sense that they simulate the economic growing of knowledge during the last centuries, similarly to the instruments. The abstraction of the musical practice in a few number of variables allows a global control of the instruments, that arrives to a certain control of the body of the performer. This kind of prescriptive approach is similar to the machines, that are totally, or almost, controlled. In this sense the composer uses the score as an instrument, as a temporal and physical interface of abstract interaction in time and space: *scores are extensions of the body of the composer in the body of the performer via the projection of the instrument represented by the score*. That creates a singular temporal dimension based on the absence and presence of the instrument: The composer constructs absences and the performer reconstructs the projected presences.

F. Notational System As Performed System

We would like to suggest a framework for the definition of score as instrument, drawing a line between the programming of the sound result and the design of instruments and scores. We would like to argue that if scores are instruments, then this common essence is still developed in NIMEs.

As highlighted by Tomás and Kaltenbrunner, circuits are conceived as scores and instruments, because their combination implies specific sounds. This relationship is at the basis of the conception of synthetic instruments. Also for the pioneer figure of Max Mathews, computer is already an instrument[362]; at the same time the computer is not a normal instrument, but it performs data that are memorized and activated. In the case of NIMEs, the computer is still central. The computer controls the loudspeaker, but the musical interface controls the computer. It is a particular instrument that not only can be controlled by interfaces, like keyboards controls organs, but it can also be programmed in infinite manners.

[362] M. Mathews, "The Digital Computer as a Musical Instrument", *Science*, 1963, pp. 553-557.

The interfaces have a role similar to that of scores: they generate information in real-time, but still record and encode data: Interfaces are, in other words, causal for scores.

Anne Veitl[363], following Cadoz's work[364], focuses on the notion of *causality*, that is the central element of the relation between scores and instrument. The comprehension and the definition of *causality* lies at the centre of the definition of the musical instrument. Veitl's model allows for a kind of generalized instrumentality: highlighting the principle of *causality* as fundamental, it becomes evident that instruments and score are part of the same causal process.

Considering the sound synthesis environments partitioned as score and instruments, Anne Veitl proposed to interpret softwares as notational systems.

Veitl proposed six criteria that seem to us to highlight some general properties of notational systems and instruments at the same time. These criteria stress the fact that softwares are notations, and, essentially, performable notations. A notational system is primarily:

a. material: it must be somewhere, memorized on a concrete and existing object, the paper or a hard disc;
b. visible: that's why the machine language is not a notation, but softwares are visible;
c. readable: it has to be read by a machine, a human being or both;
d. performative: it describes the action potential of a system. Softwares and computers are highly performative, because the material inscription is translated instantaneously in sound;

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[363] A. Veitl, “Musique, causalité et écriture: Mathews, Risset, Cadoz et les recherches en synthèse numérique des sons”, *Musicologie, informatique et nouvelles technologies,* Observatoire Musical Français, Paris-Sorbonne, 2006, Paris

[364] C. Cadoz, “Musique, geste, technologie”, in H. Genevois and R. de Vivo, *Les Nouveaux Gestes de la musique*, Editions Parenthèses, 1999, Marseille, pp. 47-92

e. systemic: the signs, or the physical elements of the system can operate structurally;
f. causal: notation must indicate and enable sounds. It must indicate the manner and the means necessary to produce the sound or the event.

In this sense, for Veitl, softwares are scores, thus NIMEs, as an expression of this essential character.

G. Tanaka : Concepts Of Instrument – Concepts Of Notation

In his brief history of musical instruments and interactive music[365], Tanaka argues that research in the NIME community has necessitated both the problematization and the abstraction of the traditional definition of musical instrument, giving rise in itself in a new "tradition of instrument building for the capture of different gestures and the affordance of new musical and expressive possibilities".

Tanaka shows convincingly how the traditional definition of an instrument as a self-contained and autonomous sound-producing object that enables a musician to perform in a live situation (Tanaka, 236) has been problematized through music technology, in the form of a primordial coupling of electricity and sound. One of the main pillars in his reflection is the very decoupling of the sonic output from the control interface, giving rise to the rich tradition of controllers. Tanaka's overview of all subsequent developments, namely hyperinstruments, studios, sensor interfaces, virtual reality, tabletops, biosignals, network music and GPS-based instruments, shows towards the necesity of a wider definition of the instrument which he carries out as follows :

"The view of a musical instrument as an *open-ended system* comprised of multiple components can be applied to digital technology and becomes a musical perspective from which to broach questions of the "instrumentality" of hardware / software architectures of live computer music performance systems.

Such a system typically consists of the following components:
· Input device—often a sensor and data acquisition subsystem to capture

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[365] Atau Tanaka, "Sensor-based Instruments and Interactive Music" pp. 233-255 in R. Dean, *The Oxford   Handbook of Computer Music*. Oxford University Press, 2009

performer gestures
· Mapping algorithms—software subsystem to translate gestural data into musical information
· Sound synthesis engine—real-time audio generation in which sound synthesis parameters are modulated by live input
· Compositional structure—a structural layer defining the musical sections or progression of the work
· Output system—audio output subsystem consisting of output channel configuration and digital-to-analog converters (DAC) ” Tanaka, p. 238

What interests us here the most is what Tanaka defines as the compositional / structural layer of the instrument, to which he assigns the progression of the work in time. In that sense, musical notation is already part of the traditional instruments as their structural inside–time layer. A very nice implementation of this idea is certainly the piano roll, whereby notation turns into an integral part of the instrument.

The consideration of notation as part of the instrument or expressive interface in itself also helps explain several mysteries in relation to complex notation, namely the simple question : does notation really need to be so complex ? can't those composers notate their pieces in a simpler way ?

The usual responses which we have already reviewed accentuate the processual, ritualistic, communicative and challenging aspects of such notation. From Tanaka's perspective, one could further argue that, being part of the instrument, notation ceases to be only utilitarian and becomes expressive, in the same way that an instrument defers from a tool :

instrumental writing should make an instrument “speak” by highlighting its capabilities as well as its limitations. This implies not only staying within the bounds of an instrument, but also pushing the envelope and testing the limits and breaking point of conventional technique. p. 239

H. Rasmussen : Models Of Behaviour For Instruments And Notations

One of the ideas that might prove handy in transferring knowledge from the field of interaction with DMIs to musical notation is the typology of musical interaction according to Maloch after Rasmussen.

Joseph Maloch et al.[366] have developed a paradigm for musical interaction based on Jens Rasmussen's model of human information processing[367], which has previously been used for interface / Digtal Music Instrument design, in particular the aXiO MIDI Controller[368]. Rasmussen has categorized interaction models as *skill-, rule-, or model-based*. Skill-based interaction designates the real-time continuous response to a continuous external signal, as opposed to rule-based interaction, which operates on a coarser time-scale as selection and execution of stored processes in response to cues (or signs, as Rasmussen terms them). In model-based (or knowledge-based) interaction, finally, conceptual goals (symbols), rather than cues or signals, are driving interaction, which now entails a considerable amount of reasoning, before lower-order actions (skill- or rule-based) are employed. (p. 49-50)

Maloch et al. argue that the performance of traditional musical instruments offers a clear example of skill-based behavior, as opposed to rule- and model-based behaviours enabled by music technology. In an illuminating example, they compare the execution of a rhythm on an acoustic or digital instrument (skill-based) to the reproduction of the same instrument by selecting a rhythm and pressing a START button in a drum machine (rule-based). And when the same rhythm is live-coded, then the task is assumed to be model-based, in the sense that the user reasons about the deconstruction and reconstruction of the given task (p. 51).

In the following figure you may see a schematic representation of the three models of interaction in response to signals, signs and symbols and several musical activities associated to each of those.

While the designation of musical performance on a traditional instrument does unproblematically conform to Rasmussen's skill-based model when it comes to

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[366] Joseph Malloch, David Birnbaum, Elliot Sinyor, Marcelo M. Wanderley, TOWARDS A NEW CONCEPTUAL FRAMEWORK FOR DIGITAL MUSICAL INSTRUMENTS, Proc. of the 9th Int. Conference on Digital Audio Effects (DAFx-06), Montreal, Canada, September 18-20, 2006

[367] Rasmussen, J.: Information Processing and Human-Machine Interaction: an Approach to Cognitive Engineering. Elsevier Science Inc., New York (1986)

[368] Cariou, B.: The aXiO MIDI Controller. In: Proc. of the 1994 International Computer Music Conference, pp. 163–166. International Computer Music Association, San Francisco (1994)

music-making without the use of notation, the taxonomy becomes more difficult in the case of notation, and even more so in the case of complex notation. Is music notation to be considered as a real-time signal when used in performance, which triggers performance? (the direct perception scenario of embodied navigation). Or would it make more sense to consider the interaction with notation in the whole learning trajectory as a mixed behavior which involves all three types of interaction?

It seems indeed that interaction with complex notation in the case of embodied navigation would profit from the inclusion of all three types of interaction: The very presence of music notation in itself, a symbolic structure, invites several types of sign- and symbol-based behavior, such as: reasoning about learning strategies and degrees of resolution in relation to detail, deciphering of symbols based on rules and interpretative decisions in the case of conflicting rules.

The radical model of embodied navigation, with its emphasis on the external transformation of musical notation to enable its direct perception for performance, would equal the gradual substitution of initially symbol- and rule-based behavior from skill-based one towards the performance.

On the other hand, our analysis of coarticulation shows equally the possibility of a coarser time-scale control in terms of embodied layers: If we consider the rhythm of the displacements in the grasp layer, for example, we could theorize it as an infusion of rule-based behavior in the fine motoric of the finger layer.

Rasmussen’s main idea is that humans interact with technology in discernible ways characterized as skill-, rule- and model-based. We argue that a model of interaction with notation can take advantage of hybrid strategies, whereby the assumption of a ubiquitous skill-based interaction as traditionally associated with playing instruments is substituted by rule- and model-based strategies.

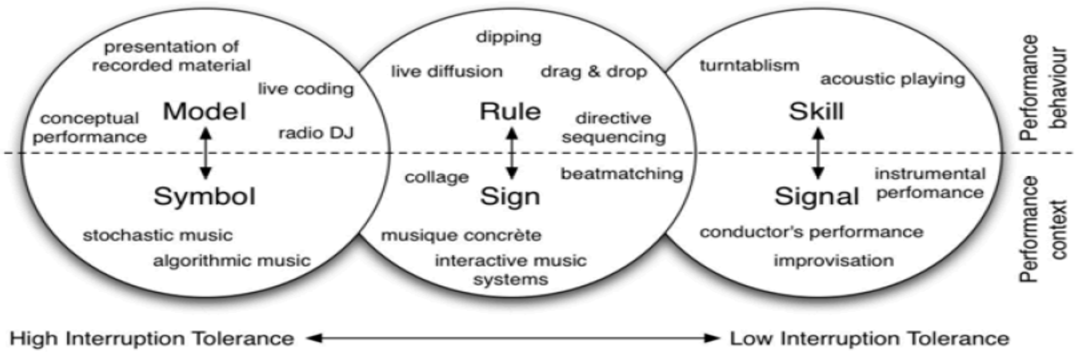

Fig. 5.1 Model visualization based on Rasmussen's typology of human information processing [21]. From left to right, the systems represented are less and less tolerant of interruption of the channels of control.

Figure 37: Rasmussen's typology of music information processing, originally in Malloch 2011, p.69, reproduced with permission.

I. Leman : From The Instrument As A Mediator To Notation As A Mediator

The reconfiguration of notation as instrument allows us also to smoothly direct Leman's mediation model of listener-performer communication based on corporeal articulations towards the communication between composer and performer. As shown above, the crucial mediator in the case of the performer-listener communication is the instrument, in the sense that it transforms the biomechanical energy of the performer, through corporeal articulations, into sonic and visual energy decoded as musical intentionality.

By the same token, such a model of communication between the composer and the performer would focus on "notation-as-instrument" as the interface-mediator, encoding the corporeal articulations on the composer's side and decoding them on the performer's side. The obvious problem in such a view of notation is its very symbolic nature, which we are trying to tackle by the real-time transformation of the notation into layers of coarticulation and intentionality nodes (part two) as well as through the implementation of augmented and interactive possibilities based on gesture capture and following (part three).

Remembering the influential moto by Brooks again, if indeed the world is its own best representation, then it is quintessential to try and merge notations and instruments into a singular entity, which is defined by affordance and interaction, without abolishing its inherent representational properties.

J. Conclusion

Technological advances have broadened our conception of notation and instrument as mutually shaping, action-oriented, open-ended systems, as much as they have contributed in their actual, material amalgamation.Tomás' tangible score offers instances of new interfaces-and-scores, which have historically followed up from graphic and action-oriented notations. In those instances, notation and instrument share common criteria (Veitl) and evolutionary cycles (Leman) beyond the prescriptive-descriptive classical dichotomy, materializing both representational and enactive cognitive features.

Eventually the very communicative chain and roles between instrument-makers, composers, performers and computer-music designers are to be genuinely rethought as cycles of synergy rather than linear models, with obvious implications for both pedagogy and creation in all respective fields.

The bidirectional relationship of instruments and notations (instruments as notations and notations as instruments) allows for the transference of ideas from the field of music interaction to the field of music representation.

The objective of this chapter was to show, how influential ideas about instruments from the field of HCI can essentially be transferred to the music notation and representation. Such ideas include:

- Notation as a structural layer of instruments, in their extended definition as open-ended systems (Tanaka).

- Historical forms of graphic and action-based notation as proto-inherent scores / interfaces, accentuating the role of affordances through prescription rather than description.

- A model of phylogenetic evolution of notation after Leman's respective model for the development of instruments (ratchet effect) and a model of musical communication based on corporeal articulations.

- Common criteria of instrumentality according to Veitl (materiality, visibility, readability, performativity, systemic nature and causality).

- Common models of behavior defined as skilled-, ruled-and model-based.

- Common role as a mediator between different actors in the musical communicative chain.

The consideration of notation as interface allows for an HCI response to questions of historical evolution, (im)practicability, impossibility, prescription versus description and use, as opposed to the aporias of traditional internalization.

3. GesTCom: Interactive Systems For The Embodied Navigation Of Complex Piano Notation

3.1 Introduction

In this chapter we present *GesTCom*, a sensor-based environment for the analysis, processing and real-time gestural control of complex piano notation through multimodal recordings.

The acronym *GesTCom* stands for "Gesture Cutting through Textual Complexity". It is a project that started at IRCAM (*Institut de recherche et coordination acoustique / musique*), Paris[369], in the context of the author's 2014 Musical Research Residency[370], and continued at LabEx GREAM (*Groupe de Recherches Expérimentales sur l'Acte Musical*), Université de Strasbourg, in the context of the current dissertation, and in co-direction with the IRCAM.

A. Concept

The *GesTCom* materializes the embodied navigation paradigm into a dedicated interactive system.

The system's initial goal was set in the realm of representation: How to address the limitations of prior means, such as the multilayered tablatures shown in part two, 4.2 and 4.4. These tablatures remain static, symbolic and subjective, while attempting to capture the dynamicity of navigation. The *GesTCom* allows for the creation of malleable and objective albeit personalized representations, through the inscription of recorded multimodal data in the notation. A derivative goal was the representation of the longitudinal learning trajectory and the archiving of embodied navigation over time.

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369 https://www.ircam.fr/ accessed 13.04.2018

370 http://forumnet.ircam.fr/espresso_event/research-creativity-seminar-the-pianist-pavlos-antoniadis/ accessed 13.04.2018

The system's further goals were set in the domain of interaction: First, how to effectuate, rather than merely represent, the transformation of complex notation through performance. This transformation followed two directions: either simplification through information reduction, seeking efficiency in the first stages of the learning process; or proliferation of information, through complex compound tablatures offering augmented multimodal feedback. Second requirement in the domain of interaction was, how to control these new notations through movement. In a nutshell, the *GesTCom* generates and controls multimodal tablatures by means of inertial sensors.

These interactive features effectively merge notation and instrument into an organic whole. Such new interface exhibits Veitl's criteria of global instrumentality as cited before: materiality, visibility, readability, performativity, systemicity and causality.

Finally, the radical vision of embodied navigation, as dynamic interaction of the elements of the performance system, with only contingent use for mental representations, is actively pursued: The performer externalizes the gestural processing of the notation, which becomes reproducible and communicable; complex notation turns into a live signal to be directly perceived, through the updating of traditional annotational practices; and the interactive dynamics of entrainment, alignment and sensorimotor learning become palpable in the relationship with the musical score.

B. Architecture And Methodology

The *GesTCom* is a modular system. In terms of hardware, it comprises systems for the capture of movement, audio, video, MIDI and capacitive data from sensors on the piano keys. In terms of software, it is equipped with modules for the capture, analysis and control of the multimodal data; and modules for the augmentation and interactive control of music notation. Each of these systems functions both as stand-alone and integrated in a novel methodology.

The *GesTCom* methodology features the following steps:

a. Multimodal recordings of the performance of complex piano notation
b. Qualitative analysis of the data and correlation to the original notation

c. Offline processing of the original notation on the basis of the data
d. Online interaction with a new output notation through inertial sensors

The first two steps, recording and analysis, are based on the library of Max / MSP objects for multimodal analysis of sound and motion, interactive sound synthesis and machine learning known as *MuBu*[371] (multi-buffer) and developed at IRCAM by the ISMM (*interaction-son-musique-mouvement*)[372] team.

The third step, notation processing, features *INScore*[373], a platform for multiple graphic representations, as well as customized command-line tools based on the *Guido Engine Library*[374]. Both are developed by Dominique Fober at GRAME (*Centre national de création musicale*), Lyon.[375]

The last step, interaction, features:

a) the concept of gesture following, implemented in a customized *motionfollower* patch after the *Gesture Follower*[376] project;

b) the connection of the *motionfollower* to the *INScore* representations through a dedicated Max / MSP patch. The outcome of this patch is an interactive multimodal tablature controlled through movement. Both the *motionfollower* and the *GesTCom* tablature have also been developed at IRCAM by ISMM.

For a brief introductory overview of the systems in question, you may visit the following videos (accessed 13.04.2018) :

https://www.youtube.com/watch?v=q-2niFpFkjc

http://www.unistra.fr/index.php?id=25062

371 http://forumnet.ircam.fr/product/mubu-en/ accessed 13.04.2018

372 http://ismm.ircam.fr/ accessed 13.04.2018

373 http://inscore.sourceforge.net/ accessed 13.04.2018

374 http://guidolib.sourceforge.net/ accessed 13.04.2018

375 http://www.grame.fr/ accessed 13.04.2018

376 http://imtr.ircam.fr/imtr/Gesture_Follower accessed 13.04.2018

C. Case Study: Brian Ferneyhough's Lemma-Icon-Epigram

The *GesTCom* methodology will be presented through a case-study for complex piano music, Brian Ferneyhough's *Lemma-Icon-Epigram* (1981). This work was selected due to Ferneyhough's privileging of a *top-down approach* to learning. This approach calls for an initial "overview of gestural patterning" of the notation, before dealing with the great amount of detail[377]. Ferneyhough's approach inspired me to develop strategies for the simulation of his tripartite learning scheme. This simulation followed two directions as to notation processing: The direction of information reduction for the first stage and the direction of multimodal augmentation for the subsequent stages of learning. The piece has been recorded in its entirety twice and the data are listed in the Appendix. In the analyses that follow, we deal with the parameters of pitch and rhythm and we focus on only the first page of the work. Such focus allows for greater clarity in the articulation of a concise methodology for the *GesTCom*. The application of this methodology on a large-scale analysis is reserved for part four of the current dissertation, namely the analysis of Iannis Xenakis' *Mists*.

3.2 Recording Of Multimodal Data

Cornerstone of the sensor-based environment *GesTCom* is the recording of multimodal data. The data are subsequently mapped on a musical score and / or on derivative representations, which are also produced by these recordings. Recordings generate, in other words, both multimodal data and notation, and are ubiquitous through all the stages of the *GesTCom* methodology.

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[377] "An adequate interpretation of this work presupposes three distinct learning processes: (1) an overview of the (deliberately relatively direct) gestural patterning without regard to exactitude of detail in respect of rhythm; (2) a 'de-learning' in which the global structures are abandoned in favour of a concentration upon the rhythmic and expressive import of each individual note (as if the composition were an example of 'punctualistic' music); (3) the progressive reconstruction of the various gestural units established at the outset on the basis of experience gained during the above two stages of preparation.", B. Ferneyhough, *Lemma-Icon-Epigram* for solo piano, "Performance Notes", Edition Peters No. 7233, 1982

A. Hardware

The recording set-up for the prototype at the IRCAM *Musical Research Residency* was kept intentionally simple and portable as to the piano's peripheral devices (Figure 38). This was a conscious response to contemporary performers' requirements for mobility, traveling and constant contact with the instrument. It consisted of a MIDI upright piano, two condenser microphones for audio recording, a Kinekt *Xbox 360* device for video recordings with potential interactive features and a pair of wireless inertial sensors providing 3 dimensions of acceleration and 3 axes of gyroscopic data each. The sensors are non-invasive and are carried on the pianist's wrists through elastic bands. They were built at IRCAM by Emmanuel Fléty.

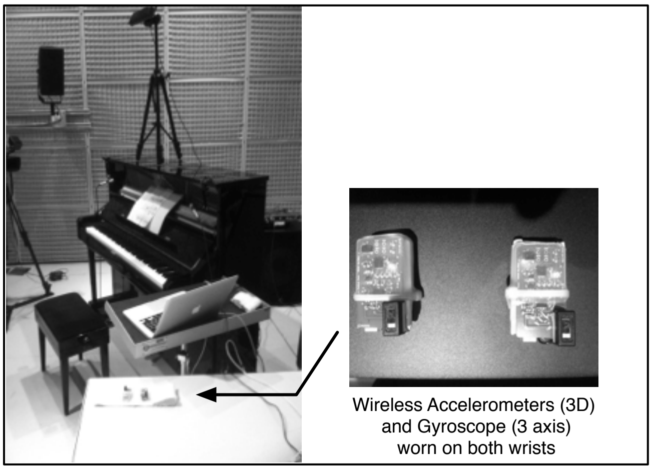

Figure 38: Recording set-up, Musical Research Residency at IRCAM

In the second phase of this research (April 2015 – today), the recordings took place at a dedicated studio for multimodal recordings at the University of Strasbourg, organized by the author with the support of LabEx GREAM (hardware) and IRCAM (sensors and software), as shown in Figure 39. The studio was built between May 2015 and March 2016 and was presented during a workshop organized by the author, in a symposium dedicated to Human-Computer Interaction in Music[378].

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[378] Universlté de Strasbourg, Journée d'études GREAM, organisation d'atelier : « Mener une étude expérimentale de l'interaction homme-machine en musiqe : concepts, outils et équipement »

The recording process has been featuring a wider range of capture systems. It included *Kinect* video (Figure 42); audio captured through two condenser microphones (Figure 43); the original wireless 3D acceleration and 3-axis gyroscopic inertial modules (Figure 44). In addition, it featured a grand *Disklavier E3* for MIDI data, and capacitive sensing data for the exact representation of finger position on the keys, through the *TouchKeys*[379] system, developed by Andrew McPherson at Queen Mary University, London. The *TouchKeys* sensors are attached on the surface of the keys as shown in Figures 40, 41. They are non-invasive in performance, with the exception of some unorthodox and extreme playing techniques, such as cluster glissandi.

Figure 39: Studio for gesture capture at LabEx GREAM

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http://gream.unistra.fr/activites/evenement/?tx_ttnews[tt_news]=12485&cHash=8f65f5fd698c4cec3c4cb488c93bb65f , accessed 02.05.2018

379 http://www.eecs.qmul.ac.uk/~andrewm/touchkeys.html accessed 13.04.2018. For a detailed technical survey, look at McPherson, Andrew, "2012:TouchKeys: Capacitive Multi-touch Sensing on a Physical Keyboard", in Jensenius, Alexander Refsum and Lyons, Michael J. (eds.) *A NIME Reader. Fifteen years of New Interfaces for Musical Expression*, Springer International Publishing, 2017

Figure 40 : *TouchKeys* sensors

Figure 41: *TouchKeys* sensors attached on keys

Figure 42: An *Xbox 360 Kinect* sensor for the registration of video, mounted on the Disklavier with a customized stand

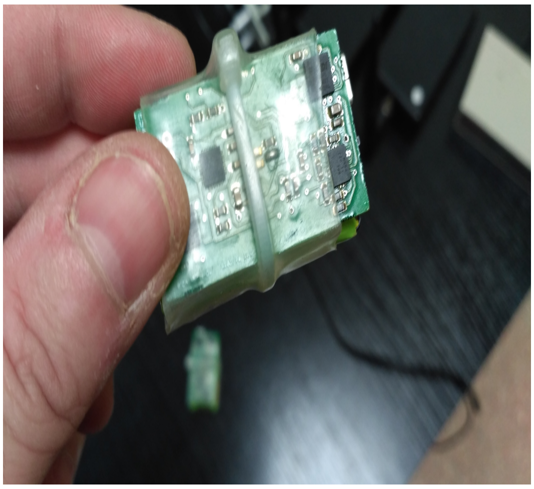


Figure 43: Condenser microphone *DPA ST 2011C*

Figure 44: Inertial sensor

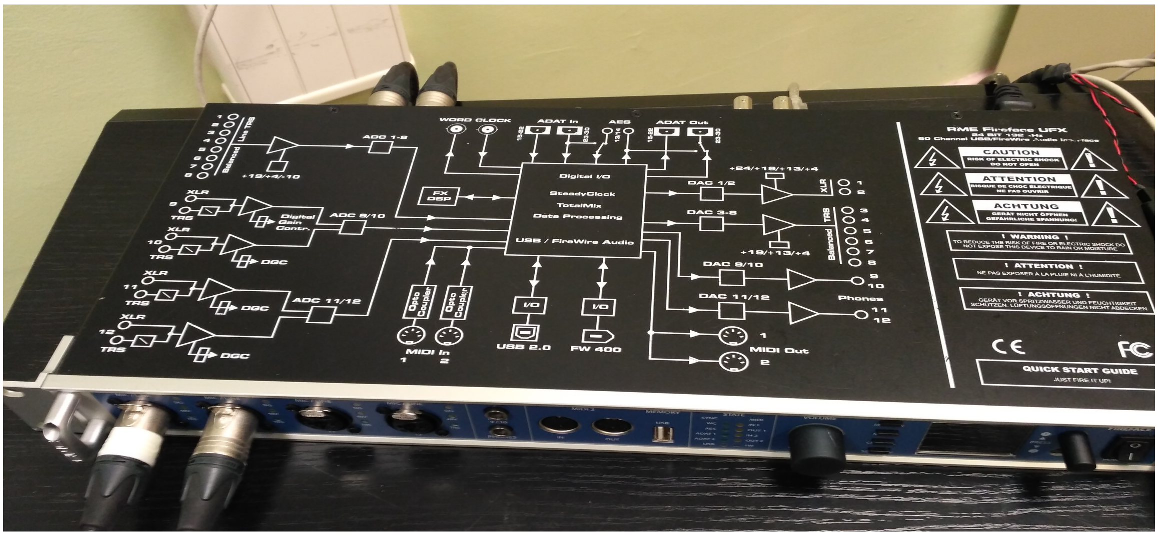


Figure 45: Soundcard *RME Fireface UFX*

B. Software

The synchronized recording of the data is effectuated through dedicated Max / MSP patches based on *MuBu*. In Figure 46 you may see the recording patch, with annotation in red clarifying the modules for gesture, audio, video, MIDI and *ToucKeys* data. In Figure 47 you may see the sensor patch indicating the 3D accelerometers and the 3-axis gyroscopes for both hands, a total of 12 signals. In Figure 48 is a close view of the *TouchKeys* OSC data on the recording patch. The colour spectrum visualizes the different positions of the fingers on the keys, with red corresponding to the inside and blue to the outside part of the key. In Figure 49, you may see the *TouchKeys* native representation of finger positions on a virtual keyboard.

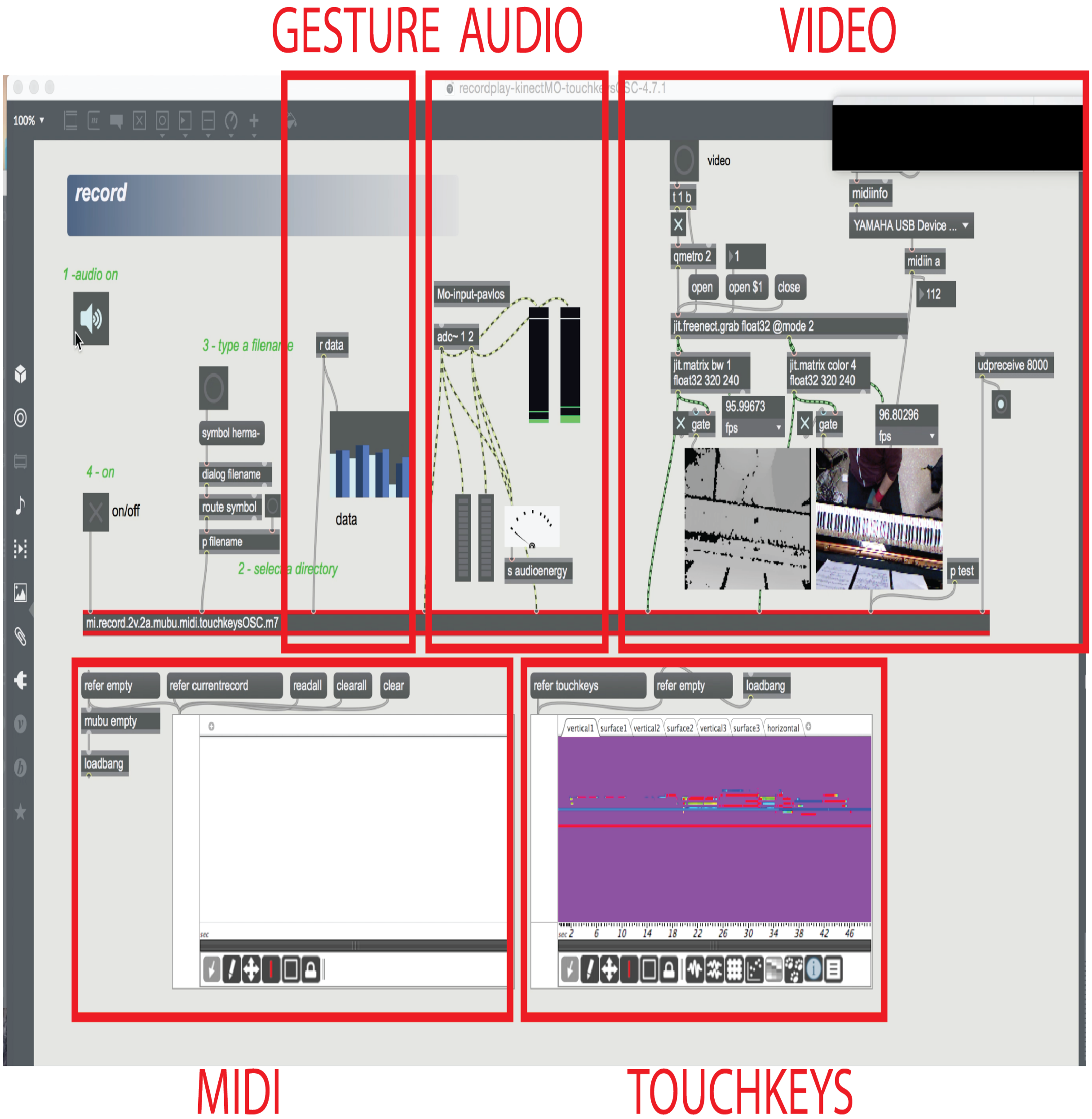
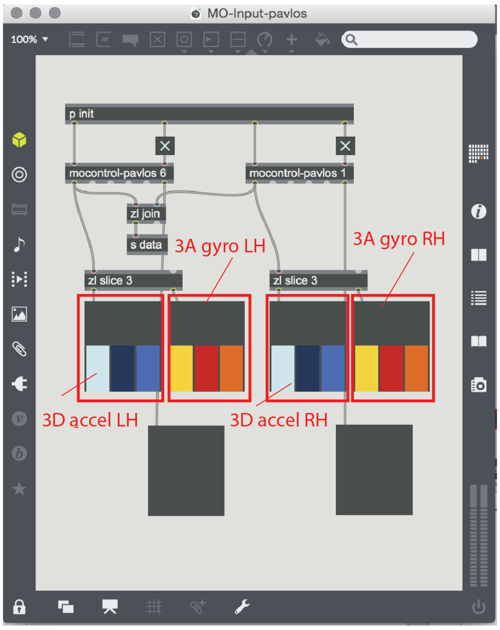


Figure 46: Max / MSP patch for multimodal recordings



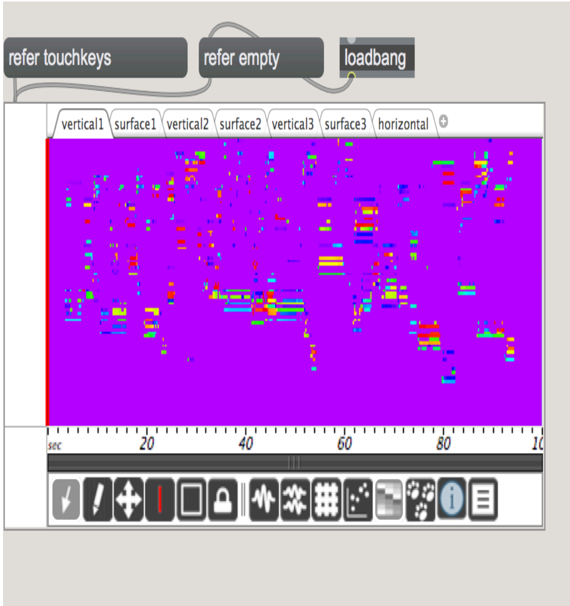


Figure 47 (left): Max / MSP patch for control gestural data

Figure 48 (right): Detailed visualization of *TouchKeys* OSC data through Max / MSP

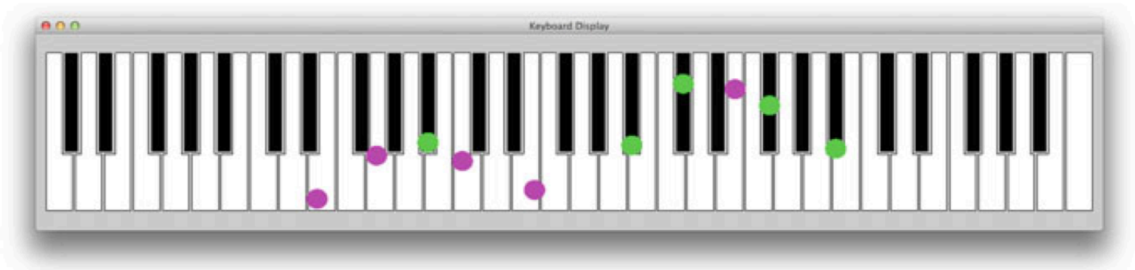


Figure 49: *TouchKeys* real-time display of finger position on the keys

C. Protocol

My general approach to the recording of complex piano repertoire emphasized the learning process over the final product.

A special focus was given to the so-called 'sight-reading' scenario[380] : a performance at the very beginning of the learning trajectory, which prioritizes an "overview of gestural patterning" (Ferneyhough) rather than precise rhythmic and other detail.

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[380] The term 'sight-reading' should not be confused with the literal use of the term, as in classical music and especially in the fields of opera coaching or chamber music, whereby training and ability ensure a satisfying performance of all notated parameters without prior knowledge of the text.

Such recording is expected to function as a *gestural template* for all further stages of the *GesTCom* : analysis, notation processing and real-time interaction.

Other recording scenarios included the four dimensions of interaction with the score-space, as described in part two, 4.5: The initial scanning of the piece described as 'assemblage view'; the constructivist scenario described as 'forward-moving stratification'; the refinement scenario described as 'resistance to the flow' ; and the performance scenario described as 'line of flight'. A detailed case-study of those scenarios in recording will be presented in part four, with *Mists* by Iannis Xenakis.

There were eventually cases, whereby no particular aim other than the recording of long practicing sessions was in my mind. In such sessions, the recorded data rarely found a function other than monitoring and archiving. The process was though psychologically important in seamlessly integrating recordings informally in my praxis, as opposed to more targeted sessions.

The basic research questions that drove the recording process were: How can they be used as a stand-alone learning archive of multimodal feedback; and how can this data be fed back into the musical score and transform it, reflecting the processing of the notation in the mind of the performer and / or in traditional annotational practices. The latter question is addressed in the next stages of the methodology.

D. Record

During the Residency, we realized a series of recordings in the course of three months (March – June 2014), focused on complex piano repertoire after 1950 (works by Iannis Xenakis, Brian Ferneyhough and Jean Barraqué), as well as traditional classical repertoire (including works by Johann Sebastian Bach and Ludwig van Beethoven). Those exploratory recordings featured several stages of the learning process, ranging from the very first approach to a new score up to the complete performance of selected passages or even complete works. A multitude of prioritization processes as to the approach of the notation, based on the model of corporeal (denoted since as "embodied") navigation, was employed and reflected in the multimodal data.

In Strasbourg, the system was more seamlessly integrated in both the research and my professional practice as a pianist. It reflected a more structured perception of the prioritization processes involved in learning, a more targeted approach as to the subsequent use of the data, and occasionally a more spontaneous approach with aimless recording. A complete list of the repertoire recorded during this second phase (March 2016-June 2018) is provided in Appendix 4 of the current.

3.3 Qualitative Analysis Of Multimodal Data

A. Aim

The qualitative data analysis aims at the discovery of a *syntax of movement* in the raw data. It comprises two steps: Comparison of the gestural data to audio and video on the one hand; and comparison to *implicit* annotations on the other. The latter step attempts to link second- and third-person descriptions as described by Leman 2008. This twofold process has led to the discovery of correlations between the *explicit* annotation of the score and the gestural data. On the basis of these correlations, I have developed a basic syntax of *Preparation-Attack-Displacement-Release* envelopes for piano playing. This PADR model is inspired by Jules Françoise's PASR model[381], in itself based on the classic Attack-Decay-Sustain-Release envelopes. Further on, we envisaged the extraction of a dictionary of gestural *primitives* (after Baptiste Caramiaux's notion in his analysis of clarinet gestures[382]) for machine learning applications based on *segmental HMM* models. These segments would coincide with the *embodied layers* of the navigation paradigm (part two), but their modeling was proven beyond the scope of this dissertation.

B. Software

For the playback and synchronization of the data we used a customized patch. The initial prototype, used for basic playback of the multimodal recordings, was refined

[381] J. Françoise, B. Caramiaux, F. Bevilacqua. A Hierarchical Approach for the Design of Gesture - to - Sound Mappings. In Proceedings of the 9th Sound and Music Conference (SMC), Kopenhagen, 2012, 233-240.

[382] B. Caramiaux, M. Wanderley, F. Bevilacqua.Segmenting and Parsing Instrumentalists' Gestures. In Journal of New Music Research, vol. 41, no. 1, 2012, 13-29.

over the period of four years to include more sets of data and to accommodate several visualization, annotation and interaction features of the *GesTCom* project.

In the following figure (Figure 50), you may see an intermediate version of the patch, whereby the basic data-sets are visualized. From left to right: A screen for the *Kinect* video (left upper corner); a dynamic real-time representation of the accelerometer and gyroscope data; and (from top to bottom) the synchronized data of stereophonic audio waveforms, static plotting of the accelerometers' & gyroscopes' data and MIDI piano-roll representation in a juxtaposed arrangement, also annotated with markers which can be extracted for further machine learning.

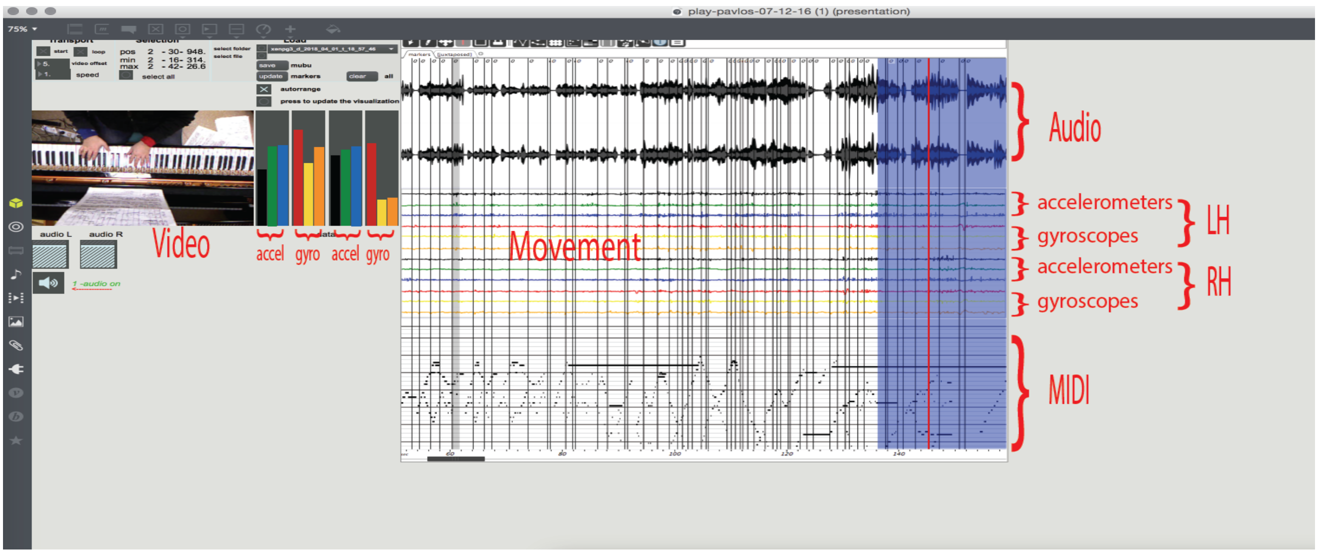

Figure 50: Clarification of the different data-sets on the playpatch

In the following figure (Figure 51), you may see the addition of the *TouchKeys* data on the bottom of the juxtaposed representation, colour-coding indicating the exact position of the fingers on the keys, as well as MIDI information for the two pedals and MIDI velocity information in the form of colour-coding of the piano-roll representation.

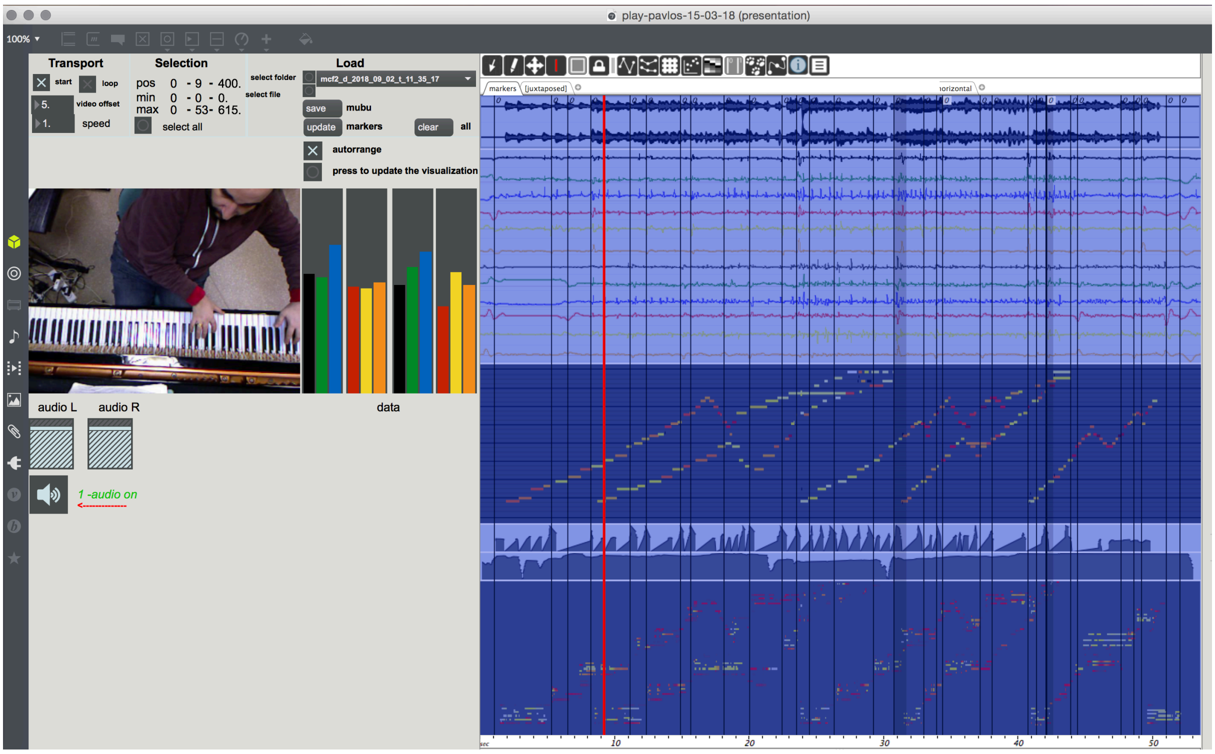

Figure 51: Current version of the playpatch with *TouchKeys* OSC data juxtaposed (bottom representation)

For the prototype patch used at the *Musical Research Residency*, please watch the following video:

https://www.youtube.com/watch?v=L8pAjnAiQ9E accessed 29.04.2018

of a multimodal recording of the last page of Iannis Xenakis solo piano piece *Herma*, described by the composer as a dense cloud of 20 sounds per second.

For the functionality of the current version of the patch and its UI (User Interface) features, please look at the following video:
https://www.youtube.com/watch?v=D4UuswTyqRk accessed 29.04.2018

C. Case Study [383]

In the case of Ferneyhough, we used the following recording for all subsequent analysis and processing:

https://www.youtube.com/watch?v=sPNw2_zKdVs , accessed 03.05.2018

The qualitative analysis of the multimodal data followed two phases:

First, we observed the 12-axis gestural signals in relation to the audio signals and the *kinect* video. The results of our observations for the first page of the work are presented in Figure 52 and are detailed as follows:

Accelerations related to attacks, that is to the amplitude peaks in the audio signals, are unequivocally discernible from accelerations related to the horizontal displacement of the hands. The first are marked with red ellipses, the latter with blue ellipses in the gestural signals. Attack accelerations appear as instantaneous high amplitude peaks in the accelerometers and often in the gyroscopes signals, while displacement accelerations are mainly captured by the gyroscopes as low amplitude and frequency peaks. Close comparison to the video reveals patterns related to the direction of the displacement, clearly marked also in the figure (“values reversed”).

Next to those two distinct types of events, *attacks* and *displacements*, we discern two hybrid events: *trills* (excitation visible in all six axis of the signal) and *displacement with simultaneous attacks*. Those events are more complex and more equally distributed between the accelerometers and the gyroscopes, and are indicated with purple ellipses.

[383] Some of the ideas here have previously been published in the paper : P. Antoniadis, F. Bevilacqua. “Processing of symbolic music notation via multimodal performance data: Brian Ferneyhough’s Lemma-Icon-Epigram for solo piano, phase 1”. In *Proceedings of the TENOR 2016 conference*, Anglia Ruskin University, Cambridge, 127-136. http://tenor2016.tenor-conference.org/TENOR2016-Proceedings.pdf accessed 14.04.2018

The sequence of the above-mentioned four types of events features two types of patterns: i) attacks or trills followed by displacements, or displacements & attacks and ii) succession of attacks without intermediate displacements. The pattern ii) indicates that the events take place inside the boundaries of a single hand-grasp, while the pattern i) indicates changes of hand position and thus the shift from the grasp to the arm layer.

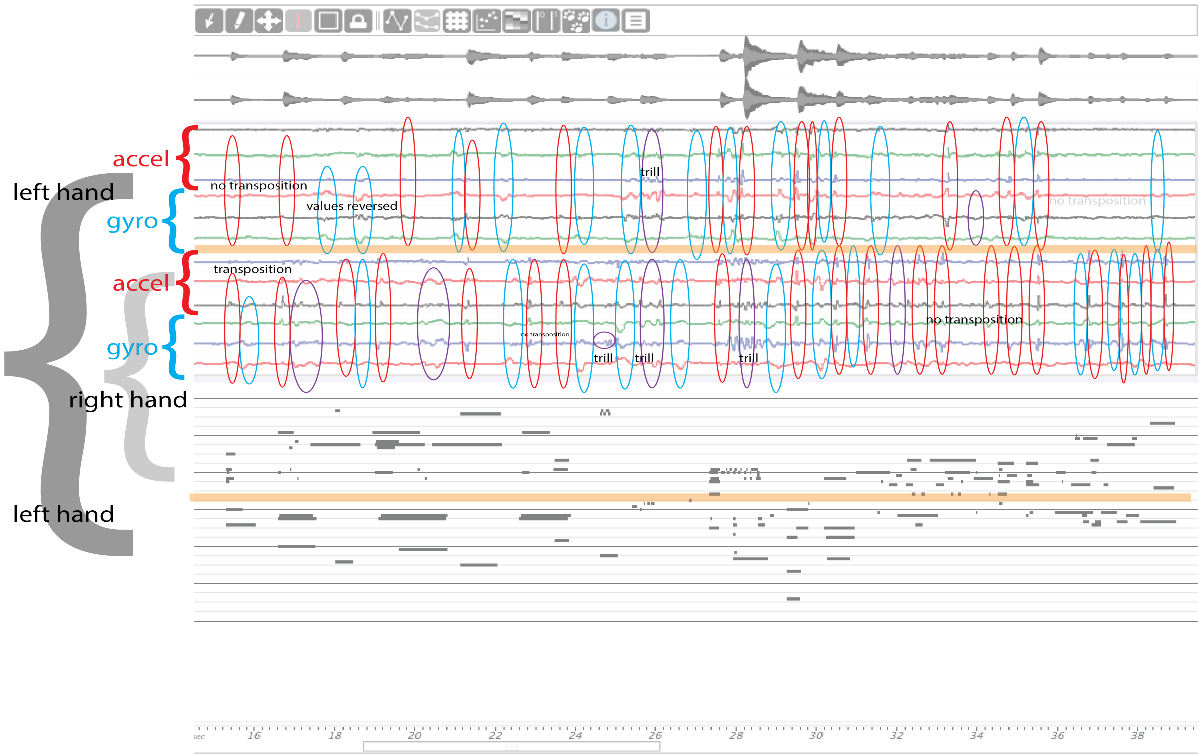

Figure 52: Annotation of gestural data according to video and audio

In short, the gestural signals offer us information about: The horizontal displacement of the hands, its direction, its intensity and the possible presence of intermediate attacks. Higher-order segmentation and parsing are also possible, as will be shown shortly.

In the second phase, we transferred an implicit annotation of the score to the MIDI piano-roll representation of our play-patch and compared it to the annotation of the gestural signals. The implicit annotation of the score is shown in Figure 53. The grasp layer is represented for both hands in the form of blue ellipses. There are no hand crossings, thus we keep the same color for both hands. The highlighted note-heads indicate grasp boundaries and simultaneously fingering: red note-heads are employed for the pinky and blue ones for the thumb in both hands.

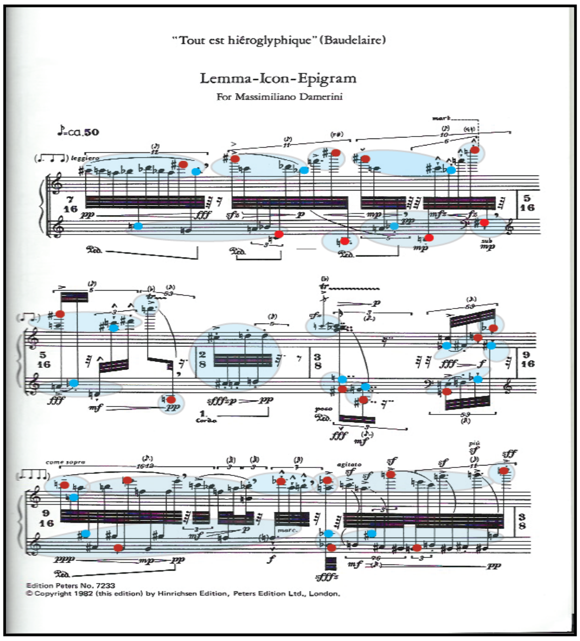

Figure 53: Implicit annotation of *Lemma-Icon-Epigram* p.1, grasp layer

Our comparative study reveals an one-to-one correspondence between the two annotations: Attack gestures align perfectly with grasps; displacement gestures align with changes of grasp. The correspondence becomes clear in the matching patterns of blue arrows in Figure 54.The significance of this alignment is that the pianist's implicit knowledge is reflected in the objective gestural, audio and video data. The implication of this alignment is that the gestural data can be used for the modeling of incoming MIDI pitch information, even *without the need for implicit knowledge*. In other words, given a set of gestural parameters, scores could be annotated automatically. A machine learning application was tested towards this direction. This process requires however more technical advances and exceeds the scope of this dissertation.

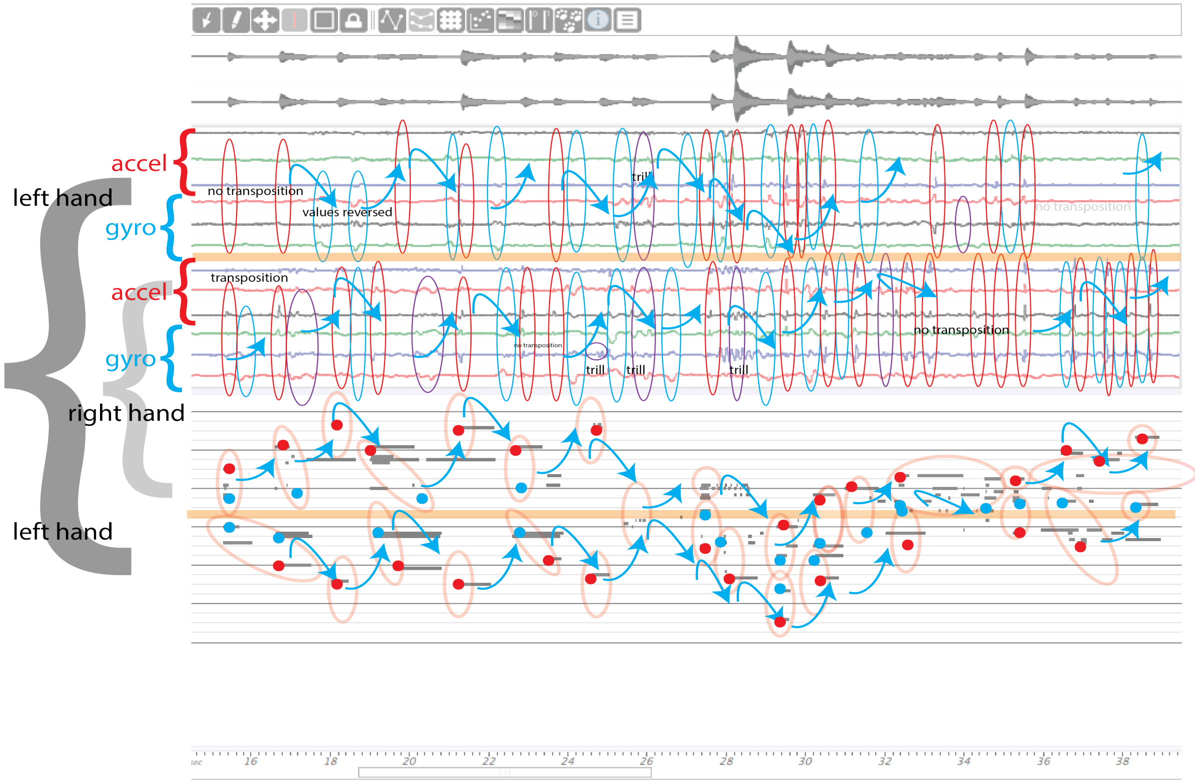

Figure 54: Annotation of gestural data aligning with implicit annotation on the MIDI piano-roll

3.4 Processing Of Symbolic Notation On The Basis Of Multimodal Data

The processing of the symbolic notation followed three directions:

a) Reduction of pitch complexity
b) Reduction of rhythm complexity
c) Multimodal augmentation

A. Pitch Complexity Reduction

The reduction of pitch complexity was carried out in relation to the syntax discovered in the data.

First, the MIDI file of the performance was automatically transcribed into a *reduced proportional representation* of pitch in space (Figure 55). We used customized command-line tools based on the *Guido Engine Library*[384] and developed by Dominique Fober.

For all representations based on this automatic transcription (Figures 55-61), clefs are implied in the beginning of each stave. A treble clef two octaves higher for the top stave, a normal treble clef for the stave below it it, a bass clef for the stave below the treble clef and finally a bass clef two octaves lower for the bottom stave. In other words, those representations are to be read exactly as in the Figures 8-9 of the multimodal tablature in part 2. In this way, the MIDI representation becomes legible, emphasizing the continuity of representation in pitch space.

Further on, this representation was gradually annotated after the gestural signals, in the form of a gradual reduction of the pitch material according to embodied layers' boundaries, that is fingers one and five.

By keeping only the grasp boundaries, we get a reduction in the amount of pitch as in Figure 57.

The shift to the *arm layer*, defined as concatenation of grasps in a certain direction of movement, allows for a further elimination of one of the two grasp boundaries, depending on the direction of the movement. Grasps now are defined by only one note (upper note for movements outward, lower note for movements inward) and the patterns of hand displacement have an one-to-one correspondence to the gestural signals. The amount of pitch is further reduced (Figure 58).

A final reduction of the pitch information is possible, if we consider only the peaks of the arm trajectories, that is the boundaries of the horizontal arm movement. This representation now does not fully coincide with the gestural signal, can become

[384] http://guidolib.sourceforge.net/ accessed 13.04.2018

though visible at a high speed play-back of the video. This representation corresponds to an exact 20% of the pitch content of the original score (Figure 59).

Eventually, the segmentation and parsing of gestures in higher-order syntactic units is possible as in Figure 60. There are six units on the basis of the contrapunctal relationship of the hands: the first three in heterodirectional / contrary movement and the three latter in homodirectional / parallel movement.

Thus, from the gestural signals' annotations and given a MIDI score we can infer a) the reduced amount of pitch material needed to describe gesture and b) the fingering of it. A consistent mapping between gestural signals and embodied MIDI representations is possible. Such a mapping significantly reduces the amount of pitch information in the first stage of a learning process, based on physical movement as a means of understanding.

In Figure 61 you may see the comparison between the original notation and the gestural template resulting from this processing.

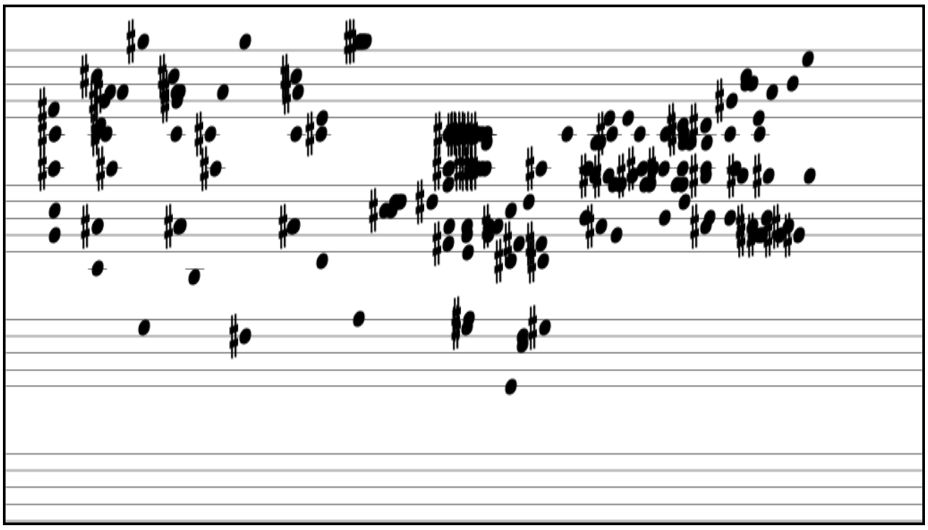

Figure 55: MIDI piano-roll transcribed automatically into a reduced proportional representation

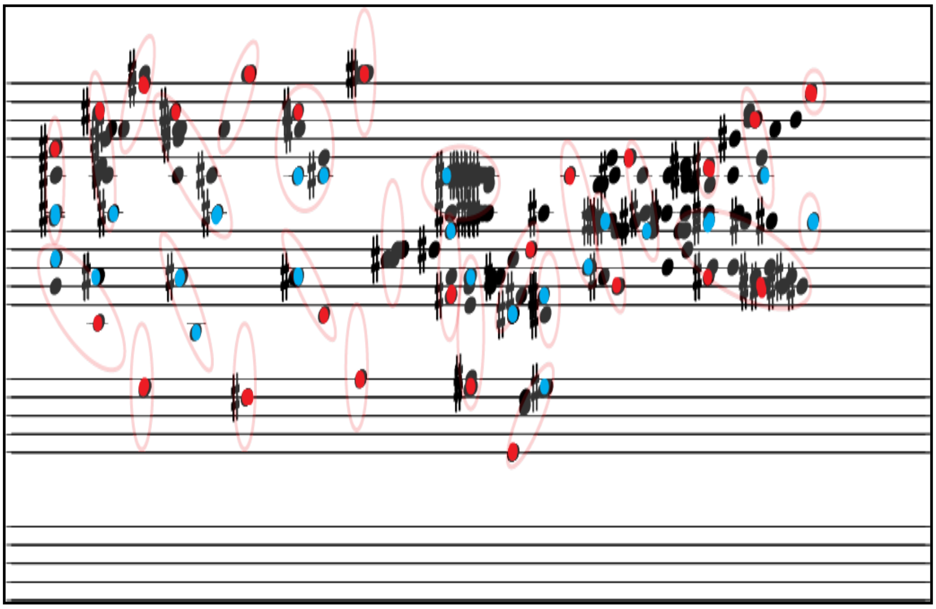

Figure 56: Annotation of the reduced proportional representation in handgrasps

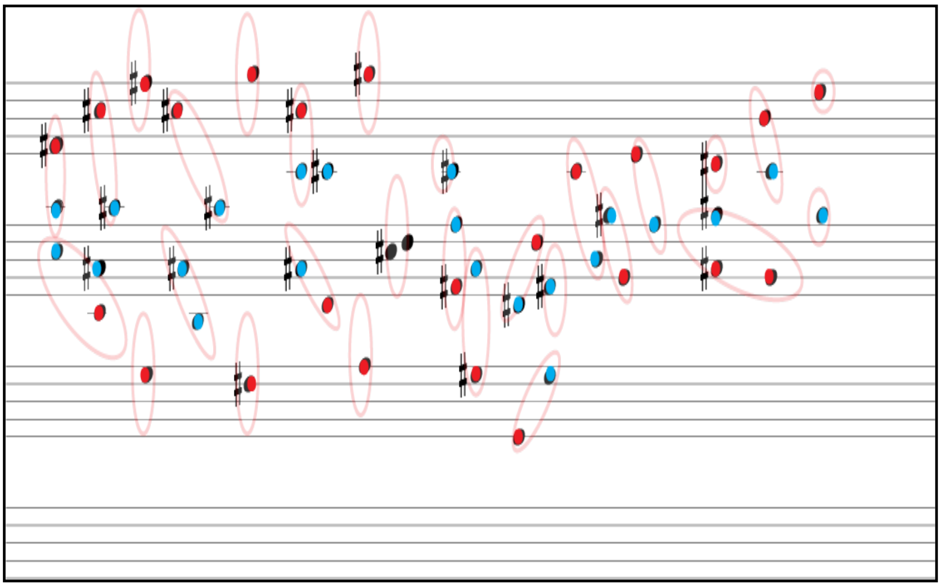

Figure 57: Annotation of the previous figure keeping only grasp boundaries

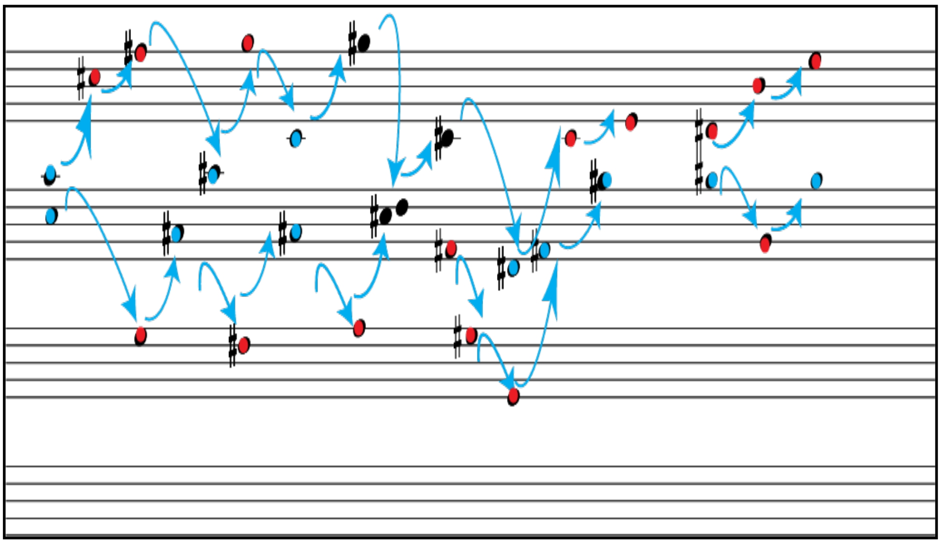

Figure 58: Further annotation keeping only one boundary per grasp, depending on the direction of movement (the upper for upward and lower for downward movements respectively)

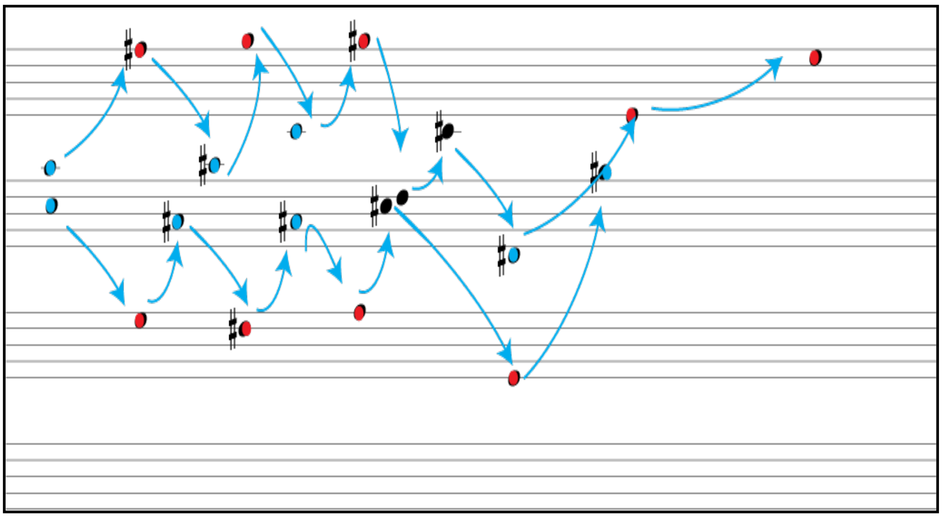

Figure 59: Representation of the arm layer by eliminating intermediate grasp changes and keeping the outer boundaries of the arm trajectories

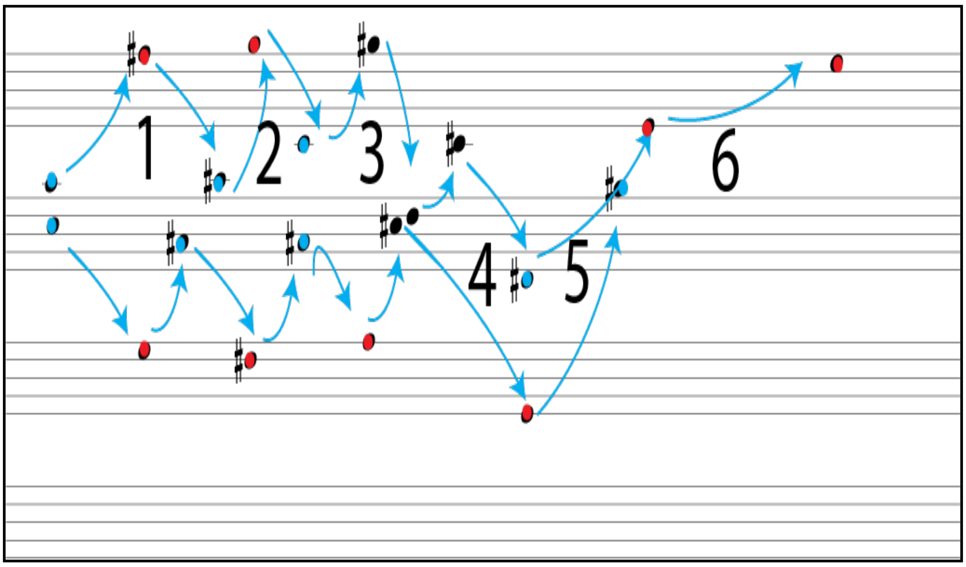

Figure 60: Segmentation and parsing. The relationship of the hands is heterodirectional for the first three entities and homodirectional for the last three

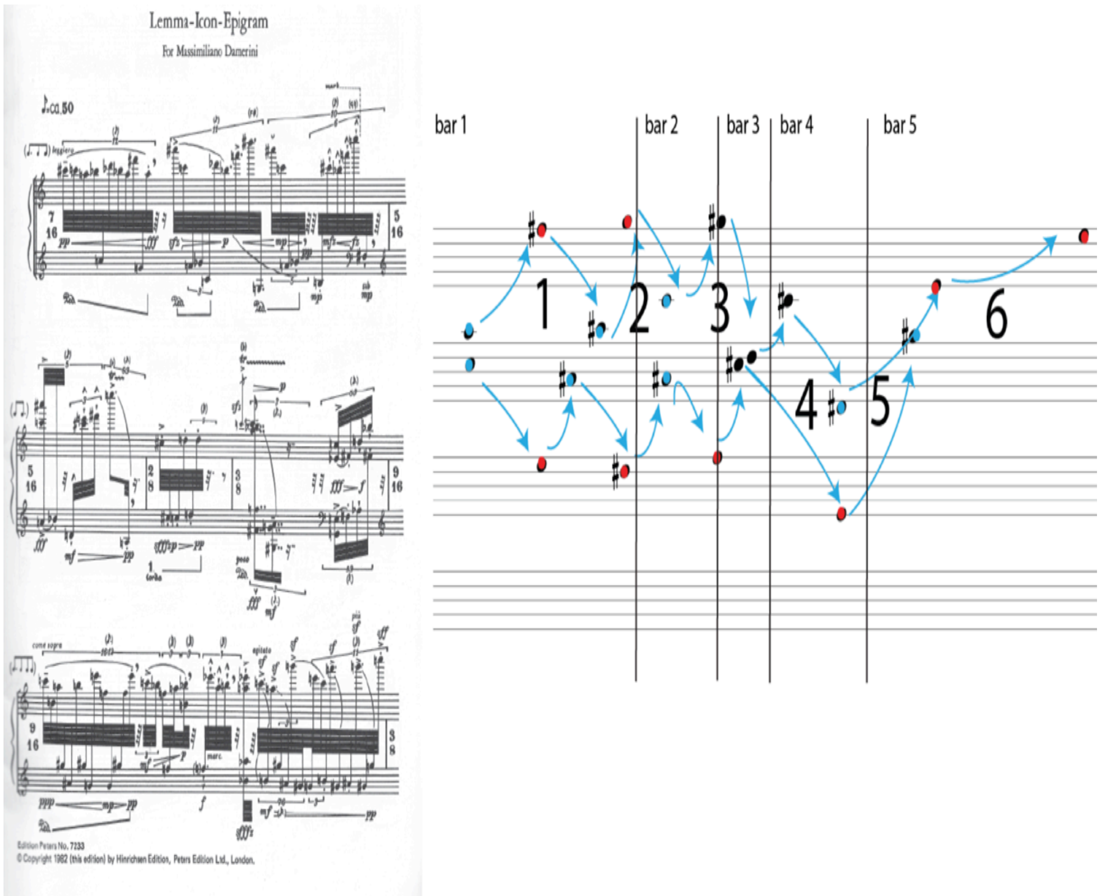

Figure 61: Comparison between the original notation and the extracted gestural pattern

In the following video, you may see the relationship between a performance of the gestural pattern in relation to a performance of the original. The PADR (Preparation-Attack-Displacement-Release) envelope is annotated in the form of markers on the audio, gestural and MIDI data, each marker indicating a hand displacement. Note that the PADR envelope remains the same or very similar between the two performances, meaning that the basic segmentation of movement in terms of displacement as indicated by the markers is retained. In this sense, this PADR envelope could be crucial in the development of systems which allow for the reduction of notational information, keeping the same gestural profiling of performances.

https://www.youtube.com_/watch?v=zytF1nEesAU accessed 29.04.2018

Concluding, the comparison of the reduced proportional representations of the grasp layer to the original yields the following conclusions, summarized in Figure 62:

Information concerning rhythm, articulation, dynamics, pedaling and expression has been removed. Our attempt is to relieve the fusion of those parameters in notation. We seek to purely represent Ferneyhough's proposed "gestural patterning" in the first phase of the learning process, in terms of horizontal displacement of hands over the keyboard and in terms of pitch reduction to the boundaries of this physical movement. We present pitch information which is definitive for the horizontal displacement of the hands. We have showed that this information constitutes implicit knowledge for the performer, but it may also be inferred from the gestural signals alone.

Pitch information is re-arranged as follows: a) It is re-notated in four staves instead of the original two. This representation of pitch-space in a continuum, i.e higher and lower pitch is visible as such in the notation, differs from the original, where clef changes, ledger lines and additional octave displacement brackets often conceal the distribution of pitch in the notational space. b) It is reduced in only the amount of pitch which is necessary for the representation of the hand displacement. This amounts to 20% of the original pitch content in the first page of this piece. c) Blue arrows indicate change of position in full accordance to the gestural signal. d) Higher-order segmentation and parsing of the output score clarifies patterns which are invisible in the original score.

Ontologically, the output score is generated from a MIDI stream during performance. It reflects on performance at different temporal scales, in the sense of its past, present and future manifestations. The latter correspond to: prior knowledge and prioritizations (as the implicit annotation); observed realization (gestural patterning); anticipated further notational transformations (when the output score enters in the learning cycle and is itself being processed and refined during the second and third stages of learning).

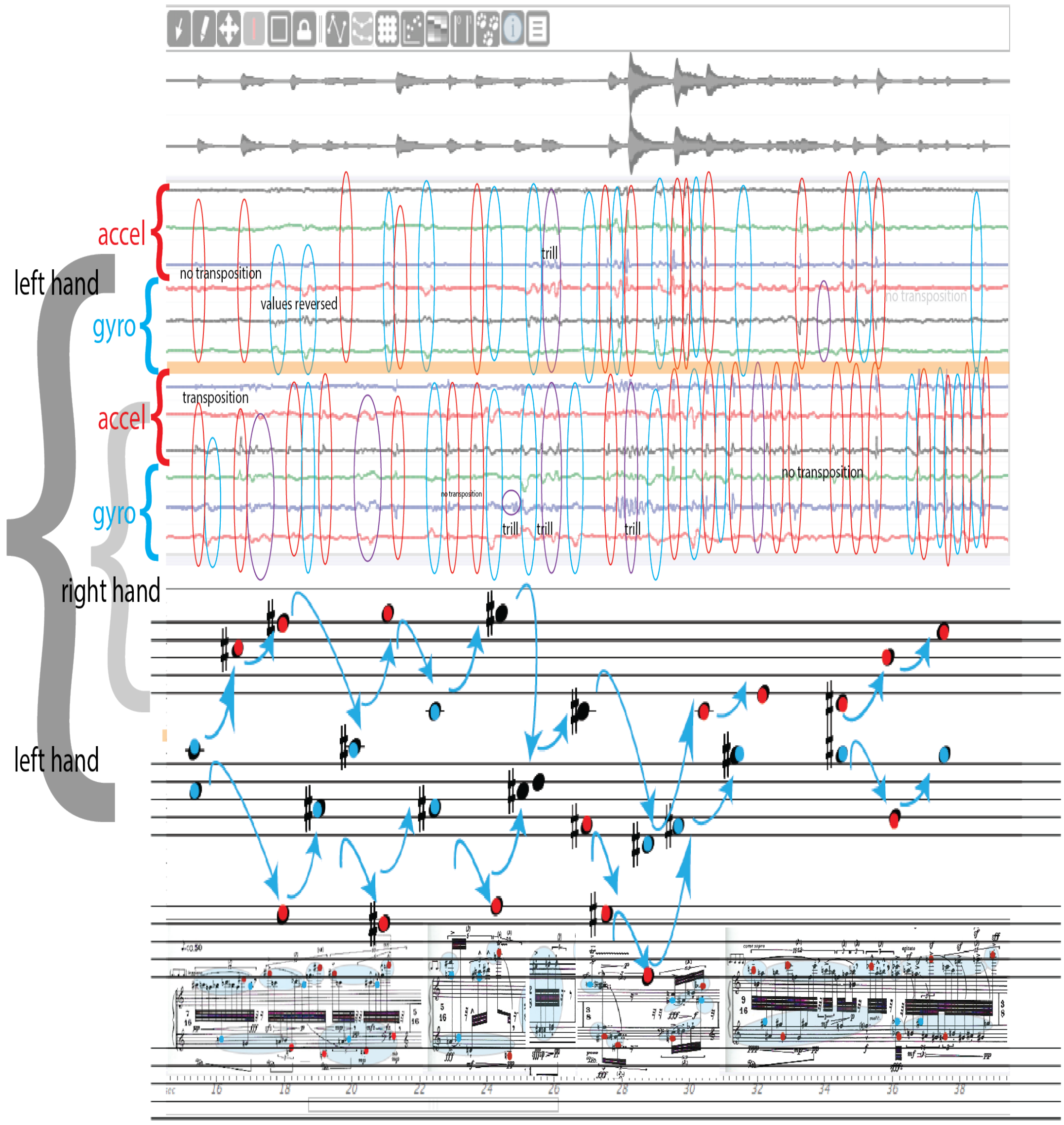

Figure 62: Relationship between gestural data (top), output gestural pattern (middle) and original notation (bottom). The top stave in the middle representation is to be read two octaves higher in the treble clef, the stave below it as in the treble clef and the stave below the treble as written in the bass clef.

B. Rhythm Complexity Reduction

The reductionist strategy applied to the parameter of pitch, as discovery and representation of a hidden gestural patterning, can equally be applied to the parameter of rhythm.

In Figure 63 we show the basic metric and phrase structure of the first page: thick brown vertical lines stand for pulse - eighth or dotted eighth beats (as they appear in parentheses by Ferneyhough before each measure); thin brown lines show the sixteenth notes subdivisions of the beat (both useful as mediation technique for organizing attacks around beats); horizontal green lines show basic phrases as defined by first-order tuplets; horizontal blue lines refer to second-order tuplets (*figural enhancement*), the pink numbers show the tempo for each note in a given tuplet group (retempoing as second mediation technique, to give the idea of relative speeds).

In Figure 64, to these layers of rhythmic information we add the gestural patterning inferred from the data, namely grasps, grasp boundaries and arm movements, that is hand displacements. Grasps are always represented by blue ellipses, grasp boundaries by red and blue blobs, arm movements by blue arrows:

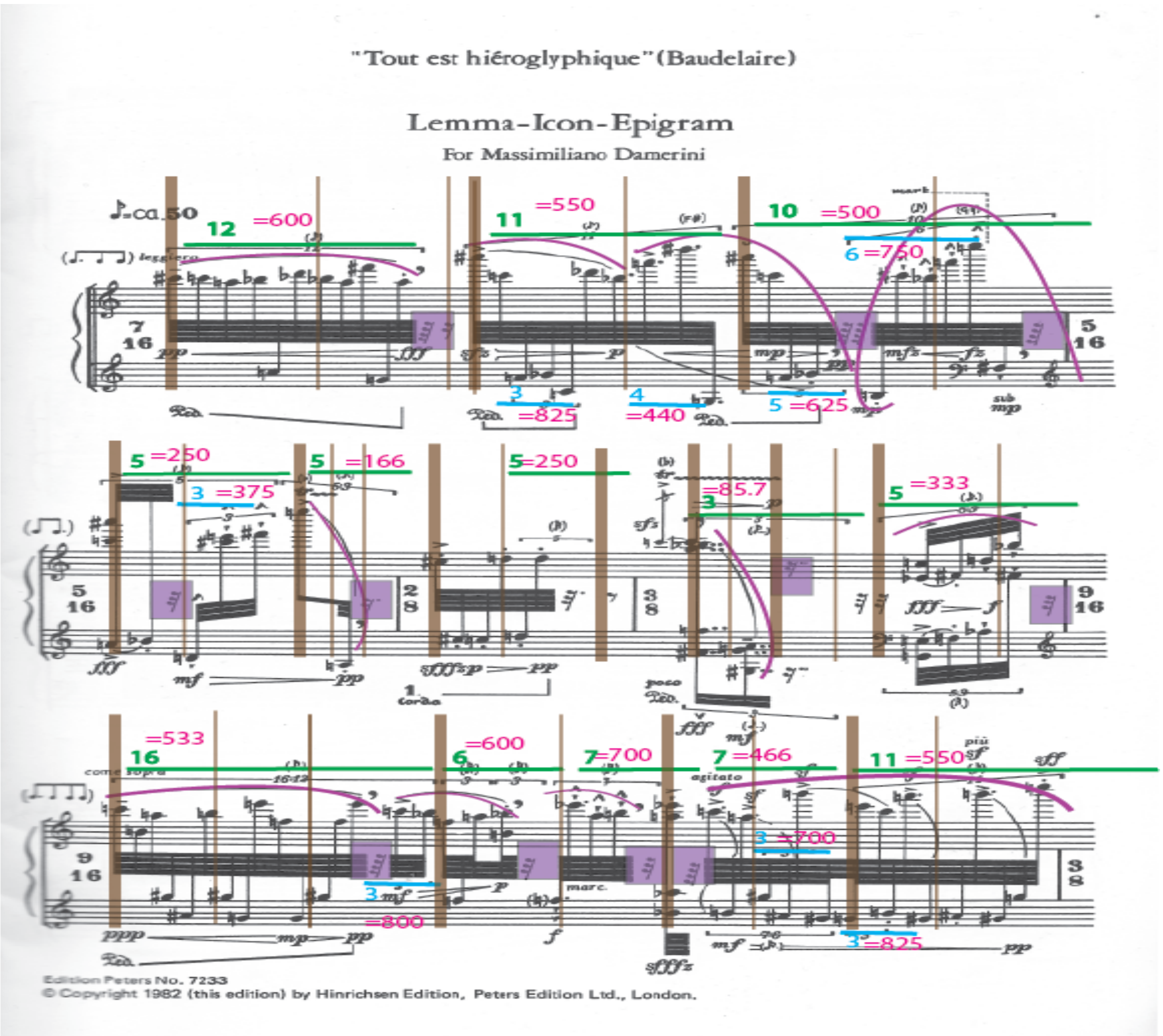

Figure 63: Mediation techniques and gestural patterning

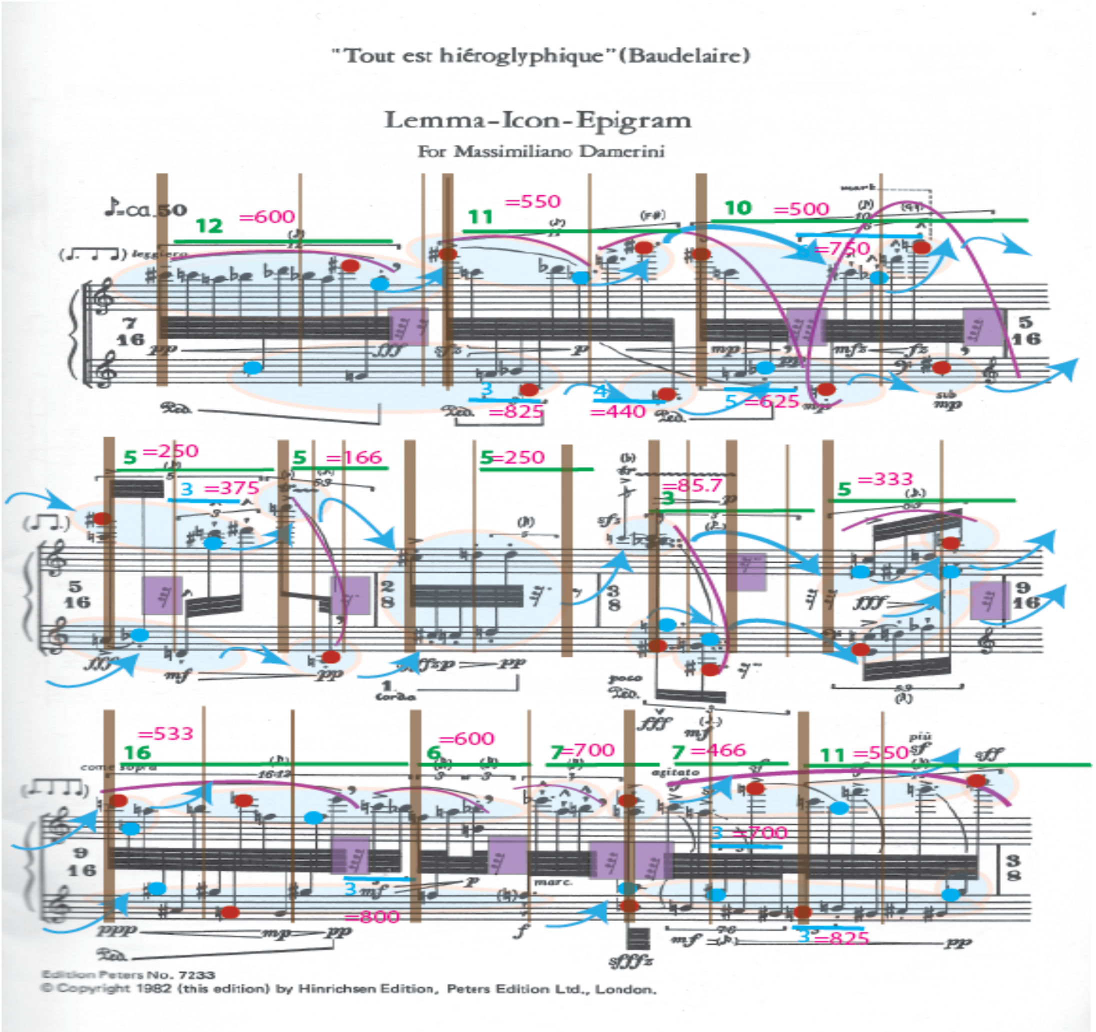

Figure 64: Mediation techniques and embodied layers

It is interesting to note that the displacement of the hands couples neatly with the phrase level, which also is the basic pulse layer, occasionaly requiring change of position on the sixteenth subdivisions, so that the gestural rhythm of the passage would be transcribed as follows:

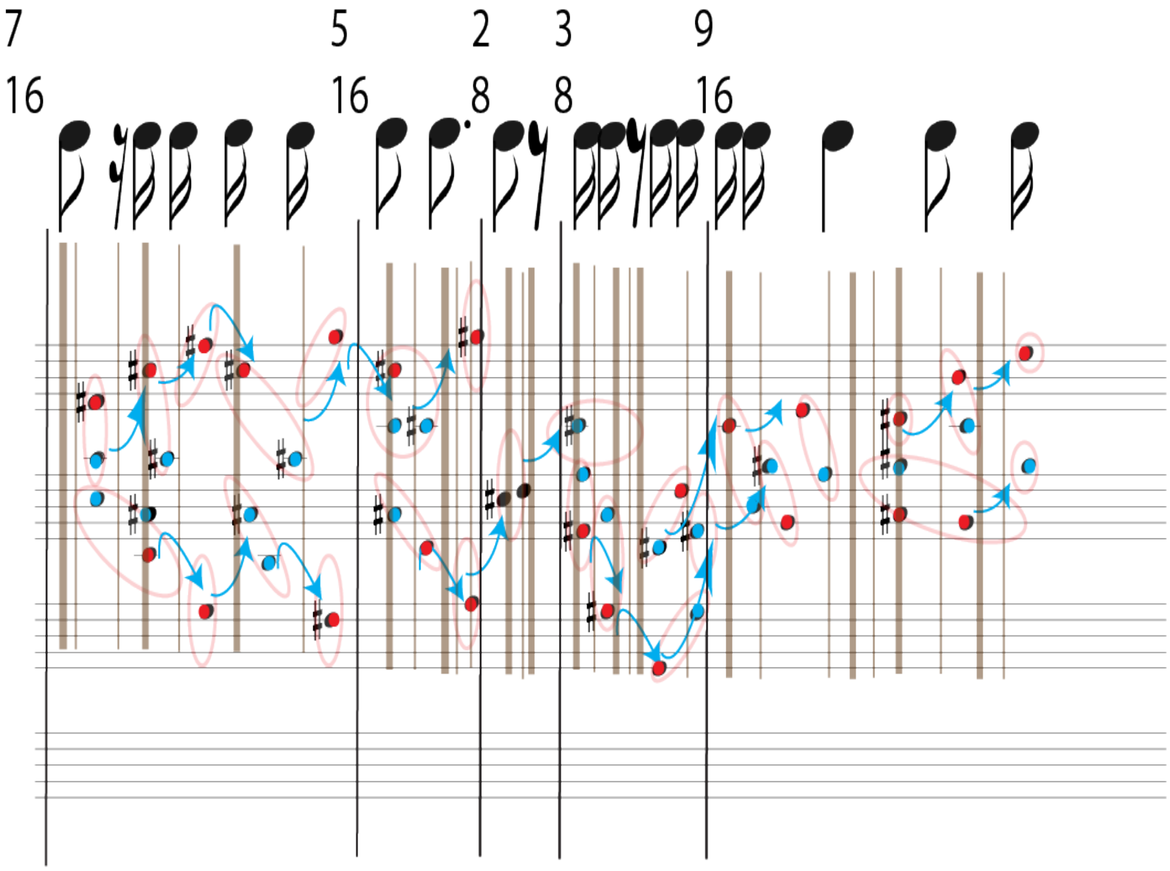

Figure 65: Simplification of complex rhythm based on gestural patterning and mediation techniques

Here is the realization of this structure through a customized clicktrack, implemented in *Pure Data* by Joao Pais[385]: The first click-track corresponds to the metric structure of the excerpt counted in sixteenth-notes; the second corresponds to the gesture patterning as above.

https://www.youtube.com/watch?v=idovxvga54c accessed 29.04.2018

Moreover, the higher-order pattern (arm layer) of three heterodirectional (contrary motion) and three homodirectional (parallel motion) chunks revealed by the pitch analysis in the previous chapter seems to be at large coupled with the basic measure units:

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[385] https://jmmmp.github.io/clicktracker/ accessed 27.04.2018

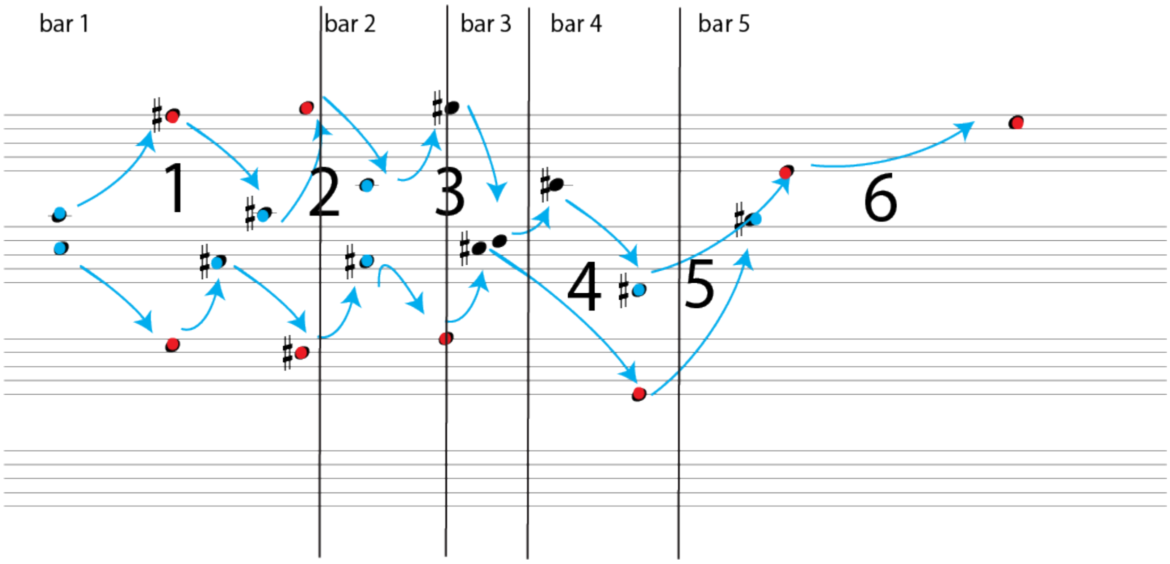

Figure 66: Coupling of gesture patterning and bar structure. Reading as usual from top – down: treble clef two octaves higher, treble clef, bass clef, bass clef two octaves lower

C. Multimodal Augmentation

At a third stage, the basic gestural segmentation discovered through the data analysis was mapped on the notational and multimodal representations derived from the recording of the performance. Those graphic components were synchronized along the gestural segmentation using the *INScore*[386].

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[386] http://inscore.sourceforge.net/ accessed 27.04.2018 *INScore* is an open source platform for the design of interactive, augmented, live music scores. INScore extends the traditional music score to arbitrary heterogeneous graphic objects: symbolic music scores but also images, texts, signals and videos. A simple formalism is used to describe relations between the graphic and time space and to represent the time relations of any score components in the graphic space on a *master / slave* basis. It includes a performance representation system based on signals (audio or gestural signals). It provides interaction features provided at score component level by the way of *watchable* events. These events are typical UI events (like mouse clicks, mouse move, mouse enter, etc.) extended in the time domain. These interaction features open the door to original uses and designs, transforming a score as a user interface or allowing a score self-modification based on temporal events. INScore is a message driven system that is based on the Open Sound Control [OSC] protocol. This message-oriented design is turned to remote control and to real-time interaction using any OSC capable application or device (typically Max/MSP, Pure Data, but also programming languages like Python, CSound, Super Collider, etc.). A textual version of the OSC messages that describe a score constitutes the INScore storage

Annotation through the *INScore* takes the form of a simple *graphic segmentation* of any image. This graphic segmentation can be explicitly coupled with a corresponding time segmentation, in a relation generally described by Dominique Fober as *time-to-space mapping*. This explicit form of mapping is expressed in the form:

$$([x_1, x_2[\ [y_1, y_2[)\ (\ [t_1/t_2, t_3/t_4[)$$

whereby pairs of intervals expressing pixels ($[x_1, x_2[\ [y_1, y_2[$) are associated to intervals of musical time expressed in rationals ($[t_1/t_2, t_3/t_4[$), with 1 corresponding to a whole note.

Augmentation consists in the synchronization of graphic objects, such as videos and signals, along the designated time-to-space mapping. It takes the form of a *master / slave relationship*.

In Figure 67, you may see a typical *INScore* script for the synchronization of a cursor and a signal to a musical score.

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format. This textual version has been extended as a scripting language with the inclusion of variables, extended OSC addresses to control external applications, and support for embedded JavaScript sections. All these features make *INScore* particularly suitable to design music scores that need to go beyond traditional music notation and to be dynamically computed. For more information please check:
Fober, Y D.. Orlarey, S. Letz: *INScore: An Environment for the Design of Live Music Scores*, *Proceedings of the Linux Audio Conference* - LAC 2012
http://www.grame.fr/ressources/publications/INScore-ID12-2.pdf

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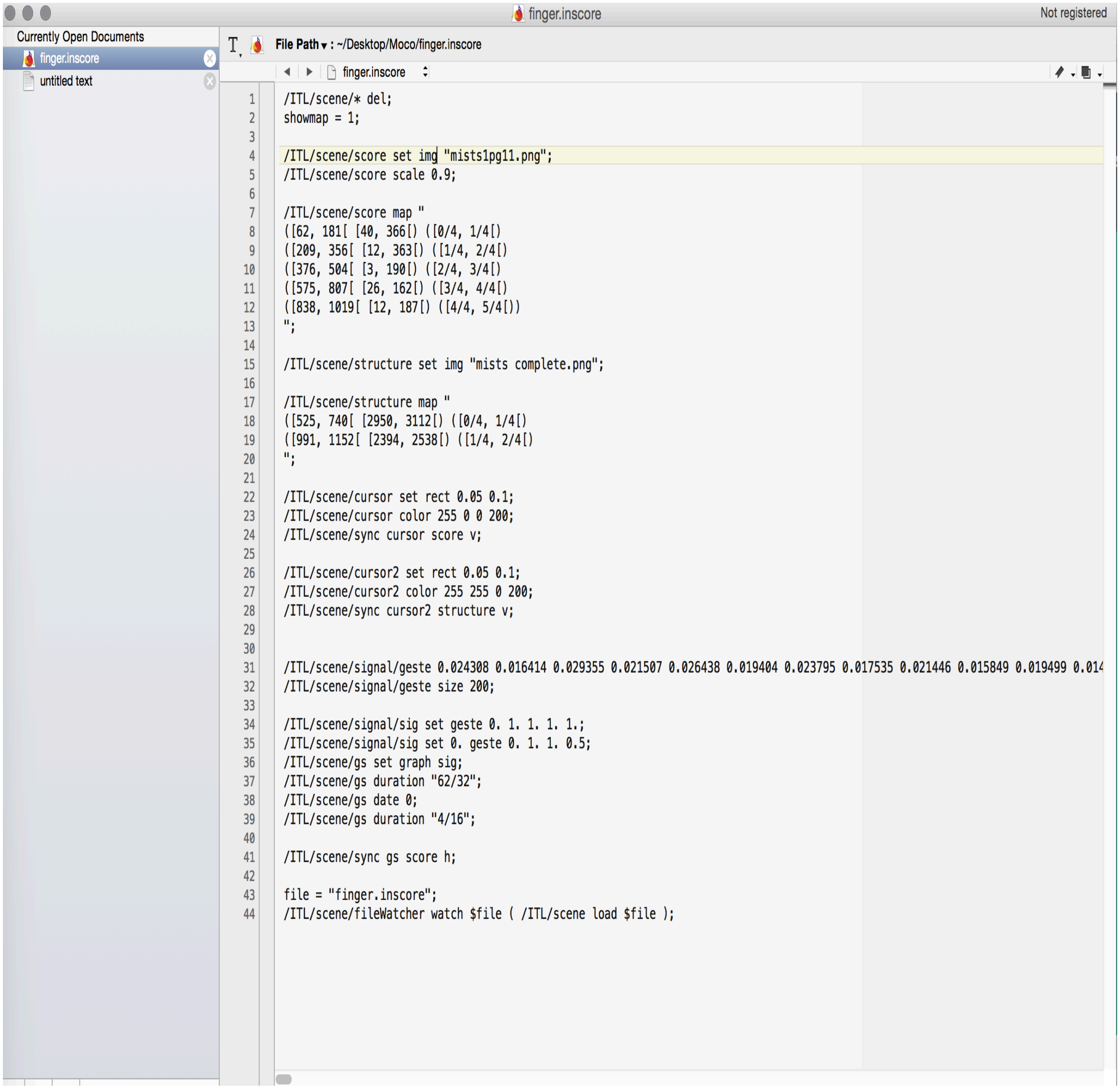

Figure 67: INScore script for the synchronization of a musical score, a cursor and a gestural signal

In the following figure (Figure 68), you may see a compound *INScore* representation including annotated scores, live gestural signals and video.

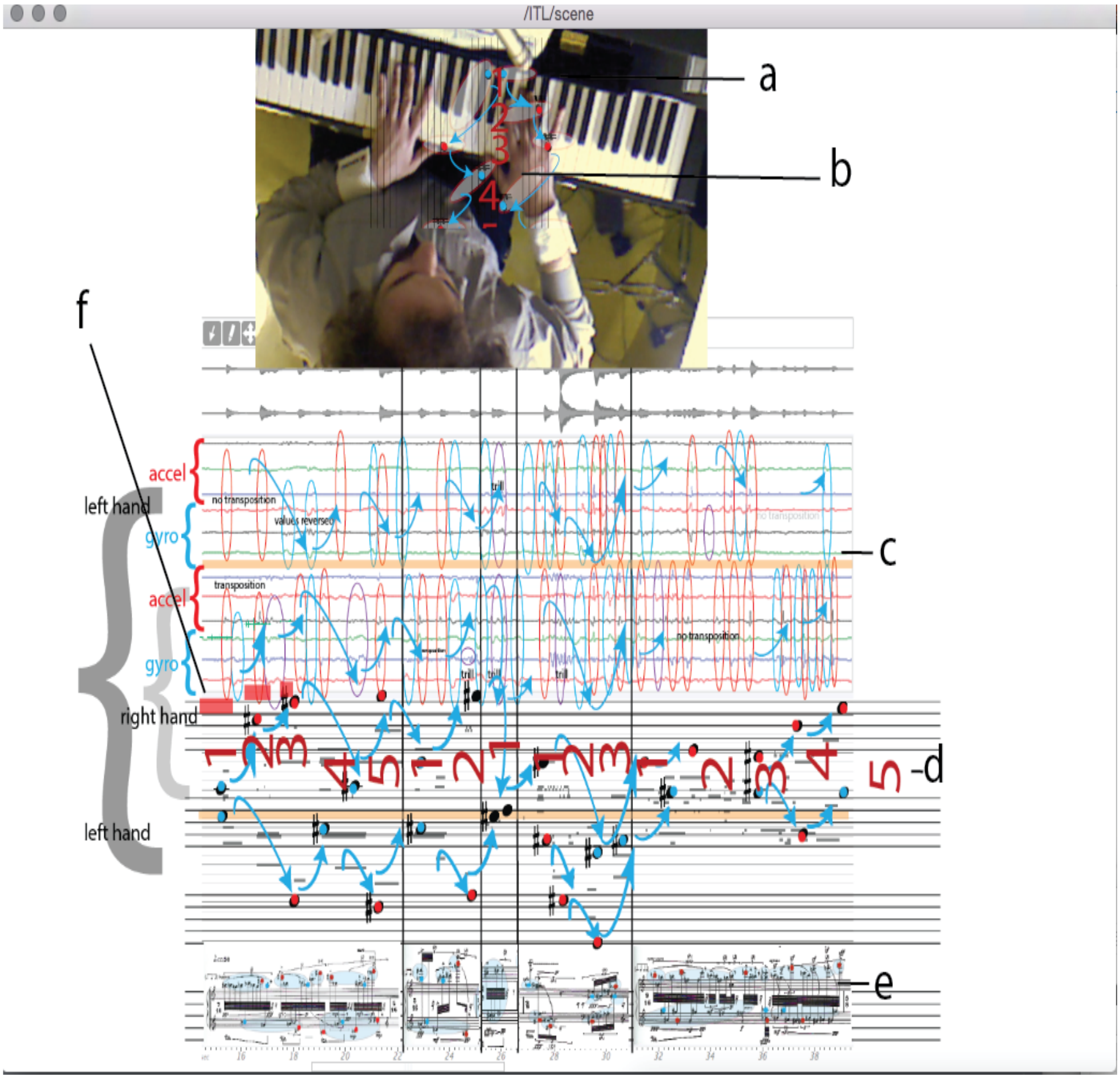

Figure 68: Compound interactive representation featuring a. video, b. video annotation presenting the basic gestural pattern, c. annotated gestural signals, d. basic gestural pattern, e. original notation, f. live gestural signal

In the following video https://www.youtube.com/watch?v=4rtRgaARiSU accessed 29.04.2018, you may see a compilation of different *INScore* representations synchronized with the *MuBu* play-patch. The representation includes the multimodal analysis, the gesture pattern, the original score, cursors, signals and other annotated videos presenting the gesture pattern, synchronized with the original playback patch. The proliferation of representations generates augmented multimodal feedback and demonstrates the *INScore's* potential.

3.5 Real-Time Expressive Navigation Of Multiple Intentionality Nodes With The Motionfollower

Thus far, we have presented the *GesTCom* features as to *representation*. In what follows, we pass into the domain of real-time gestural *interaction* with those representations.

A. Introduction To Gesture Modeling

Our work towards the creation of gesture-to-notation mappings and the use of interactive systems for complex music derives at large from previous work on gesture modeling and gesture-to-audio mappings employing machine learning techniques, as conducted by the ISMM team at IRCAM. Bevilacqua *et al*.[387] proposed a Hidden Markov Models (HMM) methodology defined as *gesture following*: Incoming gestural features, modeled as multidimensional temporal profiles, are compared in real time to templates stored during a *learning phase.* This is the first step towards implicit or explicit mappings to sound, which take place during a subsequent phase of *following*. Caramiaux[388] has further proposed a *segmental approach* to this HMM methodology for the segmentation and parsing of clarinetist ancillary gestures. In this instance, gestural features are considered as temporal and gestural segments, compared to dictionaries of *primitive shapes*, constituting prior knowledge and opening-up the way for higher-order, syntax-like modeling. Françoise has addressed the problem of temporal multidimensionality and computational limitations of the previous models through the employment of *Hierarchical HMM* and *Dynamic Bayesian Networks*[389], while addressing also multimodal modeling (simultaneous modeling of movement and sound as opposed to modeling of movement alone) and Mapping-by-

[387] Bevilacqua F., Schnell N., Rasamimanana N., Zamborlin B., Guedy F. (2011) 'Online Gesture Analysis and Control of Audio Processing'. In: Solis, J. & Ng. K. (Eds.) *Musical Robots and Interactive Multimodal Systems.* Berlin Heidelberg: Springer-Verlag

[388] Baptiste Caramiaux, Marcelo Wanderley, Frédéric Bevilacqua, "Segmenting and Parsing Instrumentalists' Gestures", in J. *New Music Research* vol. 41, no 1, pp. 13-29, 2012

[389] J. Françoise, *Realtime Segmentation and Recognition of Gestures using Hierarchical Markov Models*, Master's Thesis, ATIAM 2010-2011, Université Pierre et Marie Curie, Ircam, Telecom Paristech, 2011

Demonstration (MbD) techniques[390] (whereby the end-user controls the process of machine learning interactively). He has also proposed a lower-order syntactical paradigm for gesture-to-sound mapping: a "gesture envelope" of *Preparation-Attack-Sustain-Release* (PASR, after the classic ADSR sound envelope paradigm)[391].

These models are currently being employed in a variety of applications, including the performance arts, audio industry, sound design, gaming and rehabilitation with auditory feedback. A notable application was the "augmented violin" project[392], where those models were used in conjunction with composed music and notation. Nevertheless, many more studies are required to fully understand how a musician's movement can be modeled in a learning situation, as well as the complex relationships between gesture and notations.

The notions of: gesture following, gestural primitives, gesture-to-notation mappings and syntactical patterns (PADR), performance-oriented learning, hierarchical / segmented layering of the notation in *embodied layers* and *intentionality nodes,* are the main pillars of the *GesTCom* methodology as well, in direct relation to this corpus of work and with further perspectives for the integration of machine learning techniques.

B. Use Of The Motionfollower

The *GesTCom*'s interactive possibilities are based on the *motionfollower*, an object in Max / MSP and a customized patch conceived after the *Gesture Follower* probabilistic architecture described above.

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[390] J . Françoise, *Motion - Sound Mapping by Demonstration* , PhD Thesis, Université Pierre et Marie Curie, Ircam, 2015

[391] J.Françoise, B.Caramiaux, F. Bevilacqua, "A Hierarchical Approach for the Design of Gesture - to - Sound Mappings", in *Proceedings of the 9th Sound and Music Conference (SMC)*, Copenhague, Denmark, 2012

[392]F. Bevilacqua, N. Rasamimanana, E. Fléty, S. Lemouton, F. Baschet. The augmented violin project: research, composition and performance report. In *6th International Conference on New Interfaces for Musical Expression (NIME 06)*, Paris, 2006.

The *motionfollower* was originally implemented in the sight-reading scenario. The initial performance is used to train the system (*learning phase*), while the subsequent, varied, prioritized performances are compared to the original (*following phase*). First, it was empirically found, that given a sufficient degree of fluency of the initial 'sight-reading' performance, there is a *basic gestural profile* or *segmentation*, which can account for many subsequent interpretational differentiations and refinements, in the sense that the system can successfully follow them. In addition to empirically allowing for the discovery of this segmentation, the use of the *motionfollower* was found to provide useful auditory feedback in the very first stages of the learning process. Currently, this segmentation is not empirical, but derived by the multimodal analysis described above.

We used then the *motionfollower* in two distinct ways:

1) During the Musical Research Residency, the *motionfollower* was used as a surrogate of qualitative gesture analysis. In this sense, through the experimentation with the *motionfollower* we strove to infer basic gestural segmentation of complex notation and compare it with the implicit annotation without the motion following.

2) In the second scenario described here, the previous analysis of the gestural data provided a *gestural template*, which was subsequently recorded as the ground against which all navigation takes place. This exploration of expressive intentionality nodes, parametrical strata and decouplings is happening in real-time and corresponds to the *following* phase, while the recording phase of the template corresponds to the *learning* phase of the *motionfollower* system.

The principle of *following*, as probabilistic comparison of an incoming gesture against a recorded template, is applied in relation to the defined gestural primitives and the corresponding embodied layers as follows: In *the recording phase*, the basic gestural pattern is recorded and serves as a template for the *following phase*, whereby a great range of varied performances is probabilistically compared to the pattern. The variations include typical expressive parameters, such as tempo (accelerations, decelerations, interruptions in homogenous or heterogeneous ways), rhythmic variations including micro-rhythmic ones in the form of nested tuplets, dynamic, articulation, but also variations of the corresponding embodied layers (information reduction strategies), air-gestures and total distortions of the material (but not distortion of the basic gesture!). Please watch the following video for a demo of the *motionfollower* in the context of the *GesTCom*:

https://www.youtube.com/watch?v=fS4xj6qOtxk accessed 29.04.2018

The notion of *intentionality nodes* points to the fact that multiple intersecting compositional and expressive parameters become representable through gestural primitives, a fact which opens up the way for modeling of the complex prioritization processes involved in the expressive performance of notated music through machine learning techniques. In other words, each note in a symbolic score belongs to multiple parametrical layers or strata, whose malleable amalgamation into variable gestures can be traced as a deviation from the gestural pattern and modeled accordingly. For more information on intentionality nodes, please refer to part two, 4.5.

The system provides gesturally controlled augmented multimodal feedback, both visual and aural (Figure 69): Visual in the form of a cursor leading the incoming gestural signal against the already recorded one and aural as a gesturally controlled audio recording. The relationship between the *motionfollower* and the performer is dynamic and its success depends heavily on the good syntactical definition of the selected input gesture (according to the *PADR* model described before). The cursor “waits” for the player at points where the real-time performed information is more analytical than the input gesture (for example, as the player carefully articulates each note in a grasp constellation), or “jumps” forward in the case that the player omits information, shifting towards the arm layer. The range of followed variations is large but not infinite, meaning that the *motionfollower* should be thought more as a co-player requiring constant real-time monitoring rather than a blindly following slave. An interesting variation was the combined use of the flexible *motionfollower* with a strict metronome. In this case we used a customized metronome for complex music, the clicktracker by Joan Pais. The metronome was used during the *following phase*, reproducing either the originally notated metric structure or the approximate (and much simpler) rhythm of the basic gestural pattern. In that way, it acted like an “embodied-clicktrack”.

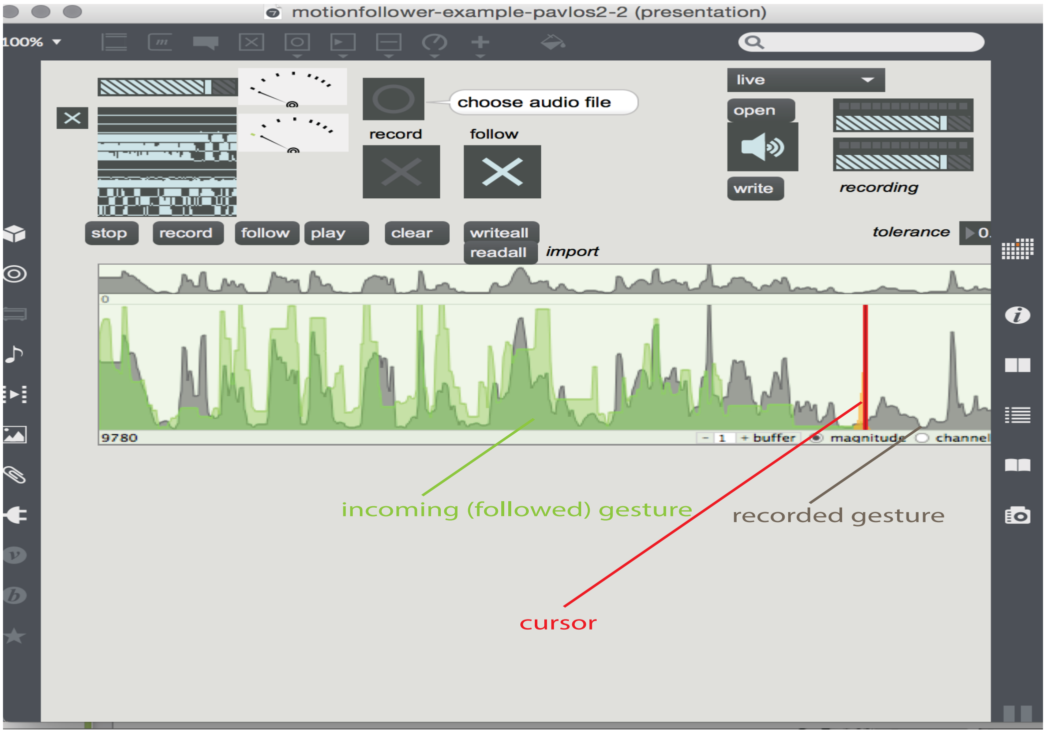

Figure 69: motionfollower patch, notice the recorded signal in grey, the incoming signal in green and a cursor visualising the process of following

3.6 Real-Time Gestural Control Of Inscore Scripts

A. Introduction

In the last stage of the *GesTCom* methodology, we connected the *motionfollower* patch to any *INScore* script, by means of a dedicated Max patch sending OSC messages. As indicated before, the *INScore* script generates compound musical representations, including various graphic objects, videos and signals. Through this connection, the functionality of the *motionfollower* is effectively extended into the domain of dynamic musical scores, enabling the creation of personalized, gesturally controlled, interactive multimodal tablatures for complex music. Such tablatures provide the user with augmented feedback and score-following possibilities. As in the case with embodied navigation, the tablature consists of embodied representations of the original. The novel part is, that those representations are generated from recordings of an actual performance and can be interactively controlled by the player.

The interaction schema takes the following feedback loop form:

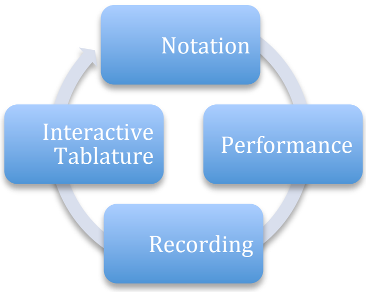

Figure 70: *GesTCom*'s interaction schema

This tool materializes the paradigm of embodied navigation of complex notation, drawing from latest developments in the computer music fields of musical representation and of multimodal interaction. The collected multimodal data reviewed in the previous sections -gestural, video, audio, MIDI and *TouchKeys* data- are appropriately mapped on the musical score, turning it into a personalized, interactive, multimodal tablature. This tablature may be used for efficient learning, performance and archiving, with potential applications in performance analysis, embodied learning, piano pedagogy, contemporary composition, free improvisation and score-following. The underlying metaphor for such tool is that instrumentalists *touch* or *cut through* notational complexity using movement, as much as they touch their own keyboards, thus the acronym *GesTCom*. Their action on the instrument forms integral part of their understanding, which can be represented as a gestural processing of the notation.

Such representability of interactive dynamics reflects the radical version of embodied navigation:

In the radical version, the interaction between the internal and external elements, and most importantly with music notation, is assumed to evade the need for mental representability and could be described through the terminology of dynamic systems. In fact, such a model will be materialized in the third chapter, through the representation of interactive dynamics with the use of multimodal interactive systems, which minimize the need for mental representation by maximizing direct perception. (part two, 3.5).

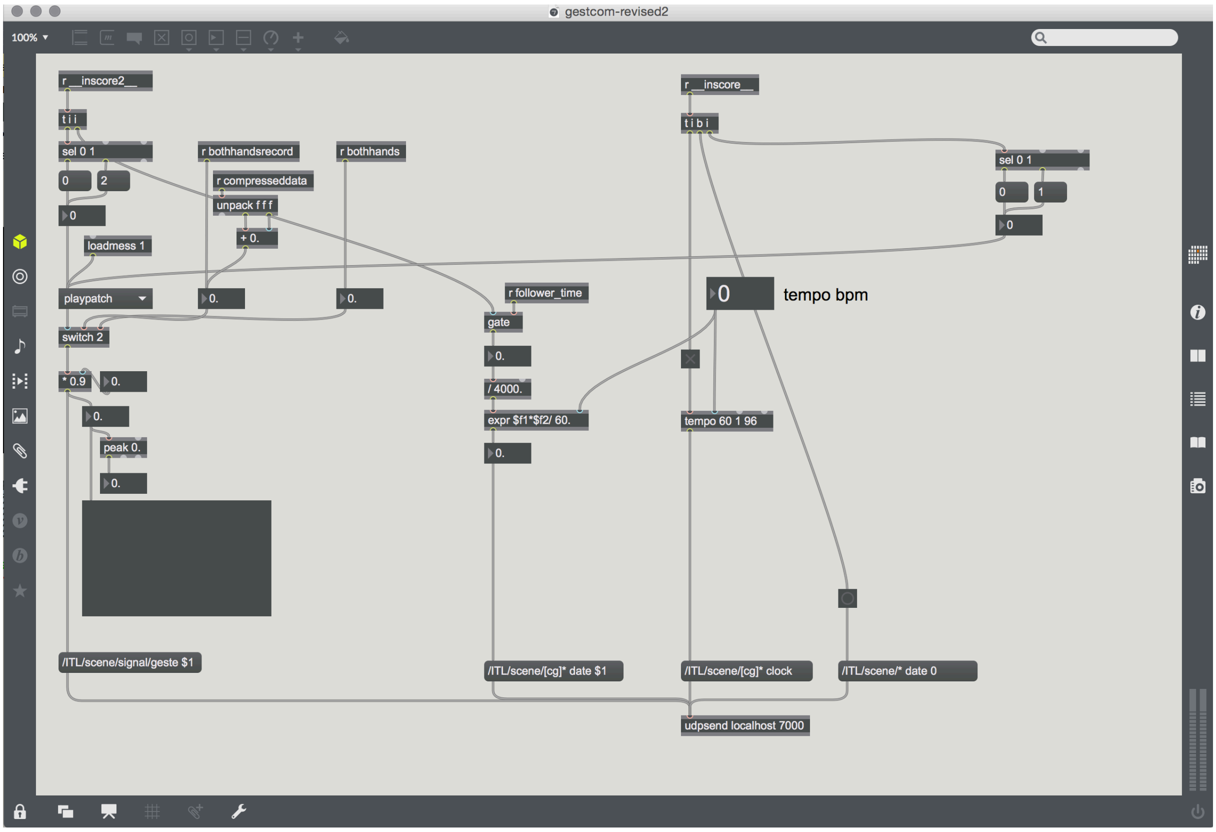

Figure 71: Max / MSP patch connecting the *motionfollower* to the *INScore*

B. Function

The *motionfollower*'s learning and following schema is used for the control of the mobile elements of the *INScore*, including cursors, signals and videos, in the context of the *GesTCom*: At the *learning phase*, the user synchronizes her performance with any element of the tablature, which has been graphically segmented and assigned a duration according to the basic gestural pattern and the *INScore* space-time formalism (explicit mapping). In the *following phase*, the player can pursue highly differentiated performances and prioritizations and control the speed of the mobile elements of the tablature through her incoming gestural signal, extending the augmented feedback of the follower into multimodal compound representations. The whole interaction schema could be described and at a later stage even sonified as an *embodied clicktrack*, which relieves the notational complexity and functions for a wide range of interpretational and expressive deviations, described above as *navigation of intentionality nodes*. In our case studies, a single template corresponding to the basic gestural structure was mapped upon several interchangeable score representations of varying degrees of complexity and multimodality. As a result, complex representations could be followed on the basis of very simple gestures, effectively turning notation into an interface for musical expression.

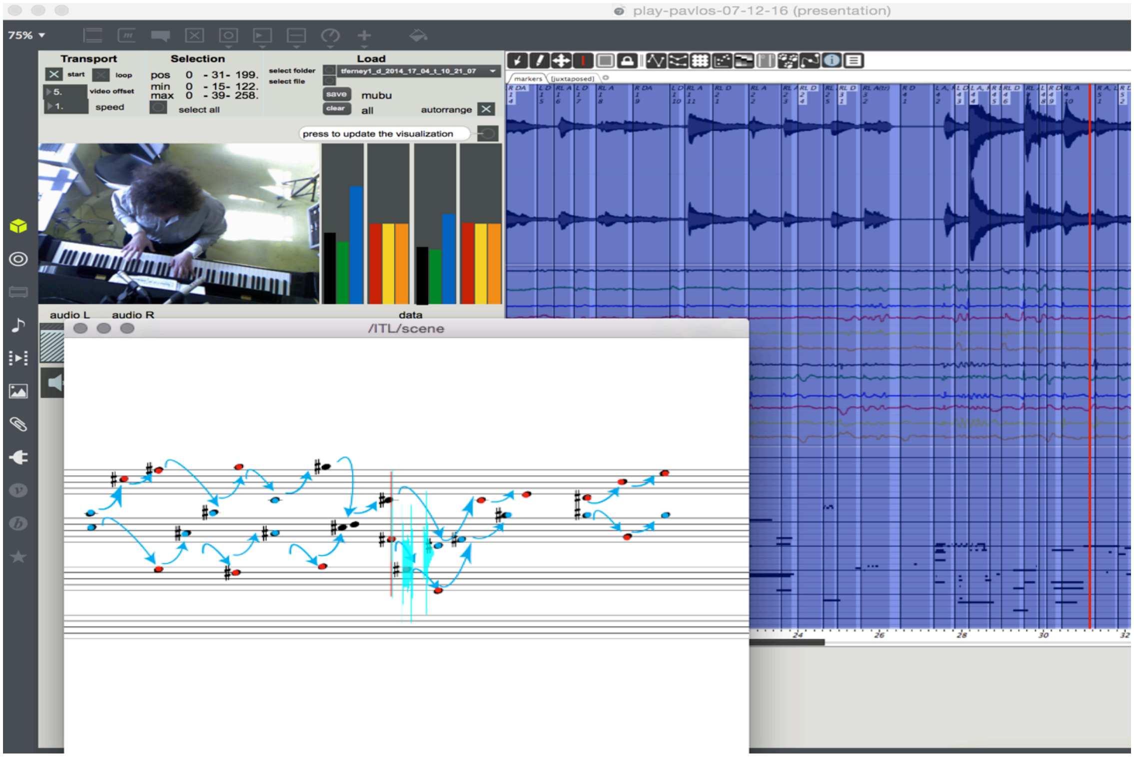

Figure 72: GesTCom controlling a compound representation of the gestural pattern and incoming signal.

A demonstration of the prototype system can be accessed here: https://www.youtube.com/watch?v=KV9nQUhhyuI accessed 29.04.2018

A demonstration of the current refined version of the system can be accessed here: https://www.youtube.com/watch?v=YLB7uayipd4 accessed 29.04.2018

3.7 Conclusion

In summary, the resulting architecture of the *GesTCom* involves the following components:

- Recording of multimodal data (*MuBu*)
- Gesture Analysis (*MuBu*)
- Derivative Representations, Mappings and Synchronizations and Personalized Tablature Creation (*INScore*)
- Interaction (*INScore* and *motionfollower*)

The system *GesTCom* proposes a novel paradigm for the management of massive amounts of information in the very first stages of the learning process, through a personal, spontaneous performative response. This initial performance segments the score in manageable chunks of information, to be used for the refinement of the performance during the next stages. Each new performance can potentially interactively transform the tablature, thus offering an accurate archive of the learning process and a means of multimodal representation / recording of the learning trajectory, including the performance.

From an embodied cognition point of view**,** output notations are embodied and extended: They are produced through performative actions, they represent multimodal data, they can be interactively controlled through physical movement and they can dynamically generate new varied performances. They can be considered as the visualization and medial extension of the player's embodied navigation in the score-space, creating an interactive feedback loop between learning and performance.

The potential applications of the system are not limited in this specific sight-reading interaction scenario: In the case of players who favor an analytic approach or do not have the experience or ability to sight-read, we can imagine an explicit mapping of the preferred gestural properties or priorities on the *INScore* and its use as ground for further learning[393].

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[393] In fact, as discussed in the section on embodied navigation, this gestural template may consist of traditional visuographic data (the multi-layered tablature articulated in embodied layers, sound-action chunks, technical patterns or other personalized / idiosyncratic gestural formations); but it might as well refer to different types of gestural data, which would accurately represent qualities of piano-specific gesture such as: homodirectional versus heterodirectional movement in the keyboard space;

In comparison to other highly developed systems providing augmented feedback to the player, such as the *3D Augmented Mirror-AMIR*[394] for violin playing, the novelty of this system lies in the fact that it directly involves notation and its transformations, thus the title „gesture cutting textual complexity".

Next to its obvious applications in pedagogy and musical performance, the system has been used as a compositional and improvisational tool, as well as a powerful resource for performance analysis.

Summarizing, the features of the system involve: efficient top-down learning of complex scores through augmented multimodal feedback produced and processed through movement; enhanced readability of reduced representations of the notational information; interaction in the form of an embodied clicktrack ; archiving of learning and performance from the very first step; externalization of the navigation between the annotations, augmentations and transcriptions of the notation; performance analysis.

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grouping of events versus their isolation; articulation and dynamics; continuity versus perforation; gravity versus muscular energy; tension versus freedom of movement; and so on. The translation of the five sets of data (audio, MIDI, video, inertial and capacitive) into meaningful information of piano-specific physical movement equals to the transition from low-level data to high-order types and syntaxes, or from raw physical energy to action-oriented descriptors. Key to our methodology is the fact, that the raw data themselves are structured *a priori* through the performative intentionality, which we externalize with the implicit annotation of the original musical score. The variety of those potential higher-order concepts aims at the accommodation of performers' idiosyncracies and the avoidance of an imposed protocol or method, which could inhibit creativity and personalized performative responses. That's why we also speak of a *methodology* rather than a *method*, pointing to the open-endedness of the whole process

[394] K. Ng: Interactive Multimedia for Technology-Enhanced Learning with Multimodal Feedback.In: J. Solis & K. Ng (eds.): *Musical Robots and Interactive Multimodal Systems*, pages 105-126. Springer-Verlag, Berlin and Heidelberg, 2011.

Future directions in the design of the *GesTCom* include: accumulating user experience; automating elements of the *GesTCom* architecture according to performative needs; creating web-resources.

1) User Experience: Testing the tool in selected communitites of performers and in a wide range of repertoires will give us an accurate perspective of performative needs and responses.

2) Architecture: Assuming the reluctance of most performers to code, it will be quintessential to keep the performer as close to the keyboard and to playing as possible, with developments in:

a) Recording: We wish to implement haptic interactions, through the recording of other forms of gestural data such as piezoelectric, probably in combination with appropriate keyboards as controllers (for example the *TouchKeys* system).

b) Movement Analysis: Instead of empirically defining the „basic segmentation“ with the *motionfollower* or through analysis, one could automatically derive it from notational representations employing machine learning.

c) Representations and Mappings, Tablature Creation: Automated time-to-space mapping through gesture, rather than through typical UI events, would considerably make the whole precess of tablature creation more performer-friendly. In this direction one can also predict the incorporation of more user interfaces, such as touchscreens, or controllers, such as the *TouchKeys*.

d) Interaction: The „embodied clicktrack“ notion can also be extended, with sonification of the movement along the mapping.

3) Implementation of the *GesTCom* as an open web resource could enable projects of collaborative learning through the collective creation and sharing of interactive multimodal tablatures.

Finally, in relation to the embodied navigation paradigm, we may summarize the *GesTCom* contributions as follows :

In the realm of representation:

a. Registration of real physical energies as opposed to mere symbolic representation.
b. Monitoring of the learning process.
c. Longitudinal archiving in both physical (data) and symbolic (notation) form.
d. Dynamic as opposed to static representation of the navigation paradigm.
e. Externalization of the internal mental processes associated with learning.
f. Extension of the traditional annotation practices through technology.
g. Reproducibility and communicability of the learning processes.

In the realm of interaction:

a. Simplification of the complex notation through performance data.
b. Proliferation of the representations and augmented multimodal feedback.
c. Real-time gestural control of the symbolic and multimodal notation.
d. Effective transformation of the notation into an interface.
e. Radical embodied paradigm with contingent use for mental representations.
f. Direct perception of notation as signal.
g. Entrainment, alignment and sensorimotor learning in the interaction with symbolic information.

PART FOUR:

CASE STUDIES

1. Introduction

The last part of the dissertation presents case-studies of the embodied navigation paradigm and / or the corresponding interactive tools selected from my repertoire as a professional performer. The repertoire presented here covers all three axes of complexity as defined in the first part: The intrinsic complexity of notation, as well as the interaction with electronics and the generation of theatrical acts. In particular:

a) An extreme case of intra-notational complexity, Iannis Xenakis' *Mists* (1980), is used to demonstrate tools for embodied interactive learning and performance analysis. Such tools offer insights about the relation between the notational surface and the musical act (performance analysis), as well as insights concerning the relation between deeper musical structure and performance (performance analysis in relation to traditional analysis). They can finally find pedagogical applications. A similarly complex case-study from Brian Ferneyhough's *Lemma-Icon-Epigram* (1981) was used in part three, to demonstrate the emergence of a methodology for the processing of complex notation through multimodal data. The difference here lies in the scope of the analysis, in both quantitative (the big amount of data) and qualitative (modes of representation and global-to-local structures ratio) terms.
b) A shorter report is made on Mark Andre's *Contrapunctus* (1998-99), a form of *post-complex* music: The relative sonic sparseness of an Apocalypse-inspired aesthetics conceals an underlying network of *intentionality nodes* inviting embodied navigation.
c) Wieland Hoban's *when the panting STARTS* (2002-2004) represents an example of intermedial convergence, with notational complexity generating further performative functions bordering on physical theatre. The piece is notated in thirteen staves, one for each finger and pedal of the instrument, making a convincing case for the transfer of Klaus K. Hübler's *action decoupling* techniques from the realm of string writing to the piano.
d) Nicolas Tzortzis's *Incompatible(s) V* (2011-12) represents another example of convergence, where all three axes of complexity amalgamate into a

programmatic conscious whole: Notational complexity in the form of dense polyphonies and complex rhythms, live state-of-the-art electronics and a new conception of the instrument shaped by technology, as well as theatrical stratification between the visual and audible aspects of the performance.

The goals of this part is to:

1. Present all three axes of complexity in a concise way.
2. Show applications of the embodied navigation, including interactive systems, in performance analysis and embodied learning.

2. Embodying Algorithms: Iannis Xenakis Mists

2.1 Introduction

As already exposed in the first part (p. 37-39), Iannis Xenakis' work is characterized by the invention of a complex musical language based on mathematics and graphic design, while generating surface immediacy and expressive force through a heightened role for physicality in performance. *Mists* for solo piano (1980) is Xenakis' third and largest work for the instrument and one of his important works in the 1980's. In more than one ways, it represents the culmination of his output for the piano, after the *symbolic music*[395] of *Herma* (1961) and the introduction of *arborescences*[396] in *Evryali* (1973). According to Ronald Squibbs[397] (p. 91), it highlights his major theoretical concepts, such as *stochastic composition*[398], *sieve theory*[399] and a *general theory of musical time*[400]. In addition, arborescences are based on graphic sketches as a further analytical tool. These general features render *Mists* particularly apt as a representation of the embodied navigation paradigm in relation to Xenakis' mature compositional style.

In relation to embodiment and notation, *Mists*' features are formulated as follows:

Pitch structures are organized in sieves and shaped through stochastic processes. Their representation in traditional music notation challenges the UTI model due to quantitative complexity. In lieu of this model, we propose notational processing in terms of coarticulation layers, body positions and choreography. PADR envelopes

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[395] Music based on *Boolean algebra.*

[396] Branching polyphonic structures.

[397] Ronald Squibbs, "Some Observations on Pitch, Texture and Form in Xenakis' *Mists*", *Contemporary Music Review*, 2002, Vol. 21, Nos 2/3, 91-108

[398] composition based on the probability laws governing random physical phenomena

[399] A general theory of musical scales.

[400] In short, the distinction between compositional materials *outside time* and the process of their unfolding *inside time.*

(part three) offer tools for “computing the sand”[401] of the dense notational surface in an embodied way.

Rhythmic structures are generated stochastically. Such rhythms are unintelligible and invite embodied navigation rather than perfect reproduction.

Complex textures grasp both arborescent polyphony as well as linear and non-linear stochastic constellations. Each texture corresponds to concrete types of action and navigation, allowing for immediacy in the perception of the musical surface.

Performance parameters such as articulation, dynamics and pedaling, are used for the further differentiation of random pitch and rhythm processes and for shaping form locally.

Space-time notation is used for the representation of non-linear stochastic materials. Such notation prompts the rethinking of representation in relation to embodiment and direct perception.

Robust form allows for the containment of the highly complex materials and for the exploration of embodiment in the macro-structural level.

Graphic representations of arborescences can be easily correlated to representations of embodiment.

Concrete challenges on performative physicality can be rationalized and demystified, as opposed to the usual mythology around Xenakis’ performance.

Two excerpts from *Mists* have already served as hands-on examples for the embodied navigation paradigm (part two, chapter 4.2, 4.4). The goals of the current

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[401] Reference to the *Sand Reckoner*, a work by Archimedes in which he set out to determine an upper bound for the number of grains of sand that fit into the universe. In order to do this, he had to estimate the size of the universe according to the contemporary model, and invent a way to talk about extremely large numbers.

chapter are:

1) to provide a global analysis of the work based on embodiment at all structural levels and all degrees of temporal resolution.
2) to extend the analysis from multilayered tablatures to multimodal data, bridging the gap between second- and third-person descriptions.
3) to provide correlations between traditional analysis and performance analysis.
4) to demystify notions of transcendence and effort for the next generation of performers, by rethinking physical effort and expression.
5) to show that embodiment reveals meanings that could not be concluded by analysis of the musical score alone.

In terms of methodology, we explored four scenarios of embodied interaction with the piece:

In the first scenario, similar to the Ferneyhough 'sight-reading' scenario presented in part three, I *scanned*[402] through the musical score, in a representation of the very first stage of a top-down learning process, which I recorded multimodally. I have referred to this dimension elsewhere as the *assemblage view*. This scenario provided me with the *gestural template*, against which all further movement analysis and learning was carried out. The experience of the piece's total duration and the familiarization of its global aspects are here the main objectives.

In the second scenario, I recorded in detail the performance of several *filters* or *prioritization processes*, which automatically rewrite the notation, providing multiple alternative segmentations. This is the constructivist scenario, whereby different approaches are tested and explored and several strata for channeling the

[402] *Scanning* has ambivalent meanings. It designates close examination as well as hasty passage; implies modern scanning technologies; but also the somatic effort of overcoming stumbling blocks, from the ancient etymology of *scanning* as "to spring, leap, climb", from the Proto-Indo-European root *skand, featuring also in the ancient Greek word *skandalon*, meaning "stumbling block". In https://www.etymonline.com/word/scan accessed 21.04.2018

performative energy are outlined. We have termed this dimension as *forward-moving stratification*, in the sense that it safeguards the continuity of performance

In the third scenario, I *sculpted* through repetition towards perfection and according to intentional interpretative choices a final sonic result in various tempi. Such scenario presents a more definitive conception of performative intentionality as to a desired sound image, as to performance in the sense of a product / object rather than as process. However, it must be noted that several compositional materials, especially non-linear ones, are resistant or even impossible to implement. Still, repeatability becomes a good measure for the rationalization of impossibility, as opposed to blanket statements about Xenakis' unperformability. We have described this scenario as *resistance to the flow*, both in the sense of looping repeatable chunks and in the sense of projecting discontinuities in the performance.

In the fourth scenario, I created interactive representations for the navigation of the notation, based on the recordings and processes above. Such tools allow for a dynamic experience of the embodied navigation on the fly, making palpable the actual passage through the state-space in the course of a single performance. We have termed this scenario "*line of flight*", as the real-time passage through the state-space established by the previous three dimensions; as a singular performance which combines the stratification of preparation with the spontaneity of the moment.

In terms of structure, the analysis will be articulated as follows:

First, I will present a correlation of the basic building blocks – textural types of the work, in relation to different types of gestural ground, comprising embodied layers and PADR envelopes.

Then, a microscopic analysis of the types of navigation that each of those types invites, in relation to different prioritisations and focuses, and an investigation of different paths and possibilities in this respect will be presented.

Third, a macroscopic analysis, both in terms of the articulation of the form of the piece and its dramatic consequences in relation to body positions and expressive gestures, as well as as the longitudinal navigation of this form and the emergence of embodied meanings, will come into focus.

All that should foster an embodied form of understanding, which cannot be static but rather perpetually renewable, explorable, navigable, re-enacted and reborn; experiential and revelatory.

2.2 Outside Time Materials: From Concept To Embodiment

Xenakis himself, in his usual laconic and aphoristic style, describes the poetics of the piece as follows:

"The construction of this piece follows two main ideas. One is the exploration of pitch series (scales) and their cyclic transpositions. These series stem from logic functions acting on simpler series of one module. Their exploitation in sound is made either in a contiguous manner (melodically) or by means of stochastic distributions such as the exponential law, the Cauchy law, the hyperbolic cosine law etc.., in order to produce sound clouds of defined density; in short, with the aid of random walks (Brownian movements).

The second idea is that of arborescences, in other words of bush-like clusters of melodic lines which undergo various rotations in the time space."[403]

Those two compositional ideas generate three distinct types of materials, which according to Squibbs become the main repository for pitch, texture and formal processes in the piece and have, *mutatis mutandis*, the same function as themes in classical music: Scales generate linear and non-linear random walks, next to the general type of branching polyphony described as arborescences.

Here follows an overview of these materials from a compositional standpoint, before proceeding with purely performative considerations.

A. Linear Random Walks

The term "linear random walks" indicates the exposition of scales (linear), whose directionality in space and whose rhythm are randomly shaped through stochastic processes (random walks).

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[403] Iannis Xenakis, *Mists* pour piano, Editions Salabert, 1980, performance note

This type of material is gradually formed through canonic entrances of an original scale (bars 1-9), resulting into a quadruple random walk, comprising four voices in canonic permutation of the same basic scale, articulated by complex non- coinciding polyrhythms as shown in Figure 73:

Figure 73: Four-part linear random walk, bars 9-11

This type of material persists in the first section of the piece, according to Squibb's analysis, bars 1-40, and makes a climactic return towards the end of the piece, (bars 122-127). Globally, linear random walks are exposed and developed in the following segments of the piece: Bars 1-13, 16-22, 24-28, 31-40, 122-127, covering 41 / 144 = 0.28 of the total duration.

The original scale is shown in the following figure and is subjected to a number of *cyclic transpositions*[404], detailed in the Squibb's analysis.

[404] Cyclic transposition is the twofold process of transposing a scale to a new key and then redefining its boundaries at will, resulting in a permutation of the series of intervals which otherwise remain the same. For a simple example, all modes in classical music constitute a cyclic transposition of the ionian

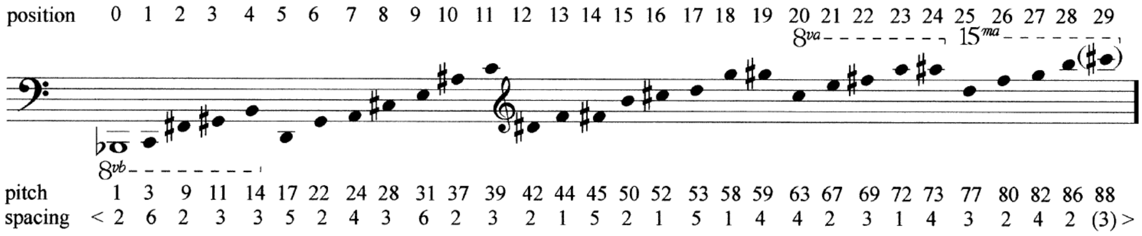

Figure 74: *Mists*, original scale. Original figure by Ronald Squibbs, in ibid. p.92, reproduced with kind permission by the author and the publisher.

One of the main features of the piece is that this deep pitch-based structure becomes palpable through the textural contrast between linear and non-linear random walks and the subsequent different gestural types associated with those, so that “textures perform a function analogous to themes in traditional music” (Squibbs, p.96).

B. Non-Linear Random Walks

The term “non-linear random walks” indicates the exposition of the above mentioned scalar material in non-linear ways through stochastic distributions, detailed by Xenakis in his preface to the piece (the exponential law, the Cauchy law, the hyperbolic cosine law and others). Such distributions seem to describe mathematically several chaotic phenomena in physics, such as gas molecule movement in a closed space. Xenakis himself describes the emerging musical textures as *clouds* or *galaxies*, whose density is controlled through mathematical functions, so as to avoid uninteresting musically results, for example too sparse textures for too long time. For these materials, Xenakis employs time-space notation, indicating only the noteheads in a grid of sixteenth and eighth notes beams, so that the final result looks like the following figure (Figure 75).

Apart from density in space and time controlled through the above mentioned mathematical functions, these constellations are further articulated in time through

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mode, keeping the same intervals each time arranged in a different order. Xenakis has generalized this principle for complex materials in the form of his sieve theory.

dynamics, articulation and pedaling, resulting in a mobile matrix of parametrical possibilities.

Non-linear random walks are covering bars 41-79, 83-92, 94-108, 111-114, 117-121, that is a total of 73 / 134=0.54 of the piece.

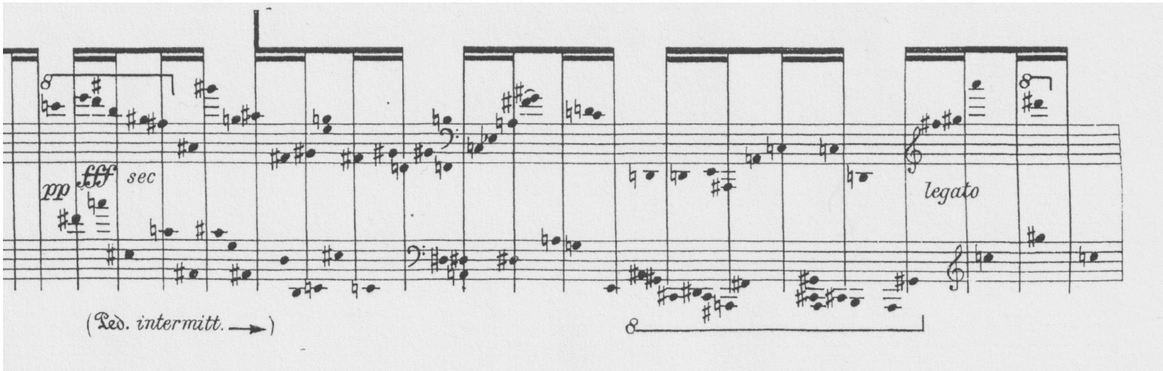

Figure 75: Space-time notation *Mists*, bars 45-46

C. Arborescences

The term “arborescences” indicates branching (or bush-like or tree-like) melodic structures, whereby an initial melody bifurcates into more. Such as in this example (Figure 76):

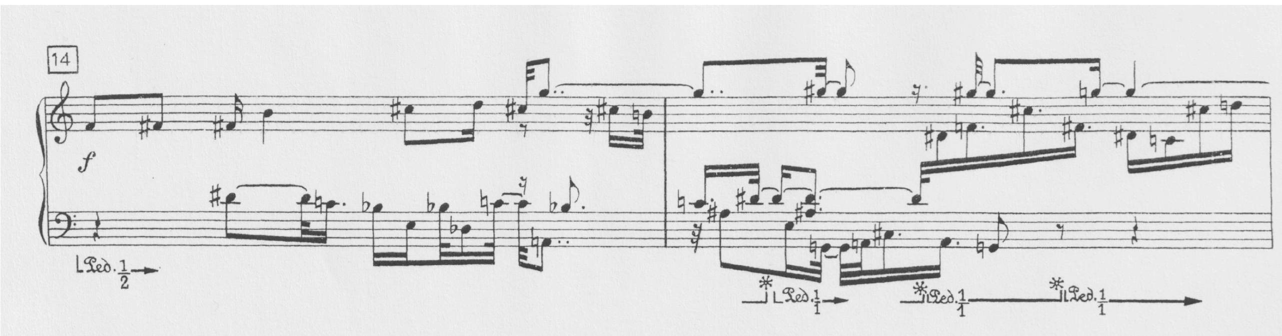

Figure 76: Arborescence, bars 14-15

Squibbs has meticulously defined the geometric transformations of these structures in the course of the piece as rotations around several axes, as well as the gradual introduction of the chromatic collection, as far as their pitch material is concerned.

Arborescences occupy bars 14-16, 22-24, 28-30, 80-83, 93-94, 109-110, 115-116, 129-134, corresponding to 21 / 134 = 0.15 of the piece's material.

D. Compositional Materials Embodied : An Overview

Those three types of compositional material, in short sieves, branches and clouds, generate three distinct types of physical movement "outside time"[405]. These types are further coupled with the dominant compositional parameters for each textural type, to shape physical movement "inside time", thus inviting a corresponding type of embodied navigation, as follows:

1. Linear random walks generate a rather *monolithic* choreography, comprising a linear and homodirectional arm layer along the whole range of the keyboard from bottom to top, with exactly three exceptions of heterodirectionality and one exception of downward movement, which are morphologically significant, marking important moments in the piece, as will be specified shortly. The arm layer is coarticulated in handgraps of an almost fixed number and ambitus. The finger layer is coupled predominantly to the parameter of complex rhythm, in the form of up to four layers of non-coinciding polyrhythms and in a finger-to-finger resolution. Secondarily, physical movement is also coupled to the parameters of dynamics and pedaling, resulting in the phenomenal, "sculpted" movement inside time. Embodied navigation is characterized by high viscosity and strong *topokinetic*[406] properties, due to the

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[405] Term originating in Xenakis, to denote the difference between deep symbolic structures and their actual phenomenological employment « inside time », for example in « Concerning Time, Space and Music », pp. 255-267 in his *Formalized Music*. By the same token, we consider here abstract types of physical movement as opposed to their employment in real-time, with all micro-variations, foldings and unfoldings that this entails. Please notice the analogy to the recording of a gestural template and its real-time following, in the case of the *motionfollower*.

[406] Reference to Shaun Ghallagher's distinction between topokinetic and morphokinetic properties in his integrative theory of gesture, please refer to pp. 187-188 of the current.

deciphering of complex rhythm and complex harmonic entities, as shown in the following figures[407].

In Figure 78, the original material of bars 9-11 has been arranged in harmonic complexes defined by their affordance of being grasped, defined as handgrasps. Blue and orange ellipses are used for the right and left hands respectively. The homodirectional movement of the arms from bottom to top is shown with the arrows, color-coding as in the handgrasps for the left and right hands.

In Figure 79, the complexity of rhythm, comprising four layers of non-coinciding polyrhythms, is tackled through the proper placement technique at a resolution of finger-to-finger accuracy. Each note, corresponding to one finger, is assigned a decimal number which shows its exact position in a given eighth note beat, the latter shown with vertical lines.
In Figure 80, the exact sequence of fingers as clarified by the proper placement technique has been clearly rewritten, corresponding to the finger layer for this passage.

Please note that, in both cases, the annotated examples allow for the direct perception of affordances concealed in the original notation. Such rewriting enables direct perception and can be automized thanks to the interactive systems explored in part three.

[407] The figures are also reviewed in part two, 4.4, where the accent falls rather in the clarification of the notion of embodied navigation rather than on their correlation to the Xenakian materials.

Figure 77: Four-part linear random walk, bars 9-11

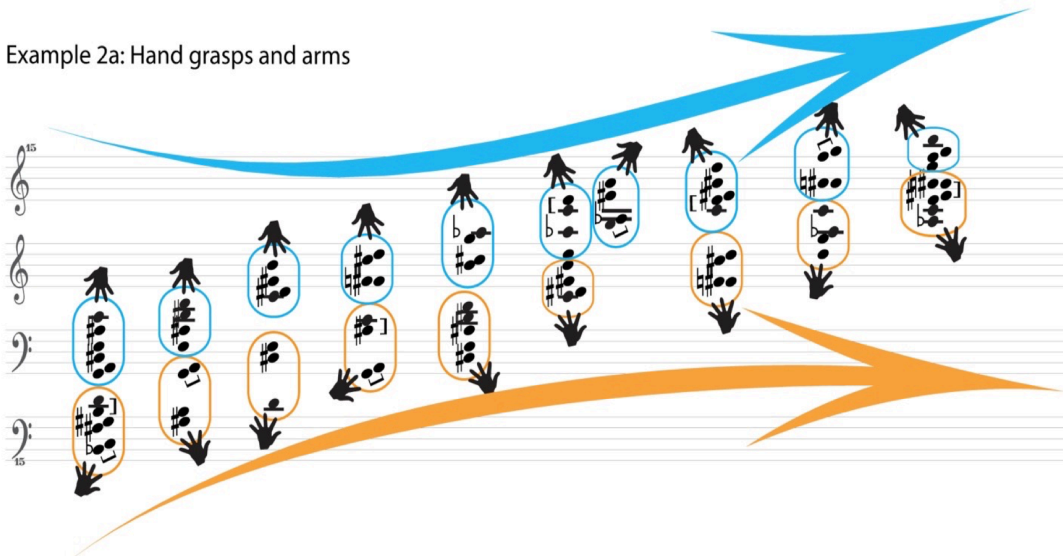


Figure 78: Grasp- and arm-layer, bars 9-11

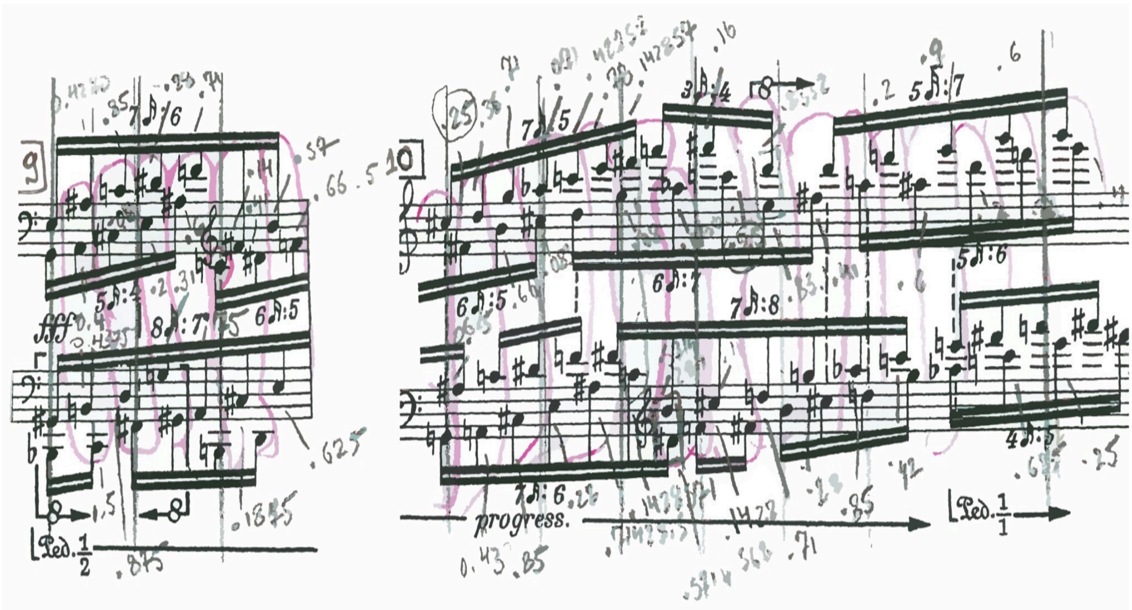


Figure 79: decimal positions for each note inside the eighth-note beat, hand-written annotation, bars 9-11

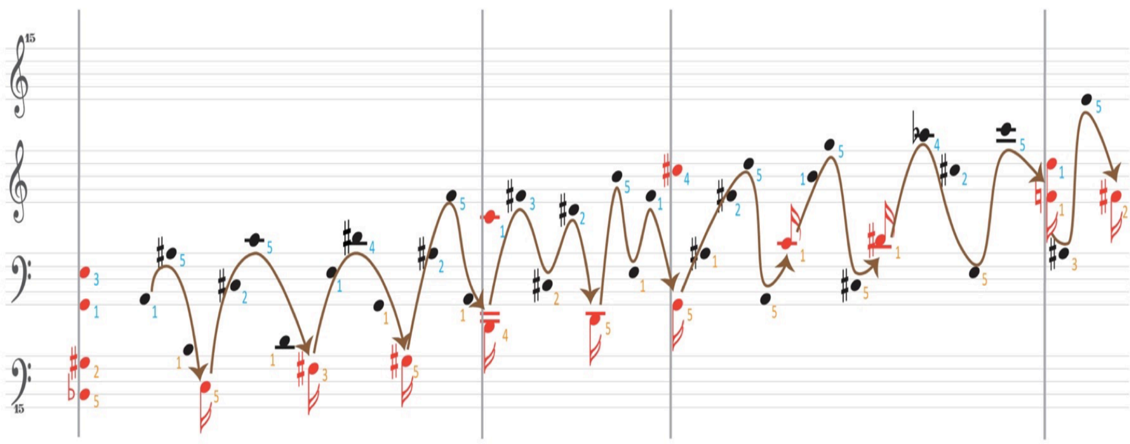


Figure 80: Finger-layer, bars 9-11

The figures above correspond to second-person descriptions and annotations, as part of a multilayered tablature, which functions as the state-space for the embodied navigation of the passage.

Such descriptions are complemented by third-person descriptions in the form of multimodal data. The analysis of performance data for the quadruple linear random walk of bars 9-11 resulted in the following PADR (Preparation-Attack-Displacement-Release) envelope (Figure 81):

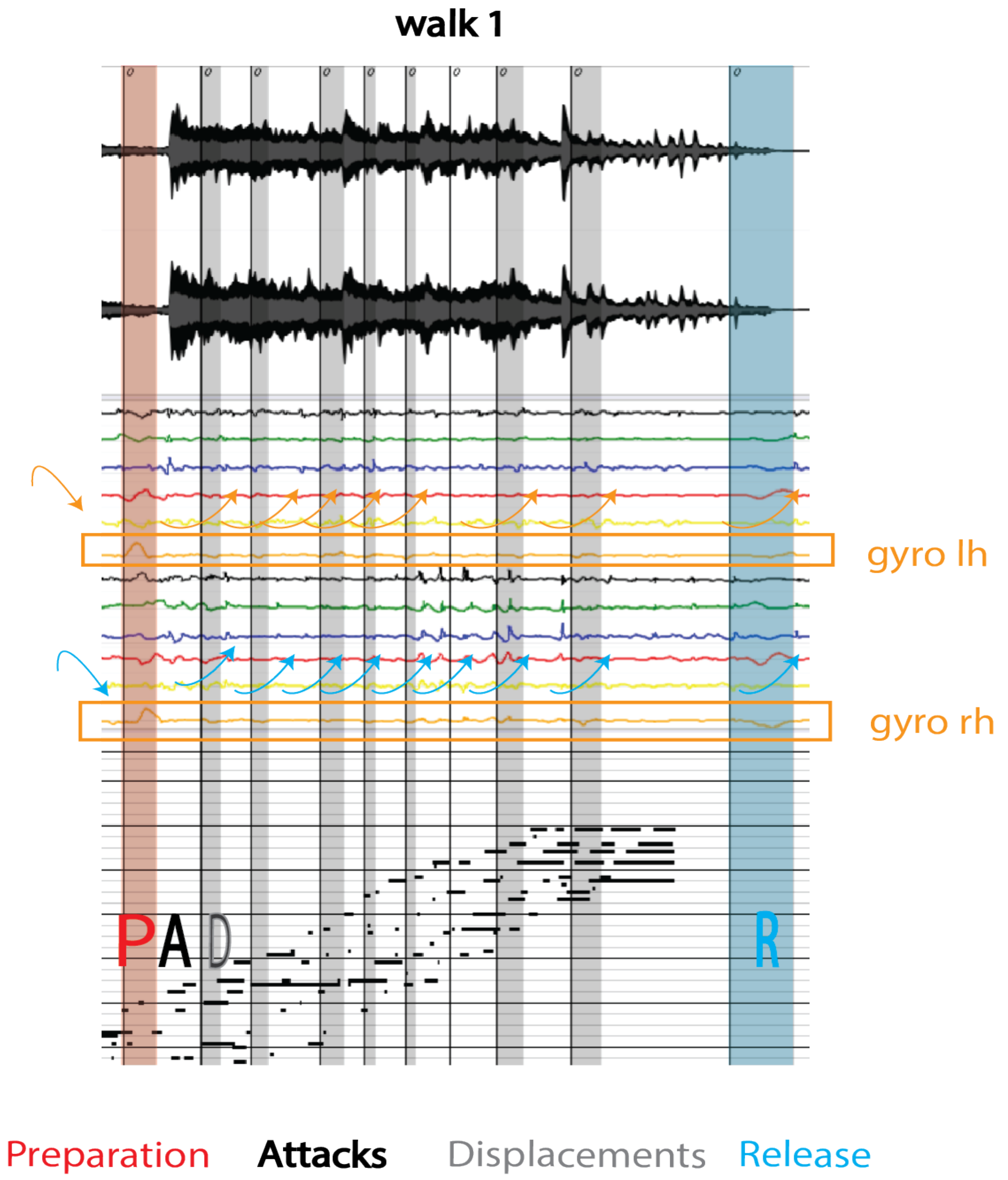


Figure 81: PADR envelope, bars 9-11

The PADR envelope has been defined by a single signal per gyroscope, as shown in the figure (orange signal in orange box), and comprises four different syntactical entities. Before and after the physical movement there is a preparation and release gesture, that is the movement of the arms to and away from the keyboard, in the red and blue zones respectively, shown with the high-amplitude gyro peaks of different direction (up for the preparation, down for the release) for both hands. The main action is articulated as a succession of attacks in the non-coloured areas and displacements in the gray zone areas. During the attacks, you will notice that the orange gyro remains inactive, whereas it is being activated during the displacements. All peaks in both hands during the displacements indicate the homodirectional character of the passage, by the fact that they point downwards. Single markers indicate the displacement of only one hand, as opposed to the displacement of both hands in slight desynchronization, which is shown in the grey zones.

2. The non-linear random walks generate a more mobile choreography, comprising a more complex relationship between the arm trajectories, articulated in grasps, quasi-grasps and isolated notes ("edges"), depending on local density and coupled at a resolution of half a bar up to three bars to the parameters of pedaling, dynamic and articulation. High fluidity of navigation and strong *morphokinetic* properties characterize this type of material.

Resuming fast the first use of this passage at part two, 4.2: In the Figure 83, ellipses designate grasps, that is groups of notes physically graspable by the author; half-ellipses with an arrow as side designate *quasi-grasps*, that is groups of notes which also require arm movement and displacement, since they are spread over many octaves, they however retain the ordering of fingers one to five, thus justifying their conception as "ideal" grasps; encircled individual notes are designated as "edges", standing at a distance from a neighbouring grasp and requiring a rapid leap in order to be played.

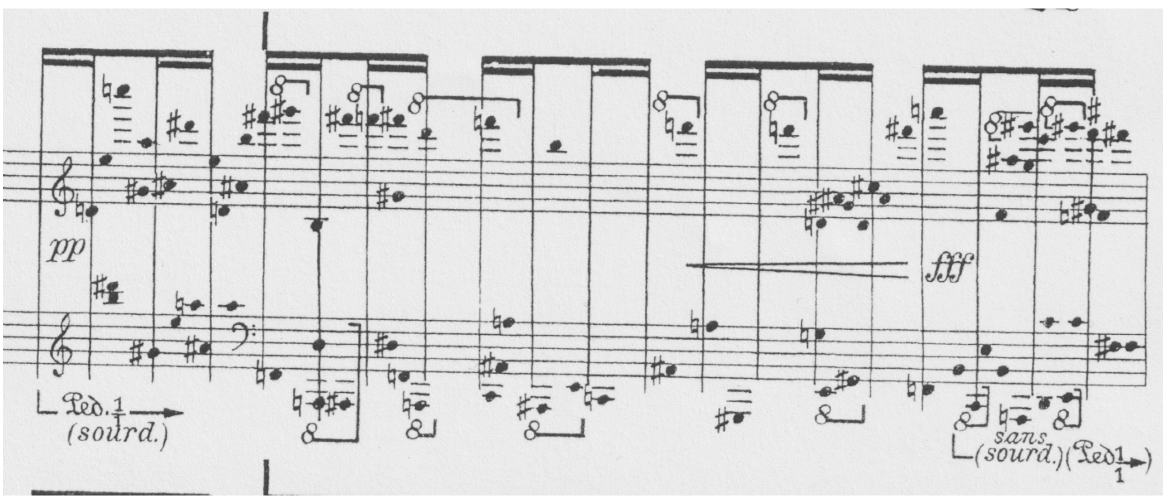


Figure 82: Non-linear random walk, bars 45-46

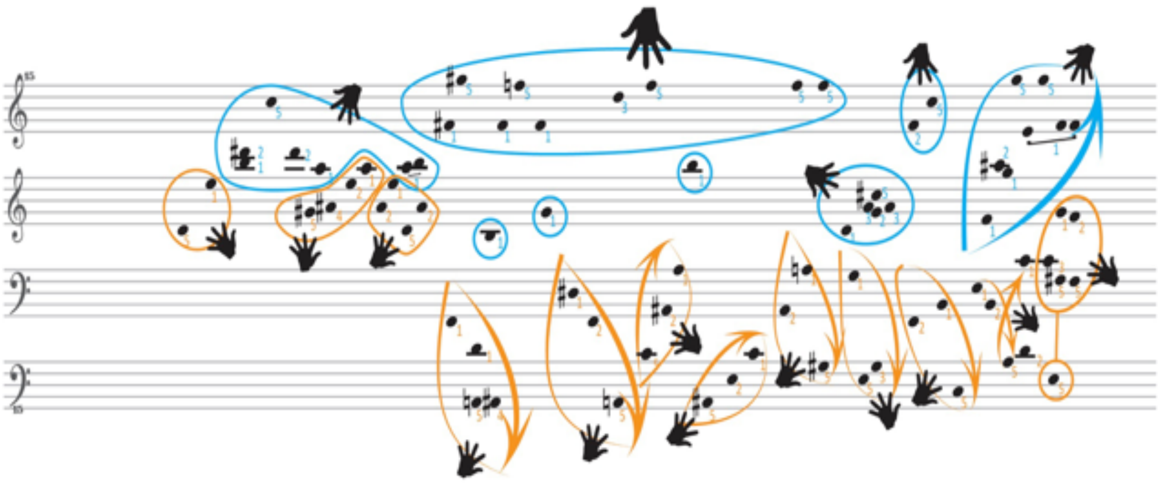


Figure 83: Grasp-layer, bars 45-46

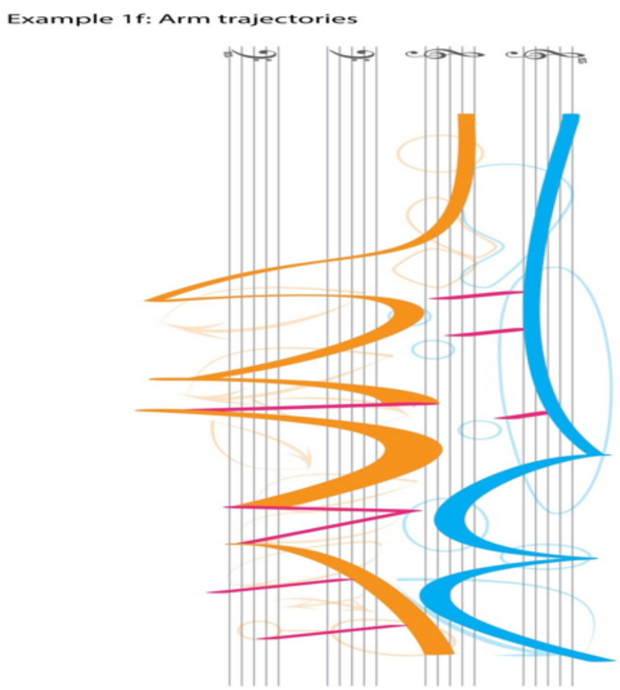


Figure 84: Arm-layer, bars 45-46, the representation scrolls from top to bottom

In the figure above (Figure 84), I have represented the complex linear trajectories of both arms, that is the arm layer of the passage, with an added rotation by 90° clockwise, which aligns the notation and the keyboard planes, giving you the perspective of the pianist on the keyboard. The choreography is notably more complex than that of the linear random walks, with the pink beams indicating moments of extreme and rapid leaps in order to attack edges (isolated notes).

This complexity is becoming clear in the inspection of the PADR envelope in the following figure (Figure 85), again on the basis of the gyro for horizontal displacement in each hand.

In comparison to the PADR envelope for the linear random walk, the one of the non-linear features more erratic and dense displacements indicated by the markers. Their direction corresponds to the upward or downward movement of the hands and is respectively downward peaks for upward movements and vice versa in both hands. There are no preparation and release gestures in the specific passage.

In the following figure (Figure 86), for a more extended passage of the same type (bars 41-52), the alternation between mobile and static areas of activity is shown through red and blue zones respectively, which are again defined by the horizontal displacement gyro for each hand. It becomes clear, that dense stochastic materials do not *necessarily* generate the vivid choreography in question, even if the latter is as dominant as to justify their characterization as mobile in principle.

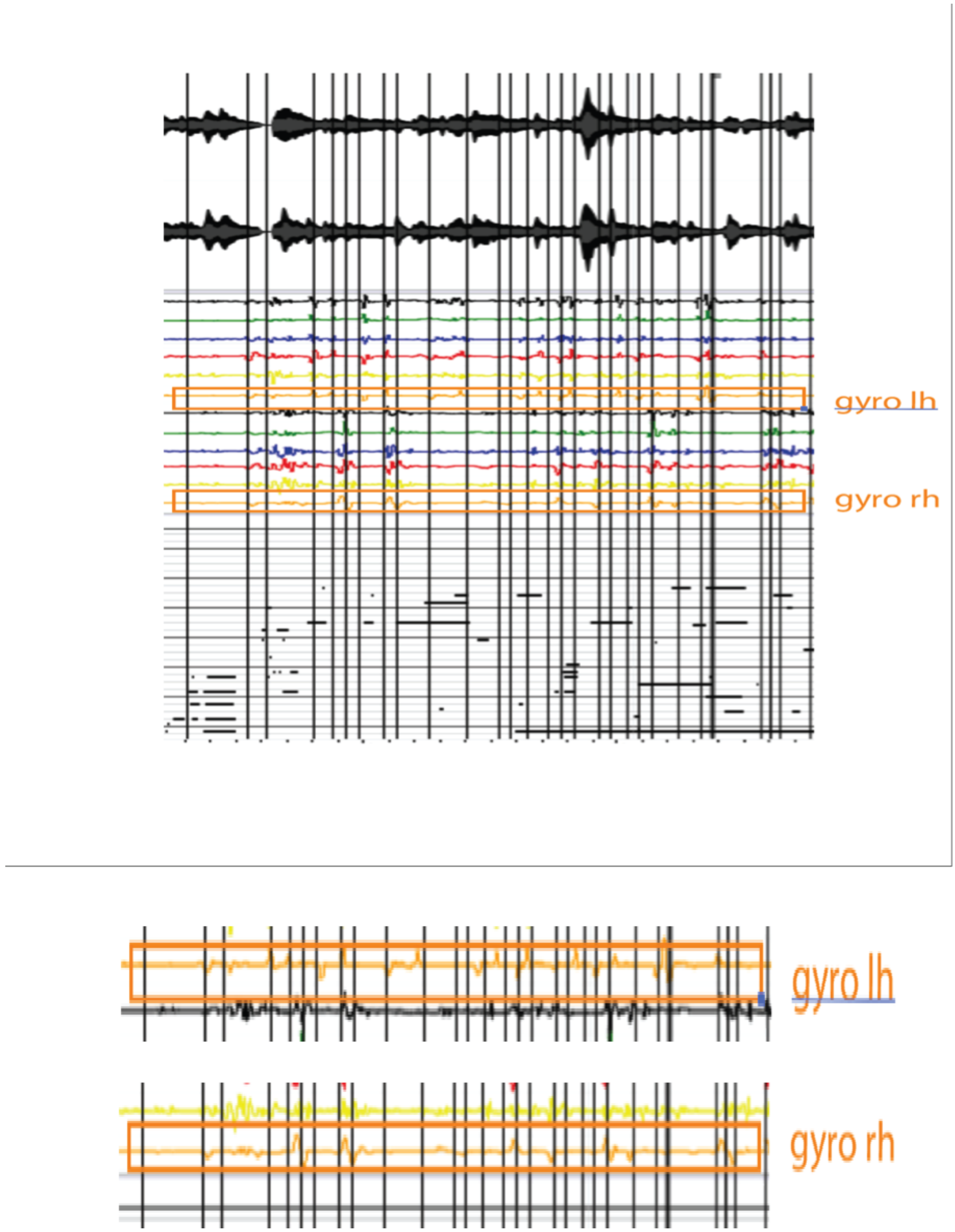


Figure 85: PADR envelope, bars 45-46: On top you may see the complete representation of the *MuBu* data; on bottom the detailed view of the orange gyroscope signal for each hand, which indicates horizontal displacement of the hands along the keyboard. The vertical lines are markers corresponding to the peaks of the signal.

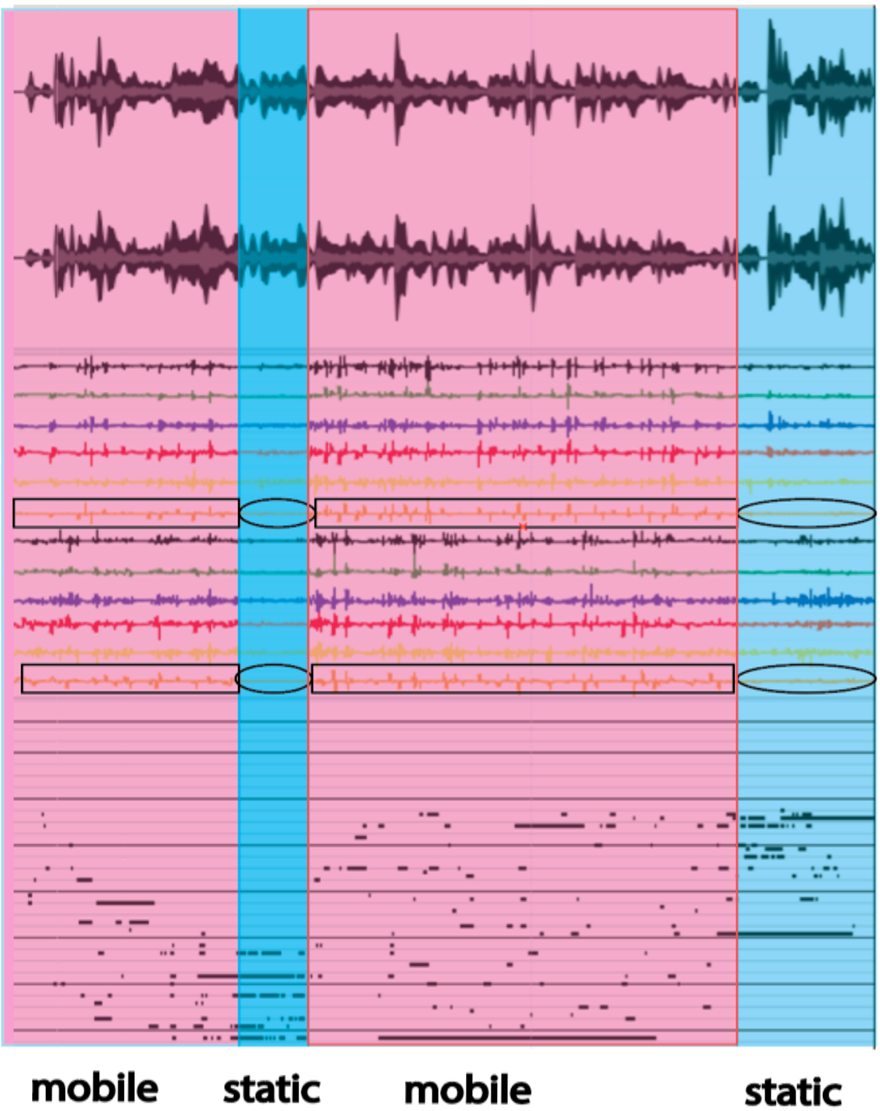


Figure 86: Multimodal data for stochastic section, bars 41-52, mobile versus static areas

3. The third type of materials, arborescences, features generally the most static type of gestural template, with more rare registral shifts, strong topokinetic properties and low viscosity.

Figure 87: Arborescence bar 129-134, two final arborescences: 129-131, 133-134

The PADR envelope for the passage above (Figure 88) shows clearly that the whole movement takes place in one register per arborescence, under one handgrasp for each hand, with a notable arm movement in the greyzone as preparation (first grey zone from the left) and shift to the next arborescence (second grey zone from the left).

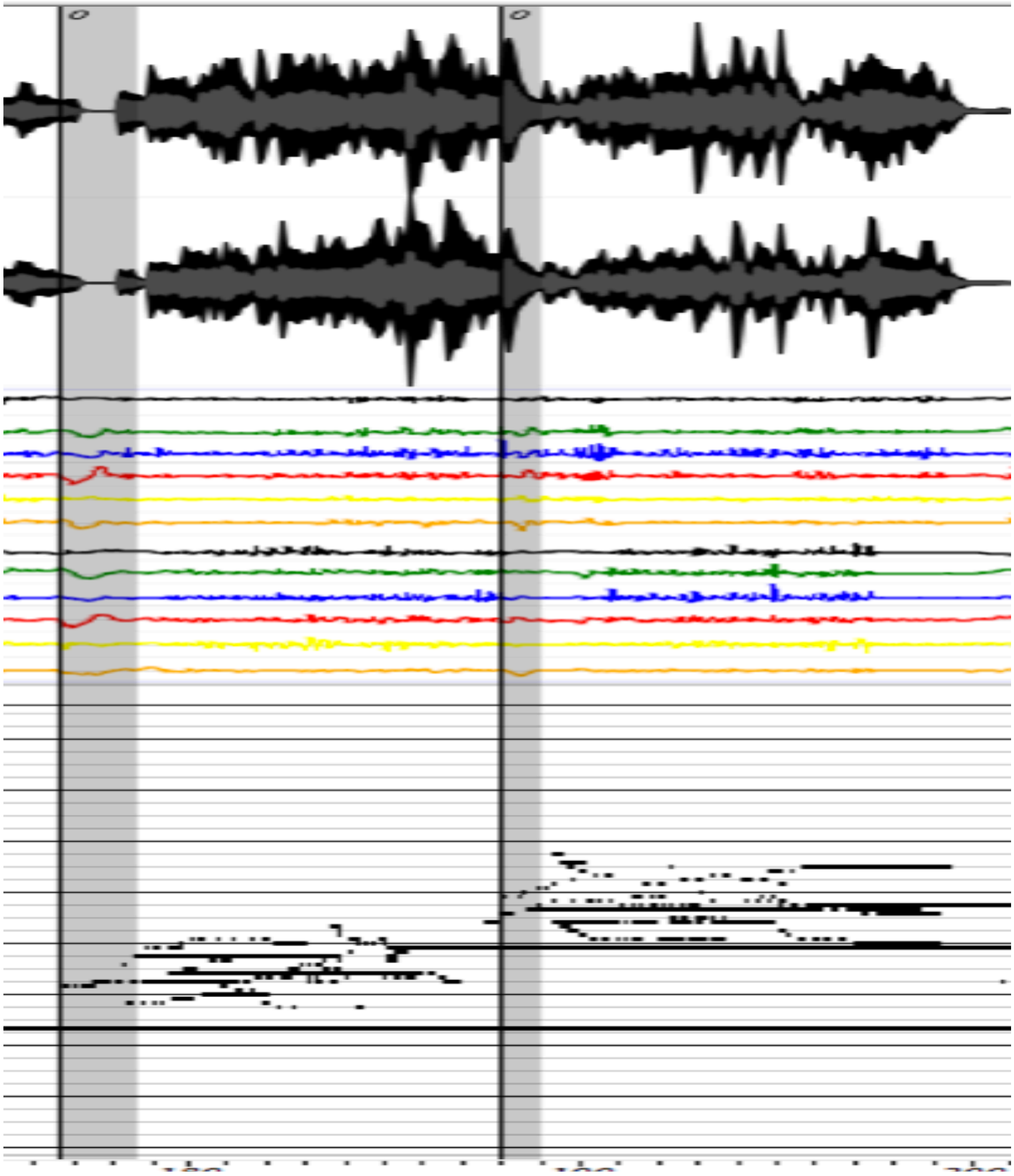


Figure 88: Multimodal data and annotation for arborescences, bar 14-15

In other words, in terms of physical movement, arborescences are interestingly enough rather uneventful, with two notable exceptions to be reviewed later.

2.3 Inside Time Materials : Shaping Musical Form Through Physical Movement

In the previous section we identified each textural type with an equivalent for physical movement and navigation: Linear random walks as viscuous homodirectional arm movements, non-linear stochastic materials dominated by fluid complex arm movements and arborescences as generally static with expressive deviations. In what follows, we analyse in detail the various manifestations and transformations of those three basic morphological types in terms of physical movement, kinesthetic metaphors and multimodal data. The articulation of those materials in time shapes the form of the piece and defines several paths for the embodied navigation.

A. Forming And Mobilizing A Monolith

The Monolith

I have postulated before that the main form of the linear random walk is the four-part ascending harmonic complex, featuring non-coinciding polyrhythms. It equals a singular viscuous ascending movement, which I characterized as monolithic, as compared to the generally fluid choreography of the stochastic sections. Indeed, this type of material is repeated exactly five times in the first section of the piece (1-40), featuring transformations in pitch, rhythm, pedaling and dynamics as shown in the following table (terms in French are original indications by Xenakis):

Table 1: Four-part linear random walks

Bar	Scale	Rhythm	Pedal	Dynamics
9-11	Original	16th	1/2 > 1	FFF
16-18	Cyclical transposition	16th	1/2 > 1	FFF
18-21	Original	8th	1/2	p<FFF>p
24-26	Cyclical transposition	Dotted 16th	sourdine	p<FFF>pp
27-28	Original	Condensed	Sans ped, sans sourd	FFF

The transformation in pitch, in the second and fourth presentation of the walk, refers to the use of a cyclical transposition of the original scale. The transformations of rhythm refer to the dominant unit of speed in relation to the beat, being a sixteenth note for the first two quadruple walks, the eighth note for the third one, a dotted sixteenth, and a condensed form of the initial polyrhythm in the last instance.

The pedaling follows a consistent linear curve from fully depressed, to half, to no pedal at all, with the use of sourdine for the fourth walk.The dynamic remains very loud for the first, second, fifth, and with a dynamic curve for the two inner, third and fourth, walks.

After qualitative analysis of the multimodal data, it was found that, based on the PADR envelope, each of these walks consists of seven to ten displacements defining the grasp layer and despite the extreme rhythmic, timbral and dynamic differentiation of each walk, as shown in Figure 89.

One may see at a glance, that all walks share the same kind of movement syntax between displacements and attacks and are being preceded and followed by preparation and release gestures. The latter characteristic is due to the fact, that all walks like that are “wrapped” in silence, being preceded and followed by rests or fermatas. Differentiations in the distribution of grasps and insertion of one-hand displacements (single markers) depend on the rhythmic profiling of each walk.

It is clear that such overview of PADR envelopes allows for the revelation of a hidden embodied subtext, namely the grasp layer, which is not readily available in the score. This structure can be used for the annotation of the score towards the direction of direct perception of this particular affordance, that is the grasp layer, as shown before. It certainly remains a personal annotation based on my own anatomical features and approaches to piano technique, a feature which can only be welcome, as performance analysis remains strictly personalized, while revealing the objective properties of the material. Which means, that however personalized an approach to the walks might be, all and each player will employ some PADR envelope to realize it. Another feature of the PADR envelope is that one can readily compare very different compositional materials exclusively from a gestural standpoint.

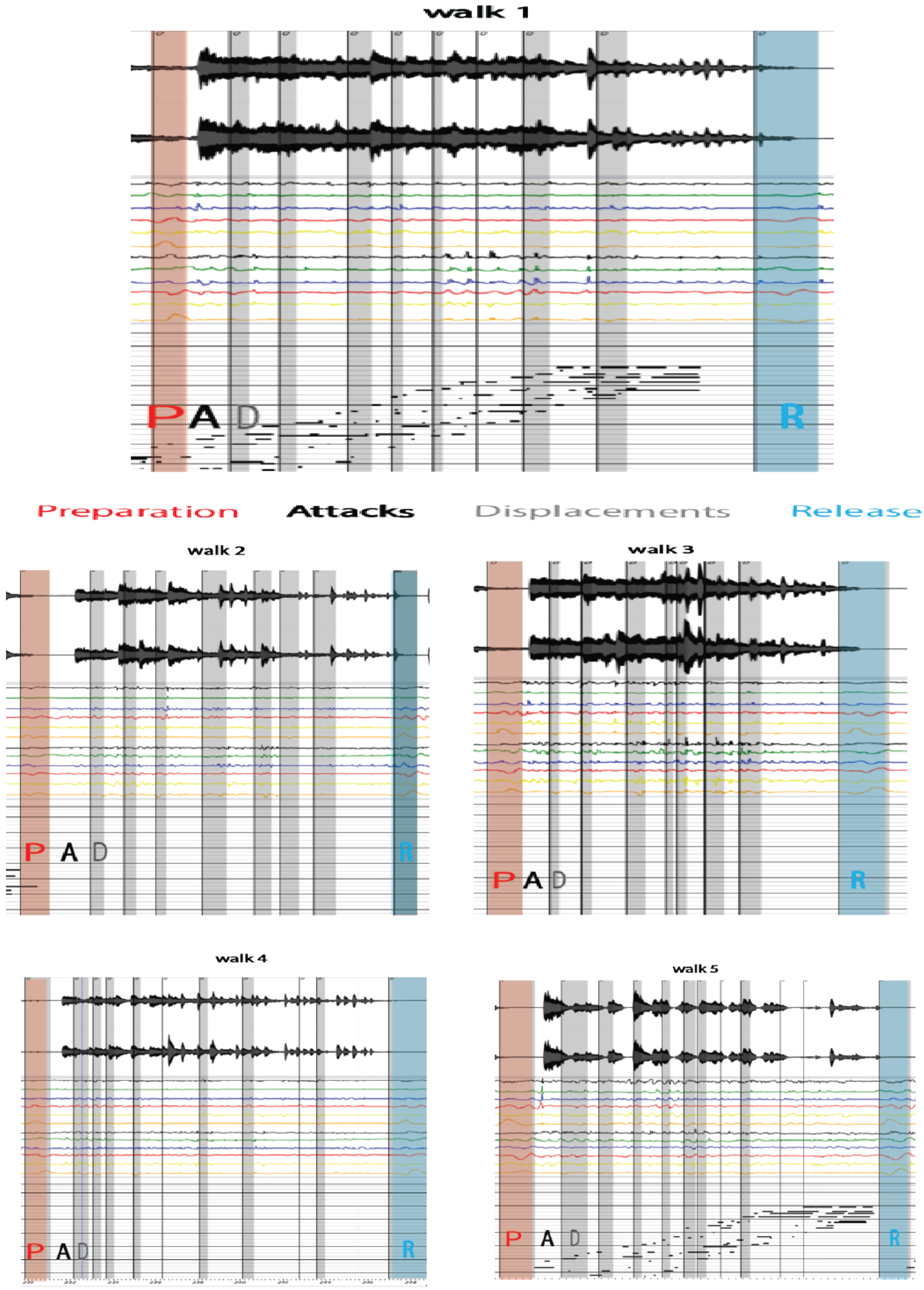


Figure 89: Overview of five four-part linear random walks, bars 1-40

Shaping the monolith in time: the viscosity of deciphering

We have already defined the quadraple linear random walks as the main building blocks of the piece, exhibiting a characteristic scanning of the whole keyboard through a unified movement from bottom to top. The linearity of this movement at the time of the performance must be compared to the painstaking viscosity of the navigation during the learning process, due to the deciphering of complex rhythms.

We defined this process of deciphering as a coupling of the gestural template a.k.a PADR envelope to several rhythmic parameters. In the already existent articulation of the arm layer into a number of hand grasps, we added several layers of coarticulation, corresponding to mediation techniques, for the simplification of rhythmic tasks. For an examination in more detail of how this sculpting takes place in the time of learning as navigation of the embodied layers and coupling with rhythmic parameters, please refer to part two, 4.4.

In the following image (Figure 90) you may see the correlation between: the grasp layer, the eighth note beat (pink markers) & the macrorhythmic elements of the passage (left side) ; and the PADR envelope for the same passage (right side)

In the left side: Blue boxes indicate the canonical introduction of the original scale pitch material. The continuous brown line indicates the continuous sixteenth notes which we have already indicated as an alignment thread for the complex rhythm. The green boxes show simultaneous attacks which are not indicated by Xenakis with dashed lines; the highlighted ratios indicate rhythms which are slower, in contrast to the initial rhythms which are faster than the main beat, thus splitting the passage in two, whereby the first half features a type of acceleration whereas the second half a type of structural deceleration; blue and orange ellipses indicate respectively right and left hand grasps.

In the right side: The PADR envelope as detailed above.

This analysis equals an analysis at different degrees of rhythmic resolution or *filters*, and it is the unique coupling of these layers of coarticulation, which produces an equally unique sonic result, constituting interpretation as interaction.

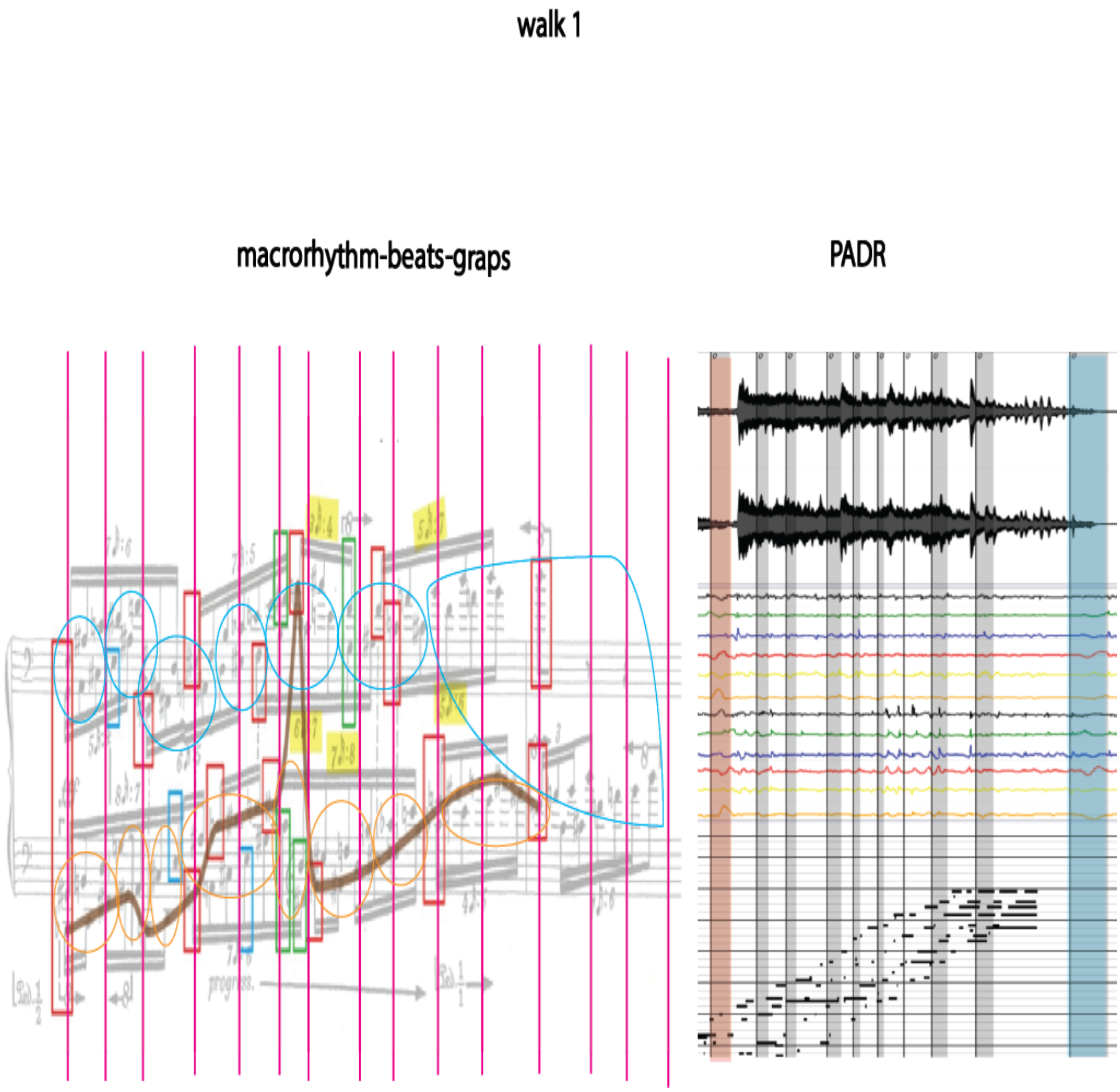


Figure 90: correlation between: the grasp layer, the eighth note beat (pink markers) & the macrorhythmic elements of the passage (left side) ; and the PADR envelope for the same passage (right side)

In terms of intentionality nodes, there are strong nodes, where more parametrical strata coincide, and these nodes would indicate a hidden macrorhythm of the passage. As an example, in the following image, the beat pattern notated on top of the upper staff is based on the succession of the red boxes, which indicate new tempi entrances. It is interesting to note, how this macrorhythm, which was at the time I learned the piece completely intuitive, can actually be explained under the light of the notion of intentionality nodes, as the points of convergence of various parametrical factors.

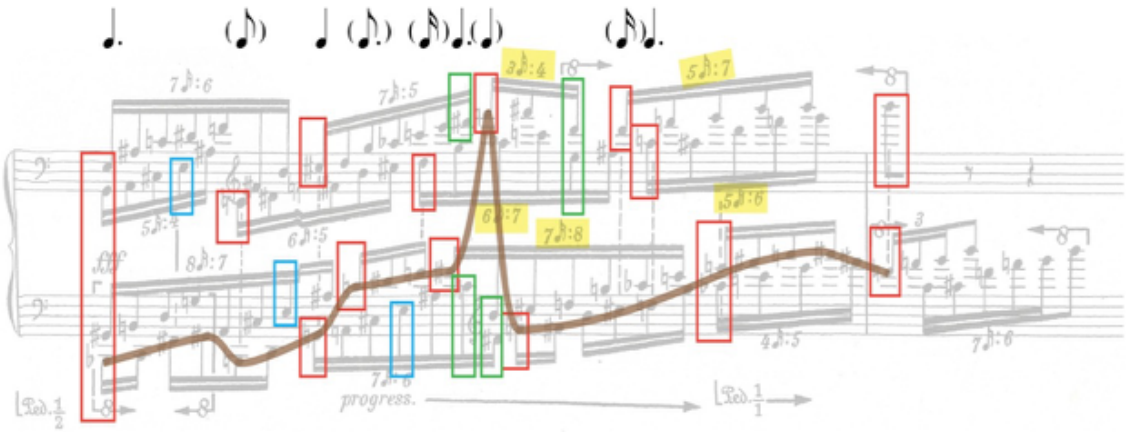


Figure 91: Intuitive beat pattern on top, indicating intentionality nodes. Performative intuition can be analyzed.

The rhythm of the passage is emergent out of the interactions of the several coarticulated layers, rather than a fixed property which can be reproduced perfectly in a MIDI-like way. The basic gesture is being co-articulated with rhythm at all hierarchical levels and degrees of resolution and is in itself shaping rhythm as emergent property.

Coming back to the navigational aspect: it is clear that none of the structures described (one-handed grasps, two-handed finger layer, macro-articulation) is alone capable of providing sufficient rhythmic accuracy and playing capacity. The rhythm is disclosed through movement inside the passage, deciding a) where to stop (focus) b) which is the vehicle of the movement or localization of the focus; horizontally (how far do you go) and vertically (on which layer of detail do you focus). The focus is always happening against a *horizon* of gesture, or the very term focus is useless. The qualities of this movement, such as speed, viscosity, direction, focus, define the performed outcome.

In what follows, we will review the three notable exceptions to the monolithic manifestation of the linear random walks: a) the initial exposition of the scalar material in the form of canonic entrances, until the point wherer the monolith of quadruple walks is introduced (bars 1-9); b) the further mobilization of the scalar material and its quasi-fusion with the arborescences (bars 31-39), as if under some sort of centrifugal force which pushes towards the stochastic explosion of the second part, starting in bar 41; c) the return or re-exposition of the monolithic quadruple walks shortly, before the end of the piece (bars 122-127), albeit in a mobilized form where they for the first time cross each other in space, resulting in a fantastic climactic wave in both directions. This cadenza of the previous monolith finds a relief in the one and only downward exposition of the four-part random walks, bars 126-127, as a sort of coda for this type of material.

Introducing the Monolith

These five monolithic four-part walks are being gradually formed through the canonic introduction of the original scale's material.

The linear random walks, occupying about 1/3 of the piece in total, can be categorized according to the following parameters:

a) Texture: Monophonic, heterophonic, polyphonic
b) Timing of entrance: canonic, simultaneous
c) Direction in space: homodirectional, heterodirectional

The first exposition of the linear random walks (bars 1-11, Figure 92) features all types of texture, as presented in the following example. The basic scalar material is presented from bottom to top starting monophonically (bar 1), with four further quasi-canonic entrances (bars 1, 4, 5, 6), before a two-part heterophonic exposition of the scale simultaneously in two different rhythmic distributions (bars 7-9) and the first four-part harmonic exposition of segments of the scale (bars 9-11) occur. In each successive entrance, the exposition of the scalar material takes place in gradually shorter intervals, in other words there is a condensation in time of this scalar material, until they collide into the two-part and four-part textures.

The canonic entrances and the transition from monophonic to two-part, three-part and eventually four-part writing is punctuated in performance by leaps of the left hand towards the bottom of the keyboard in bars 1, 4, 5, 6, 7 and 9, in order to mark a new beginning of the random rhythmical unfolding of the original scalar material. Such leaps are indicated by orange arrows. The right hand follows homodirectionally this movement, taking over the previous material of the left hand or initiating itself segments of the scale in bars 5, 7 and 9. Thus, purely textural events are embodied in an unmistakeably dramatic, both visually and kinesthetically, way, marking the textural events. While such grand gesture physically and visually articulates this passage and marks the new textural additions, it should however not disturb the linear character of the exposition, marking thus one of the interesting decouplings known from all polyphonic music, that is the requirement for multi-voice textures to be achieved bimanually.

In terms of embodied layers, those leaps indicate the activation of the arm layer to the direction opposite from the predominant homodirectional movement of hands from top to bottom. The leaps are clearly discernible in the gestural data, and in particular in the bottom gyroscope signal for each hand (orange color), as shown in the following image (Figure 93).

Please note that the upward peaks of the gyroscopes, indicated in blue and orange ellipses for the right and left hands respectively, are the only upward peaks in a sequence of otherwise downward peaks in both hands, clearly showing the displacement of the hands downwards in a general upward movement.

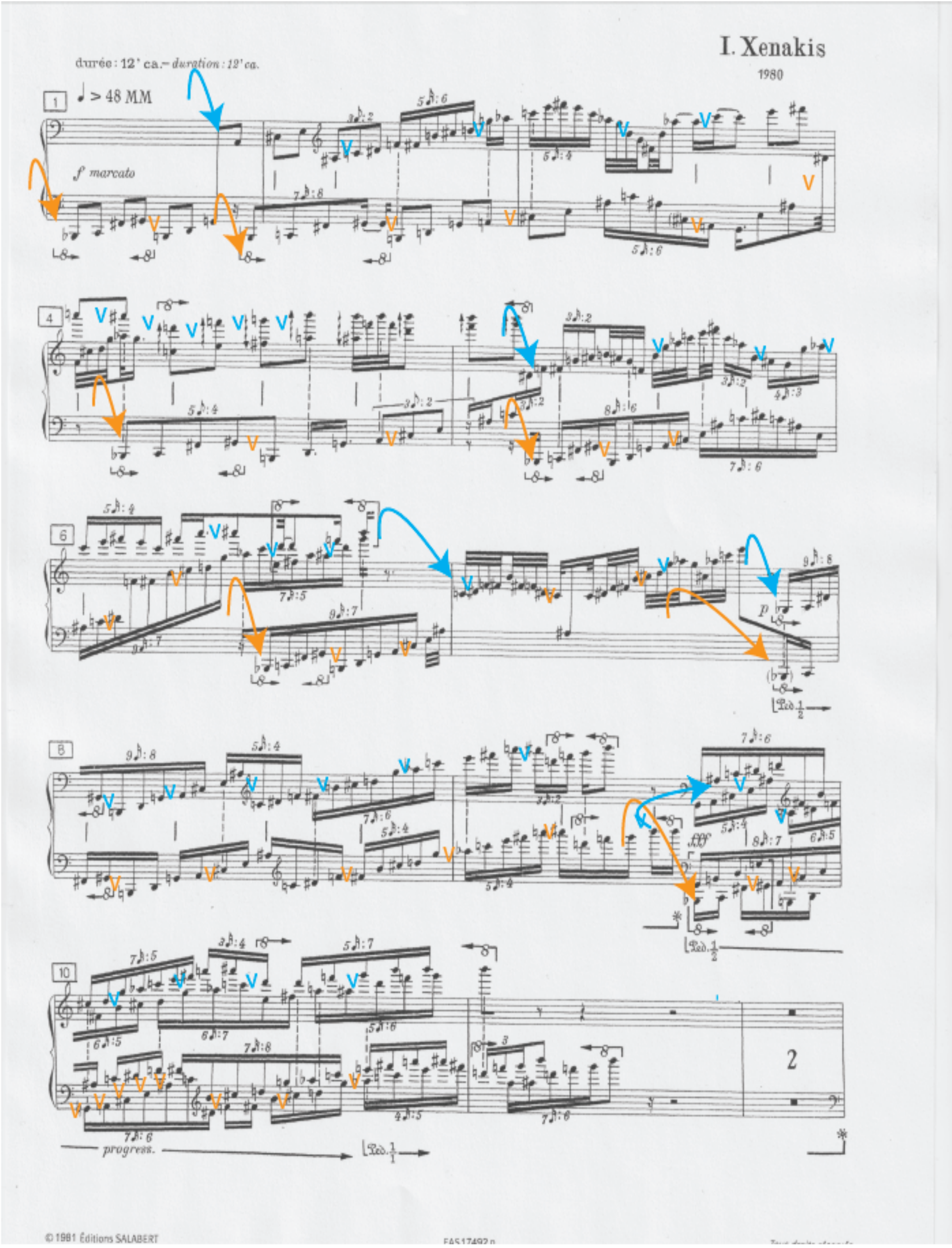


Figure 92: Canonic presentation of linear random walks, arrows indicate activation of the arm layer and "v" the switch to new grasp

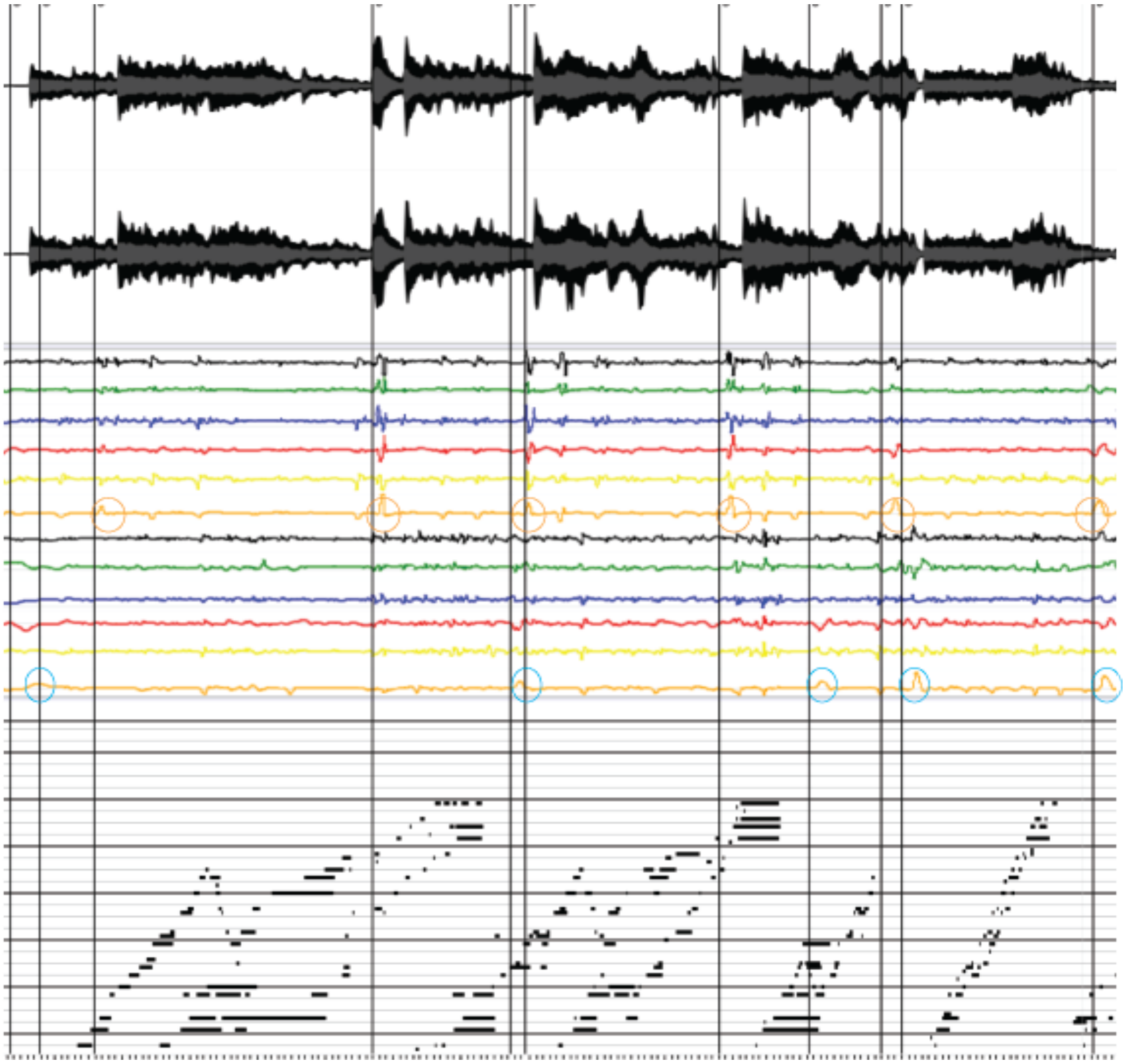


Figure 93: Activation in the marked gyroscopes shows the activation of the arm layer, bars 1-11

It would not be an exaggeration to state that the macroform of this first page of exposition of the linear random walks material is actually articulated by the dramatic activation of the arm layer, that is the displacements, in the places indicated by the graph above. Physical movement becomes a determinant of musical form. One could go as far as to say that, from an embodied perspective, the macroform of this exposition actually *is* the arm layer.

Moving on from those central moments into the basic homodirectional movements in the exposition of the scale, we note that they are further articulated by changes of position, or an activation of the hand grasp-layer, which are indicated as follows in the original notation (Figure 94).

As a rule of thumb, and with obvious exceptions, the lowest note in a hand grasp is to be played with the pinky for the left hand and the thumb for the right hand, while the highest inversely with the fifth for the right hand and the thumb for the left hand, as also remarked in the Ferneyhough case-study in the previous part of the dissertation.

The succession of handgraps is equally discernible in the gestural data (Figure 95) as gyroscope peaks of the inverse direction and lower amplitude in comparison to the ones indicating the arm leaps.

Under the large-scale rhythm of the canonic entrances and over the surface rhythms, articulated by melismatic irregular deviations from the eighth-note pulse, one finds the “real” rhythm or polyphony of the physical movement expressed in the succession of the handgrasps. The relation between the two hands is articulated by the decouplings in those handgrasps, which are marked on the musical score as Figure 94. The convergence or divergence of this layer with other musical parameters becomes one of the measures for the difficulty of a given passage.

A few observations concerning the timing of the grasps and the relation between the right and left hand succession of grasps:

The general duration of the graps is between one and two quarter notes, with the notable exception for part of the four-part random walk in the bottom of the page. Such rhythm is slower than the pragmatic beat of an eighth-note, but coincides with the composer’s indicated beat of a quarter-note faster than MM 48.The general homodirectional nature of the passage has as a consequence the close timing of the displacements, which appear almost in pairs.The relation of the displacements to the quarter beat is aso of interest, since with some exceptions, they occur offbeat, thus enhancing the “swing” of the Xenakian polyrhythms.

Figure 94: Exposition bars 1-11, grasp layer

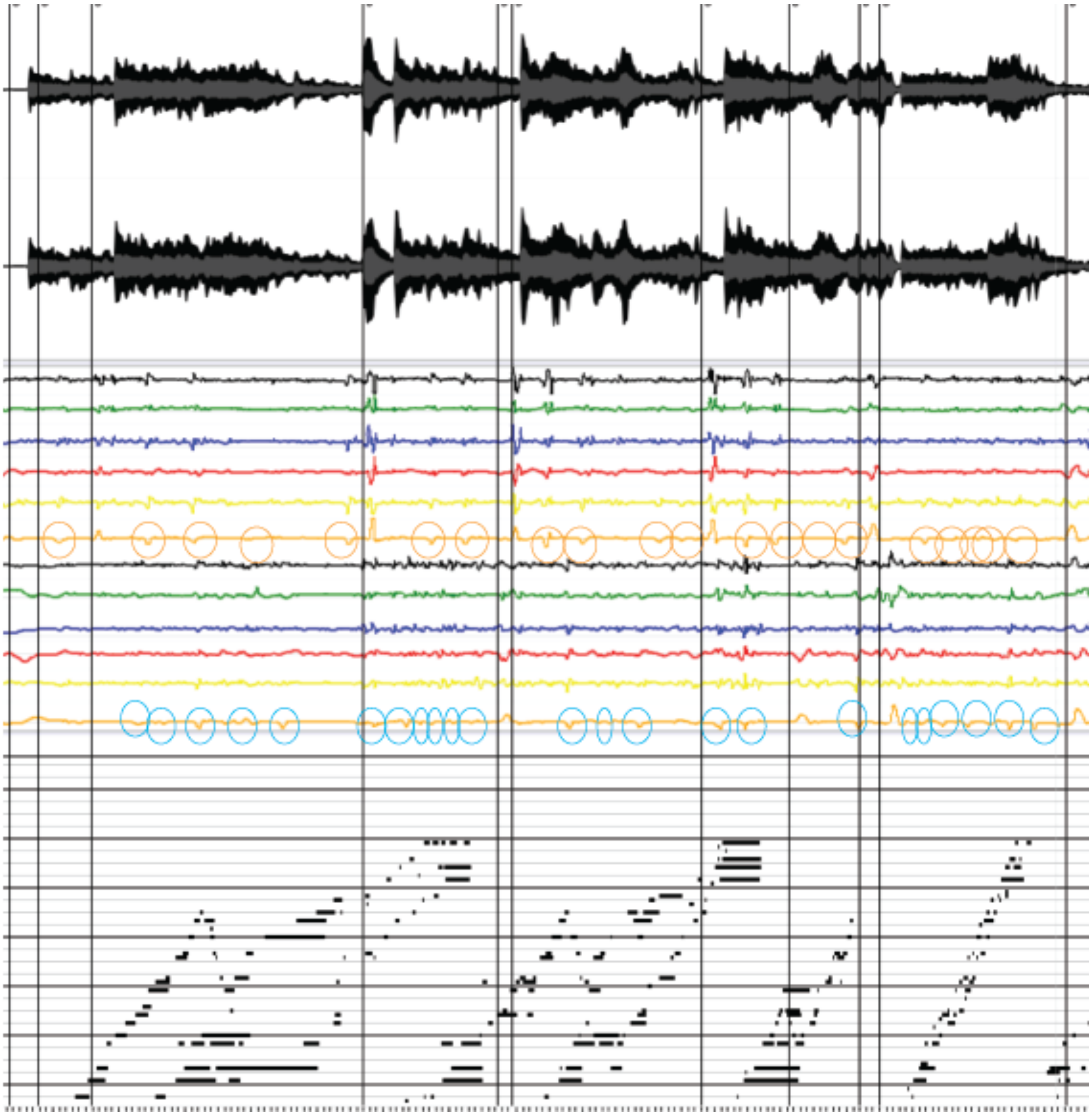


Figure 95: Grasp layer visible in the multimodal data, bars 1-11

In the following video you may see the performance of the passage, with multimodal annotation of the grasp layer. Please note that in the *TouchKeys* data on the bottom, the handgrasp layer becomes readily visible in relation to the markers indicating displacement.

https://www.youtube.com/watch?v=io9iGpVUAkI accessed 29.04.2018

Mobilizing the Monolith

Two moments in the piece are marked by the further mobilization in the keyboard and pitch space of those dense, slow moving textures, and more importantly, from the introduction of heterodirectionality in the up to now homodirectional relationship between the hands. The first moment corresponds to bars 31-36, whereby rapid scales in contrary motion are functioning as the climax of the first section of the piece before the introduction of the stochastic material in bar 41. Interestingly enough, these scales are resuming in single tones, out of which branch out new scales produced through cyclic transposition, themselves occasionally branching out into new formations. One might even speak of a fusion between the textural types of scales and arborescences, thus marking the end of the first section of the piece. Rob Squibbs describes this passage indeed as a transition to the stochastic part, although he does not indicate a fusion of the two textural types.

In the following image (Figure 96), you may see the alternation of segments defined mostly by the dynamic of the passage, both in the notation and in the multimodal data. In the latter image, I have included the PADR segmentation, which corresponds to my handwritten annotation of the passage. From the image becomes clear the decoupling between the basic directionality of the scales and the displacements: Peaks in the MIDI representation do not necessarily coincide with a change of the hand position, thus creating an interesting decoupling between what is notated and what is being done.

A video of a performance of the passage is available here:
https://www.youtube.com/watch?v=pChQSca3_Ls&t=151 , accessed 01.05.2018, from 2’33” to 2’50”.

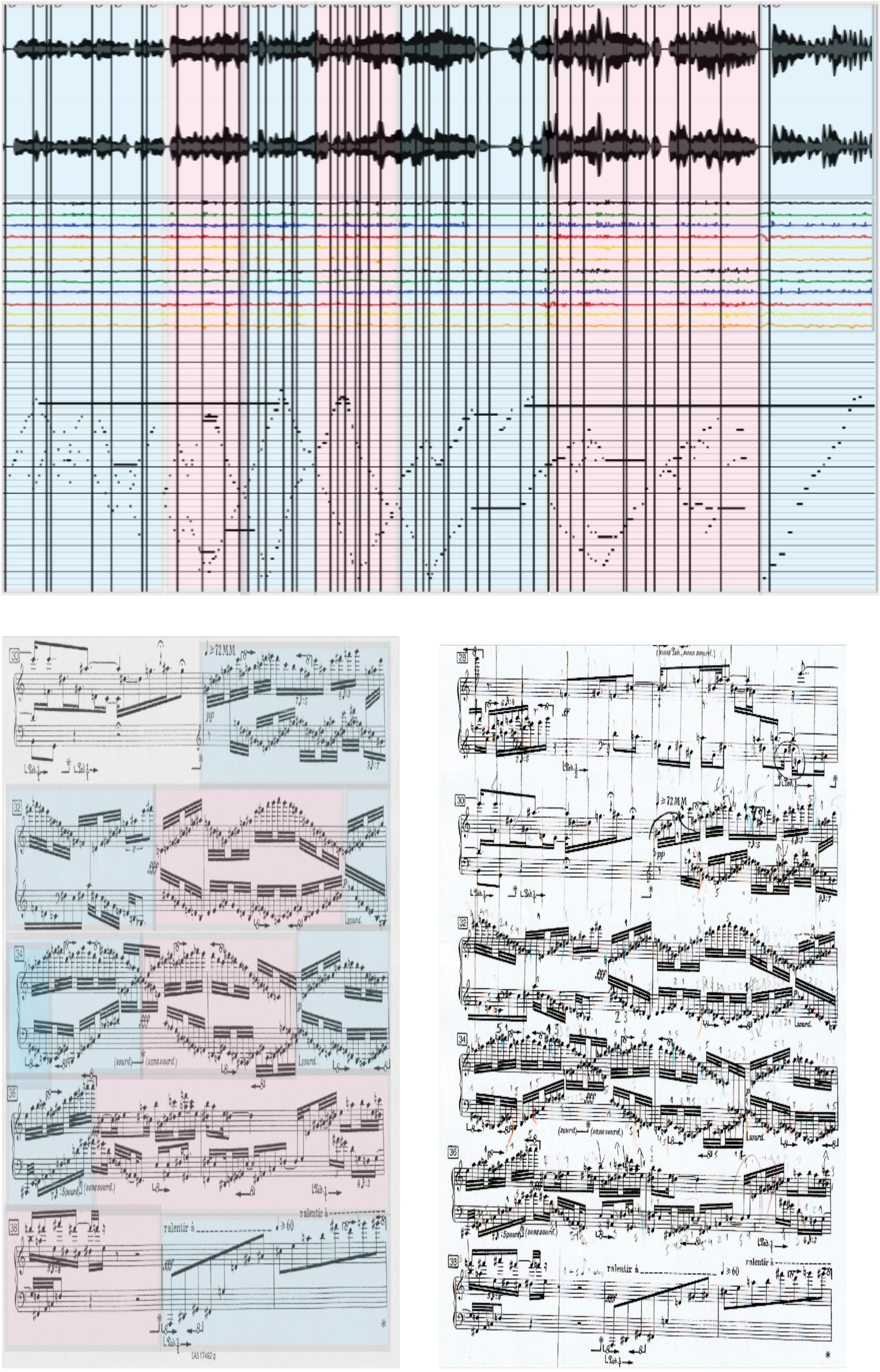


Figure 96: Scales mobilized heterodirectionally, bars 31-38

The second mobilization of the monolith appears towards the end of the piece. After a long absence of the linear walks and alternation of the other two types of material, namely stochastic and arborescences, bars 122-127 mark the re-exposition with the walks, but with a considerable climactic twist: The monolith has been “inflicted” by the mobility of the first cadenza, giving birth to an enhanced cadenza of linear random walks which cross each other in this extended passage. This fantastic climactic moment, a “wave” of the previous monoliths, finds a coda in the one and only downward exposition of the four-part random walks, bars 126-127.

In the figure below (Figure 97), you may see the three “knots”, whereby the walks cross each other for the first time in the piece, resulting in a re-arrangement of the notated material in order to avoid the (impossible) crossing of the hands: The left hand needs to play the upper staff and the right hand the lower one after the first and the third knot. Otherwise, the situation is pretty much as in the scales section, with the passage being articulated by the PADR envelope. The blue section marks the only downward presentation of the linear random walk in the piece.

A video of a performance of the passage is available here: https://www.youtube.com/watch?v=pChQSca3_Ls&t=585, accessed 01.05.2018, 9’44-10’21” corresponding to the wave and 10’21”-10’30” to the downward exposition of the walk.

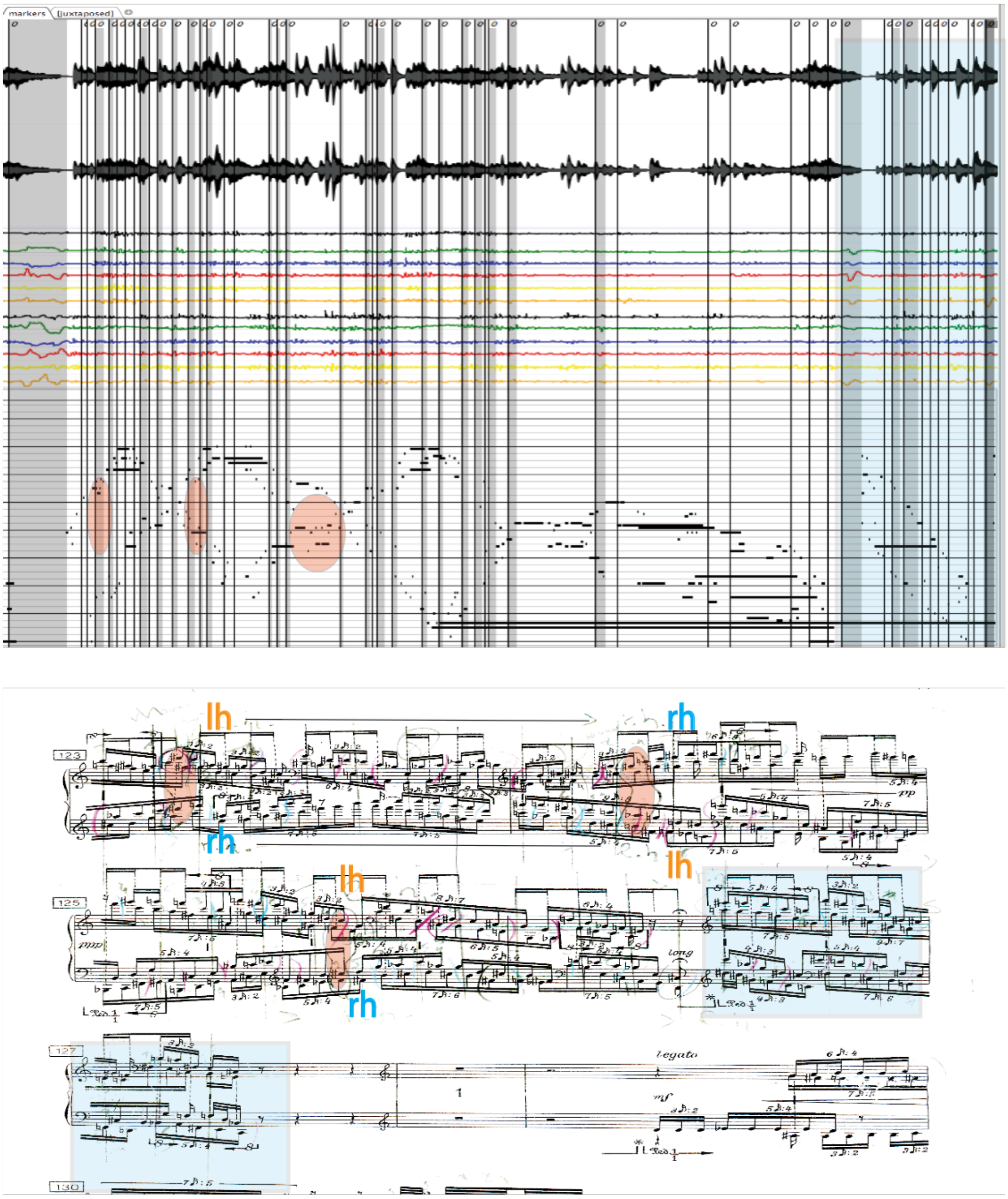


Figure 97: Wave of crossing linear random walks. The orange ellipses indicate the “knots” where the switch of hands is taking place. The blue area indicates the only downward exposition of the walk in the piece.

Conclusion

From the analysis of the development of linear random walks, a very specific macroform or envelope becomes very clear: A first phase of formation and polyphonic exposition is being followed by the harmonic exposition of the material, the latter being then mobilized in both its basic scale and its dense harmonic version.

This textural transformation is equally marked by the particularities of physical movement: An initial phase characterized by the activation of the arm layer when a new voice enters in the first phase; the homogenous homodirectional movements with viscuous rhythmic deciphering in the second phase; the contrary motion of the scales section without hand crossings; and the last phase, where all the above characteristics merge: dense harmonic complexes in contrary motion with “knots” and hands not crossing but taking over, counterintuitively, the material of the opposite staff.

The common denominator in all these very different relationships of the arm layer is its linear articulation in PADR envelopes, which are defined by the displacement of the grasps, usually in a limited amount of chunks. It is this intermediate articulation between fingers and larger movements, which acts as the embodied carrier of the information management.

The embodied chunks do not coincide with the compositional gestures. This radical decoupling stands at the root of music performance and the interaction between embodied layers and compositional parameters constitutes interpretation at an atomic level.

B. Stochastic Explosion

Surface embodiment: pedal, dynamics articulation

The main exposition of the stochastic section is arranged in short segments differentiated by pedal use, articulation and dynamics, as well as pitch and rhythm density. This solid exposition (p. 4-7, bars 41-79) is followed by a second, “perforated” section (p.7-10, bars 80-121), whereby stochastic materials are irregularly alternating with arborescences: 80-83 arborescence, 83-92 stochastic, 93-94 arborescence, 94-108 stochastic, 109-110 arborescence, 111-114 stochastic, 115-116 arborescence, 117-121 stochastic.

In the table below (Table 2), you may see in detail the sequence of the stochastic segments and their differentiation in terms of pedal, dynamics and articulation. The interaction of these parameters in their embodied manifestation shapes the final sonic output in performance (indication in the original French terms by Xenakis):

Stochastic solid	Pedal	Articulation	Dynamics	Stohastic perforated	Pedal	Articulation	Dynamics
41	Ped 1/1 + sourd	Non sec	p	**83-84**	Sourd	Non sec	pp
41-42	Ped 1/1 + sourd	Non sec	FFF	**84-85**	Sans ped	Sec	FF
42-43	Ped 1/1 + sourd	Non sec	pp	**85**	Ped 1/2	Non sec	ppp
44-45	Sourd seul	Non sec	pp	**86**	Ped 1/2	Non sec	FFF
45-46	Ped + sourd	Non sec	pp < FFF	**87-88**	Ped 1/2	Sec	FFF
46-47	Ped	Non sec	FFF	**89-90**	Sans ped	Sec	pp
48	Ped	Non sec	FFF > pp	**90-92**	Sans ped	Sec	FFF
48-49	Ped 1/2	Non sec	pp	**94-95**	Ped	Sec	FFF
49-50	Sans ped	Non sec	pp	**96**	Sans ped	Sec	FFF
51-52	Sans ped	Sec	FF > pp	**96-97**	Ped	Non sec	ppp
53	Sourd	Sec	pp	**97-99**	Sans ped	Sec	FFF
54	Ped 1/1	(Non sec)	FFF	**99**	Ped	Sec	FFF

54-55	Sans ped	Très sec	FFF	**100-101**	Sans ped	Non sec	pp < FFF
55-56	Ped 1/1	(Non sec)	ppp	**101-102**	Sourd	Non sec	ppp
56	Sans ped	Sec	FFF	**102-103**	Sans ped	Sec	FFF > pp
56	Ped 1/2	(Non sec)	p	**104**	Sans ped	Sec	pp
57	Sans pedal	Sec	FFF	**104-105**	Ped	Sec	FFF
58-59	Ped 1/1 > Ped0/1	(Non sec)	pp < FFF	**106-108**	Ped	Peu sec	pp > FF
59-60	Ped 0/1	Très sec	FFF	**108-109**	Sans ped	Non sec	ppp
61	Sourd	Très sec	pp	**111**	Ped	(Non sec)	ppp
61-63	Sans ped	Très sec	FFF	**111**	Ped	(Non sec)	FFF
63-64	Sourd	Sec	p	**111-112**	Ped < Ped 1/2	(Non sec)	ppp < FFF
64-65	Ped 1/2	(Non sec)	FFF sub	**112-114**	Ped < Ped 1/2	(Non sec)	ppp < FFF
66	Sourd	Non sec	pp	**117-118**	Ped	(Non sec)	FFF
67	Ped	l.v.	FFF	**118**	Sans ped	Sec	FFF
67-68	Sans ped	Non sec	ppp	**119**	Sourd	Sec	ppp
68-70	Ped 1/1	l.v.	FFF	**120**	Sans ped	Sec	ppp < FF
71	Sourd	Non sec	ppp	**121**	Ped 0/1 < 1/1	Sec	FF < FFF
71-72	Ped 1/1	l.v.	FFF	**121**	Ped	Sec	FFF
72-73	Sourd	Non sec	ppp				
73-74	Sans ped	Sec	FFF > ppp				

75	Sourd	Non sec	ppp
75-76	Ped 1/1	Non sec	FFF-mf-pp
76-77	Ped intermitt.	Sec	FFF
77-78	Ped	Legato	FFF
78-79	Ped intermitt.	Sec	FFF

Table 2: Interaction of pedal, dynamics, articulation in the stochastic section

Indications in the original French terms by Xenakis: Pedalling alternates between several degrees of sustain pedal (*Ped*) and left pedal (*Sourd*); *Sec* stands for staccato articulation.

The absence of any reference to the pitch & rhythm density in this table is intentional: First, because pedal, dynamics and articulation are parameters that relate to performance in a more direct way than pitch and rhythm, since they have historically exhibited a lower degree of abstraction and synthesis; then, because pitch and rhythm density will be, in what follows, associated exclusively to the PADR envelopes. In that way, I hope to show that a) performative embodiment reveals morphological entites not readily visible in the score and b) that those entites constitute an independent layer in coarticulation with the rest of the embodied parameters mentioned above.

Middlegroung analysis based on the PADR envelope

The difference of non-linear walks as compared to the linear ones becomes readily available even with a coarce, at a glance comparison of their respective PADR envelopes. In the following example (Figure 98), you may see the characteristic alternation between mobile and static segments of the stochastic section, page 4 of the Salabert edition (bars 41-52), as opposed to the simple PADR envelope of the first quadruple linear walk (bars 9-11). The mobile parts (in pink) are characterized by an elaborate choreography of the two hands, visible as peaks in both directions in the bottom gyroscope for each hand, as opposed to the lack of peaks in the blue zones, whereby independent of density, there is no displacement in the envelope. In fact, the latter observation is crucial, since it constitutes a decoupling from the structural ideas and concepts of the piece: That is, despite of and independently from the linear or non-linear distributions and the pitch & rhythm density, the PADR envelopes constitute a distinct layer of the work.

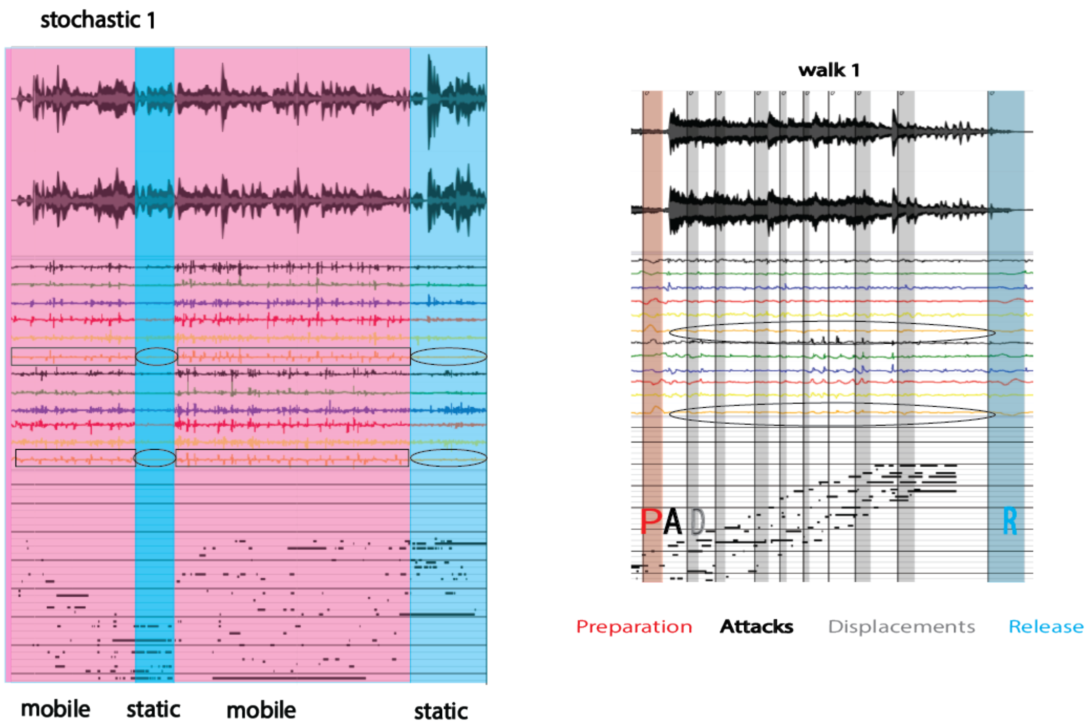


Figure 98: Comparison of linear and non-linear materials in terms of PADR envelopes

The basic distinction between static and mobile sections independent of pitch & rhythm density is further articulated in a middleground description defined by quantitative and qualitative features of the PADR envelopes, the registral relation of the two hands and the pitch & rhythm density. In the following figure (Figure 99), I provide a complete representation of the PADR envelope on the musical score, represented for simplicity with arrows, blue and orange for right and left hands respectively, indicating displacement. Five different types of segments are thus defined:

- Mobile sections featuring dense displacements in heterodirectional relationship of the hands, in wide registral distribution, and with high pitch & rhythm density: pink filter.
- Mobile sections with sparser displacements in mostly homodirectional relationship of the hands, in wide registral distribution, and with lower pitch and rhythm density: green filter.
- Mobile sections with dense or sparse displacements in strictly homodirectional relationship of the hands and in close registral distribution, with high or low pitch & rhythm density: orange filter.
- Static sections with little or no displacement of the hands, which remain locked in their respective register, with high pitch & rhythm density: blue filter.
- Static sections with little or no displacement and low density: purple filter

Table 3: Middleground articulation based on hand displacement

Bars	Middleground
41-43	green
44-45	orange
45-48	pink
48-49	green
50-53	blue
54-59	pink
60-66	blue
67	purple
67-68	blue
68-70	purple
71	blue
71-72	purple
73-74	blue
75-76	purple
76-77	orange

77-79	blue
84-85	blue
85-88	orange
88-90	blue
90-92	orange
95-97	blue
97-105	orange
106-107	blue
108-109	orange
111-114	orange
117-118	purple
119-121	pink

From this middleground description we draw the following conclusions:

a) The pure stochastic section is different from the second one alternating with arborescences. It features the alternation of complex choreography with more linear and static materials, while the following section focuses on the linear and static materials, before concluding with a dense cloud.
b) The pink sections pose the greatest performative challenges, as opposed to the more linear and static materials. Given that they constitute only 13/79 bars, about 1/6 of the stochastic section, the challenge is rationalized and contained.

So, it becomes clear how the initial complexity of parametrical interplay is actually managed and reduced in well-defined chunks based on physical movement and choreography at all hierarchical levels. In fact, the issue of large-scale prioritization and navigation is indissolubly bound to this sort of evaluation of global difficulty: Instead of asserting that "*Mists* is a difficult piece", it is much more refined to be able to locate exactly the challenging parts and the relatively easier ones, thus the necessity of a top-down first step of global familiarization and assessment of the challenge.

Summarizing, here are the main typologies we have explored thus far in the analysis of the stochastic section:

a) Pure stochastic versus stochastic in alternation with arborescences (41-79 vs 80-121)
b) Mobile versus static distributions
c) Segments differentiated by compositional parameters: timbre (pedal), articulations (several degrees of sec or non-sec), dynamics (discrete or in continuous transformation), texture (sparse or dense, distributions in time-space and in the keyboard-space)
d) Middleground sections in relation to the embodiment of pitch & rhythm density

Figure 99: Middleground description of the non-linear random walks based on hand displacement

C. Arborescence Rotations

As can be readily seen in the following comprehensive figure (Figure 100), arborescences have generally static envelopes (blue), with the prominent exception of one extended arborescence, which marks the end of the long first exposition of stochastic material (bars 80-83, red filter) and which draws its pitch material from the chromatic collection rather than from the scale and its cyclic transpositions.

The generally static choreography generated by the arborescences is counterbalanced by their hidden rotation architecture, which Squibbs reveals in Figure 101.

In addition to those rotations, the arborescences are creating a virtual arch in pitch space, thanks to registral displacement.

The third type of transformation has to do with the time interval that seperates the arborescences: fifteen bars between the end of the of the prototype and the first transformation, only four bars to the one following, and then a considerable gap of 18 bars, during which not only non-linear materials are alternating, but also the return of the linear walks mark what Squibbs describes as the third section of the piece. The final two appearances of arborescences are compressed, with only two bars of silence in-between.

How are the arborescence transformations manifested in terms of physical movement? The rotations themselves are not actually generating any differentiation in a mostly static harmonic material, given the narrow space in which the voices are unfolding.

The actual arch in space depends on what precedes and follows them: in the case of the two last arborescences, the physical displacement becomes clear. The third and lowest arborescence is surrounded by materials in an altogether different register. The second stems out of a comparatively mobile stochastic material and is followed by a fermata, while the original is also in some sort of registral difference to the stochastic ones surrounding it.

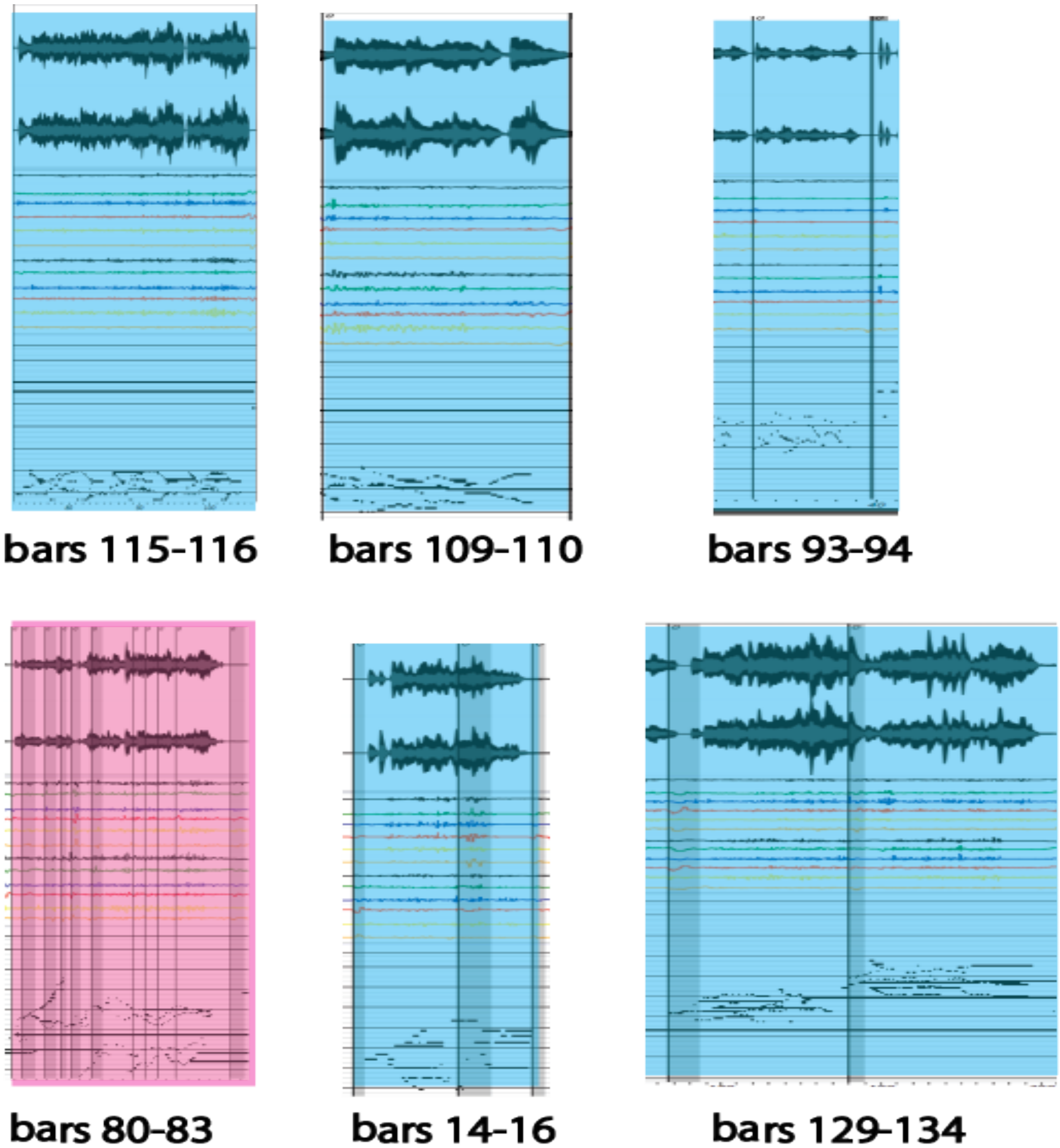


Figure 100: Overview of arborescences in terms of PADR envelopes. Notice the dense displacements in bars 80-83, as opposed to the static renditions in bars 115-116 and 109-110.

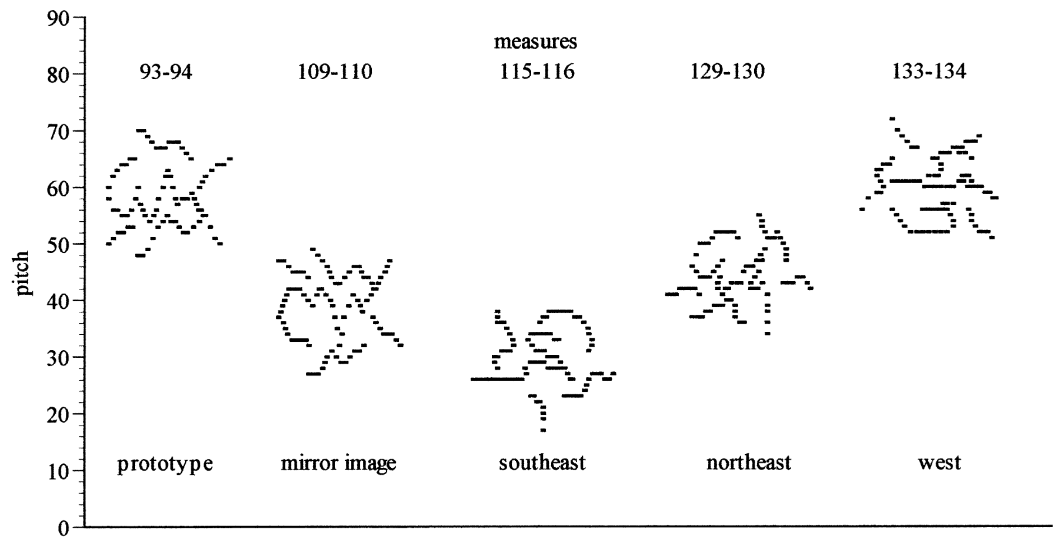


Figure 101: Rotation in space of the arborescences, in Squibs, p. 102. Reproduced with kind permission.

2.4 Four Navigation Scenarios: Scanning, Stratifying, Resisting, Interacting

We have already explored: a) the outside time compositional building blocks, after Xenakis's definition and Squibb's analysis; b) their embodiment, after my own experience of having already performed the piece; c) as well as the inside time unfolding and articulation of those materials. Such analysis corresponds to a neat, global view of the piece *after* it has already been learned and performed, that no performer could have formed in the beginning of the learning process, when confronted with what seems like an infinite amount of information – with a task of "computing the sand", to remember Archimedes. In that sense, and to resort again to Xenakis's influential distinction, this is an embodied albeit not really dynamic analytical view of *Mists* outside time.

In what follows, I will try to give a sense of the very learning trajectory itself, by exploring four scenarios of embodied navigation. These scenarios correspond to what I have elsewhere termed as dimensions or tropes of the space-score, namely:

(1) The *assemblage-view,* as an outside-of-time, highly personalized gestural template, which is produced through the very first scanning of the piece in an embodied way, as assemblage of movements, gestures and positions.

(2) The *forward-moving stratification*, as the establishment of lines of continuity in this template. The outcome of such a process is the structured view of the piece as in 2.2, 2.3.

(3) The *resistance to the flow*, as the projection of discontinuities in the template and the repetition to perfection.

(4) The *line of flight*, as the real-time passage through these dimensions, that is, as a singular unrepeatable performance.

All in all, such a type of analysis soughts to offer a simulation of the very learning process and a feeling for the dynamic systemic nature of the task that the performer is faced with. As a first word on this issue, here is a "stream of consciousness" sort of excerpt from my own diary of my learning process of *Mists*, back in 2006:

"I never start learning smaller chunks serially and I never do it away from the instrument. I always try to scan the whole several times (quasi sight-reading), usually mapping it with very detailed fingerings and positions at first and increasing speed of access later, as well as "folding" it in tighter units. The outcome constitutes the *ground of gesture*. I always insist on the physicality of that movement, but it is always taken for granted that this involves also analytical insight, even of a more intuitive type. According to how things evolve, the navigation focuses on different hierarchical levels, freely sculpting detail or becoming aware of larger units. The question of continuity becomes here crucial through the question of interrupting it: Where does one stop when learning? When I get tired of detail or feel physically and mentally fixated, I move either forward or on another hierarchical level, *in between* hierarchical levels and structures. When I feel dizzy out of too much movement and very unfocused, or in danger of a generic approach, I smoothen out my navigation by repeating, and so on. A continuous process of stratification of a smooth score space (and vice versa, a smoothening of the highly stratified notated score, in a Boulezian/Deleuzian sense), *a sort of higher rhythm of learning*, is always there to organically interweave things together. Usually it is not very much time, until I get a certain physical feeling of the whole and start fixating things for the performance and making proper interpretative choices and putting priorities, albeit a certain degree of elasticity as remnant of this process survives in the future performances". (Antoniadis practice diary, 2006)

A. Scanning

In the first scenario, *scanning*, very similar to Ferneyhough's idea of an initial 'sight-reading' which unveals a global gestural patterning (part three), I scanned through the musical score, in a representation of the very first stage of a top-down learning process, and recorded the process. This scenario provided me with the gestural template in the form of multimodal data for each of the eleven pages of the Salabert Edition of the piece. All further movement analysis and learning was performed against this very gestural template. This navigation of the whole is registered as the first attempt to experience the duration of the piece and its global aspects, rather than refine the details of the performance. In that way, it allows for a) an evaluation of the amount of work that has to be carried out b) an evaluation of the prioritization processes, which will enable a more efficient learning process c) an early identification of larger entities and patterns, a sort of embodied morphology and d) a mnemotechnic support, a sort archive of this assemblage view, which can be used for the rapid familiarization with the global aspects of the piece.

Such mnemotechnic support becomes really indispensable, given the rich datasets at work here, which can provide multimodal feedback for almost all aspects of the learning process: This feedback employs the modalities of vision (the data are representable) and hearing (audio and MIDI), with further sonification possibilities (for example, of the displacement envelope), while at the same time referring to performance data.

In the following video https://www.youtube.com/watch?v=eNQsusviPIg , accessed 01.05.2018, you may see an example of how this process is implemented for the dense cloud of bars 45-46.

From the beginning of the video up to to 2'10", I am dealing with only a couple of handgrasps (end of bar 45), sculpting them in detail and deciphering the original entangled space-time notation. Then I figure out the dense heterodirectional middle part, before a final performance at 6'44".

In the following video https://www.youtube.com/watch?v=55tuHhRU-EM, accessed 29.04.2018, you may see the same process for the climax of the piece, the wave of crossing linear random walks, with a representation of the PADR envelope in the middle section of the recording (1’21”-3’09”).

B. Stratification

In the second scenario, I recorded in detail short ordered segments of the piece, applying several filters or prioritization processes in my performance, which transform the notation providing several alternative segmentations. This is the constructivist scenario, whereby different approaches are tested and several strata for channeling the performative energy are explored. Comparison of the segmentations reveals a common PADR envelope against which all the navigation takes place, with or without interactive systems.

The prioritization processes or filters used in this process were partly decided in advance given the experience of our research and partly emerging during the process, and can be categorized as follows:

- Embodied layers (templates for the finger-, grasp- and arm-layer).
- Air gesture.
- Performance without metronome in several tempi.
- Performance with metronome in several tempi.
- Dynamic and articulatory differentiation.
- Occasionally “expressive” as opposed to a “deadpun” performance.

One of the most valuable contributions of such a process, next to the augmented multimodal feedback provided by the *MuBu* recordings, is the function of *renotation*, through Dominique Fober’s customized command-line tools based on the *Guido Engine*. In that way, performance becomes writing and prioritized performance becomes automated notational processing – automated but still though offline.

In the following examples, you may watch the videos of multimodal recordings and corresponding reduced proportional notations for for one difficult stochastic passage, bars 45-46, also analyzed in part two. There are recordings of: a scanning process (more economical than the one above); finger, grasp and arm layers; air-gesture; dynamic prioritization and (expressive) performance.

https://www.youtube.com/watch?v=VTdBlyV6qVE, accessed 29.04.2018

Here are the emergent processings of the notation:

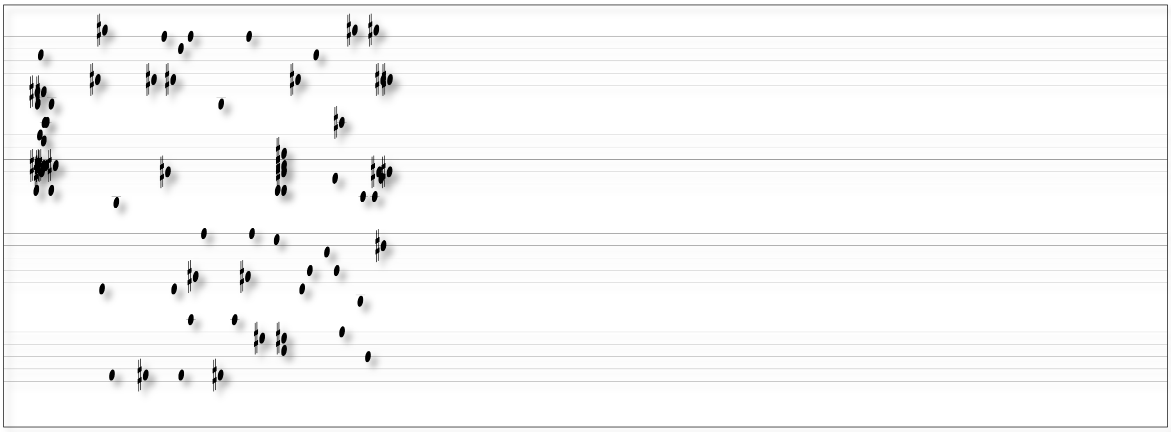


Figure 102: Renotation after scanning

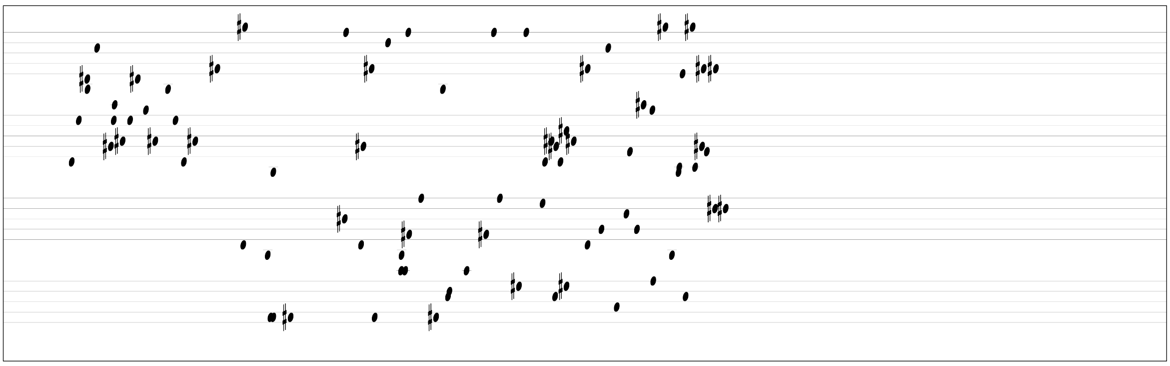


Figure 103: Renotation after finger-layer

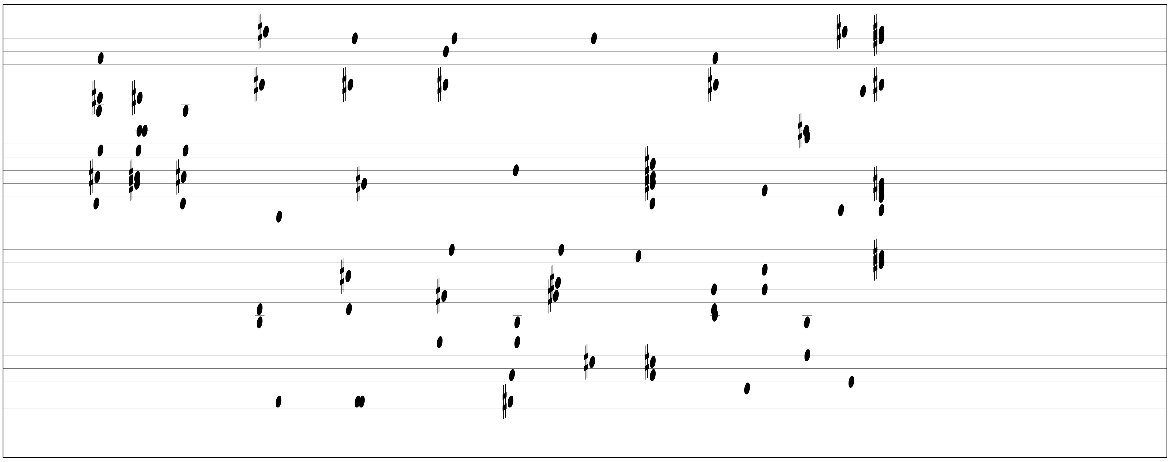


Figure 104: Renotation after grasp-layer

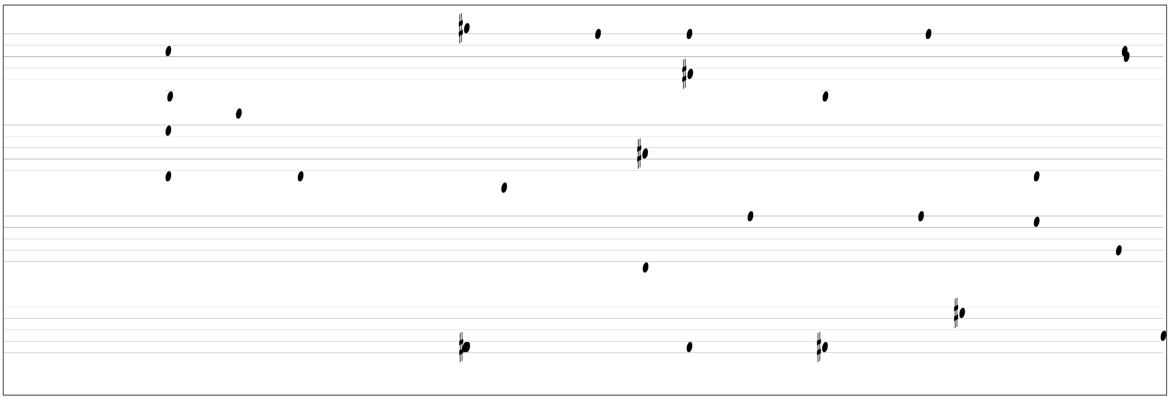


Figure 105: Renotation after arm-layer

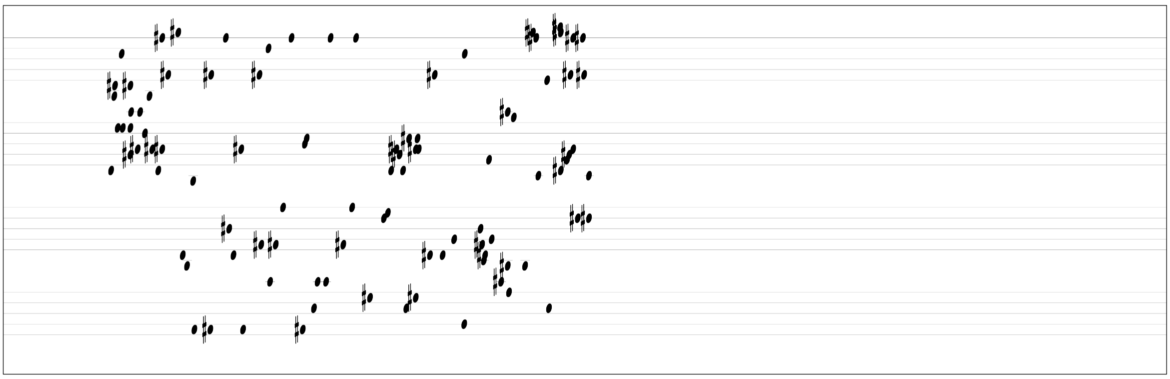


Figure 106: Renotation after expressive performance

It becomes clear that different performative filters are made visible in notational form, allowing for the emergence of different chunks according to physical movement. As has extensively been shown before, such chunks can be further used for the creation of interactive representations or in themselves as learning materials. Please note that in these four-stave representations, the two upper staves are always to be read as in treble clef and treble clef transposed two octaves higher, and the two lower ones in bass clef and bass clef transposed two octaves lower, ensuring thus the continuity of the MIDI representation in the notational space. That is: the readability of the MIDI representation.

C. Resistance To The Flow

In the third scenario, I sculpted each of the segments defined above in perfection through *repetition*, resisting to the forward flow, and according to intentional interpretative choices towards a final sonic result. The success or not of this process gives a measure of what usually is termed impossibilities and challenges in Xenakis's work overall. In the following example, I am using a metronome to refine the rhythmic performance of the striated space in Xenakis' space-time notation. In the first and second examples I am performing stopping before the next beat, while in the third example I play uninterrupted through the segment. Notice the impossibilities in the last example.

https://www.youtube.com/watch?v=GnLKPmu36kQ accessed 29.04.2018

Here is also the alternative segmentation provided based on the eighth note beat:

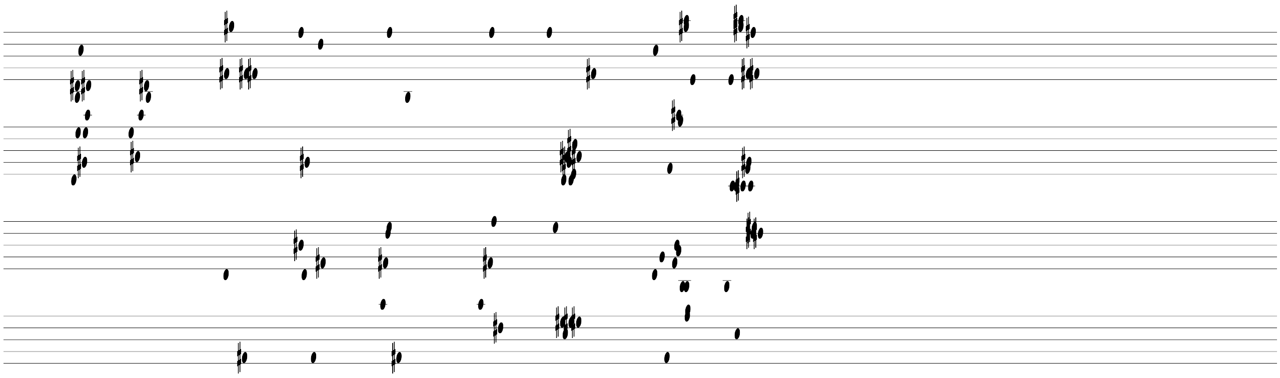


Figure 107: eighth beat segmentation

D. Line Of Flight

In the fourth scenario, I created interactive systems for the navigation of the notation through physical movement in real-time and as a passage through the state-space created by the three previous scenaria, based on the extracted through comparison gestural template. Here is where the *motionfollower*, the *INScore* and the *GesTCom* were used as described in the third part of the dissertation.

Please note that: The gestural template / PADR envelopes in question can either be discovered intuitively during performance (online) or through comparative analysis of different takes (offline). In all cases, PADR envelopes, while belonging to a particular performance with particular prioritizations, are cross-referenced with the PADR of the rest of the scenarios.

In the following video, an initial recording of the canonic entrance of the linear walks serves as the basis for gesture-following of varied performances in terms of speed, articulation and dynamics. The gesture-following is inscribed in the *INScore* simplified notation, thus providing score-following possibilities.

https://www.youtube.com/watch?v=Rql732JUm5M , accessed 29.04.2018

It is important to think of these learning tools under the light of both the dynamics of interaction as explained by Leman 2016 (entrainment, alignment and sensorimotor learning), as well as in relation to Cox’s 2002 call for advanced tools for complex music: The processed musical notation becomes fluid through the integration of multimodal data and turns into a real-time signal that drives learning and performance.

2.5 Conclusion : Form And Detail

According to the analysis by Squibbs, *Mists* exhibits a ternary form (bars 1-40, 41-121, 122-134) based on the traditional notion of relative pitch stability in the outer sections and more flux through the use of transpositions with less common tones in the middle section of the piece, combined with the stochastic distribution as the textural event which *per se* that defines the piece. But how viable is such a schematic representation in performance? Is it possible that the experience of learning the piece might provide a different perception of its morphology?

In his early text "Aspects of Notational and Compositional Practice", Brian Ferneyhough refers to notation's "implied ideology of creation" as a presupposition for a renewed esthetic foundation of closed form. In his own work, this ideology is manifested through the famously dense and detailed notational surface, which invites performer's choice as to the order of exploration and the prioritization of materials.

The obvious question that is raised here is: can we trace an implied ideology in Xenakis's notation? and if so, what are the implications for the paths during the learning process and the interpretation as prioritization?

I haven’t focused here on Xenakis’ *New Complexity* foreshadowings, through prioritization as necessary omission of information due to unplayability, like in *Synaphai* or *Evryali*. I have rather prioritized a least celebrated aspect of his notational ideology: the tension between a clear global design based on algorithms and graphs and the mind-numbing local complexity due to polyphony & masses and their traditional notation . The handling of this paradox constitutes in my opinion the main performative challenge in Xenakis, to engulf and interconnect all the rest.

From Xenakis' interviews and writings, we have very strong indications for a) a desired grasp of the whole from the very first learning stages and b) the prioritization of performative elements which *project* that whole. But this prioritization has to be calibrated against the paradoxically highly polyphonic and analytical traditional notation, in a way which does not produce generic results: It is the inner articulation of the massive effect, the distinction of polyphonic entities, rather than clouds and galaxies in themselves, that pose problems.

To put it in a very empirical way: How is a mist to be built? How clear and discernible are the limits of objects inside that mist supposed to be?

The notion of embodied navigation emerges here as a way to cope with this pronounced ideological tension between conception and notation. Such approach does not favor the perception of the intended whole as a neat mental image, but rather as disclosure through the vehicle of performative physicality. An overall mobilization of the form, in the sense of a busier interpenetration of all three textural types -a sort of form as hyper-polyphony, becomes here clear from a performative point of view: a bipartite model of exposition and development- a form of developing variation, in lieu of Squibbs's suggested three-partite model. This principle of increased mobilization on different hierarchical levels can be seen as the organic evolution of a simple linear material: from line to bending, to cluster of lines, to simple arborescences, to a faster tempo of lines in opposite directions, to stochastic explosion, to arborescences with repeated notes and more rhythmic complexity organized in an arch, to a crossing wave, and all that in a context of a busier higher polyphony of materials. The whole piece could be approached then as a gradual polyphonic "bending" or diffraction of the initial monolithic material. Thus, the title *Mists* refers as much to developing degrees of obscuring clarity, on top of the literal description of the musical surface in the stochastic section.

Perception of this very clear "arrow of obscurity in time" in performance -a dynamic rather than proportional and sectionalized one, based on the various degrees and perforations of performative continuity rather than analytic measurements-, in combination with Xenakis' own ideological manifestations and paradoxes, is never adequate in itself as a mental representation to be reproduced. This mono-timeline is in itself opening in a perpetually renewable multitude of learning paths, reflecting the very specific properties of the materials: a movement inside the materials and *in-between* them, as a movement between the actual physical movements and tension-distributions experienced physically; thus as a movement between the various embodied hierarchical layers. Those embodied chunks hardly coincide with the composer's algorithmic stratification on any level of form. This experience grants performative physicality with its unique ontological position as the *per se inside time* manifestation of Xenakis' work, rather than treating performances as a quasi *outside time* given.

3. Post-Complexity: Intentionality Nodes In Mark Andre's Contrapunctus

3.1 Mark Andre's Contrapunctus As Post-Complex Music

In comparison to both the extended case study of *Mists* by Iannis Xenakis, as well as to Brian Ferneyhough's *Lemma-Icon-Epigram* in part three, *Contrapunctus* by Mark Andre[408] presents us with an example of what I term *post-complexity*. I will argue

[408]"Mark Andre, born in Paris in 1964, creates in his music existential experiences for the listener, spaces characterised by subtle, minutely worked-out processes of transformation. His chamber works, delicate and concentrated, have been described by the *Hamburger Abendblatt* as "acoustic houses of cards that no wind can blow down". In his orchestral works the practicing Protestant also shows himself to be a sensitive explorer of sound, guided by the spiritual dimension of the creative process.

After his studies in France, including those at the Paris Conservatory with Claude Ballif and Gérard Grisey, Mark Andre found a new musical home in Germany. He describes the encounter with the music of Helmut Lachenmann, the score of whose piano concerto *Ausklang* he happened to stumble across, as having been a revelation. He subsequently went through extensive composition studies with Lachenmann at the Academy of Music in Stuttgart, and studied musical electronics with André Richard at the experimental studio of Southwest German Radio, in the meantime moving the focus of his life from France to Germany. Here he soon received grants and prizes, such as the Kranichsteiner Music Prize at the Darmstadt Summer Courses for New Music (1996), first prize at the Stuttgart International Composers Competition (1997), and the composition prize from Frankfurt Opera (2001). In 1998 he received his first invitation to teach at the Darmstadt Summer Courses. In 2002 he received the Advancement Award from the Ernst von Siemens Music Foundation.

Particular interest was aroused by the 2004 premiere of Mark Andre's tripartite music theatre work *…22, 13…* at the Munich Biennale. This work's title refers to a passage in the Apocalypse of St. John. His orchestral triptych *…auf…*, which he completed in 2007 and whose final section was premiered in Donaueschingen, received the prize from the SWR Symphony Orchestra of Baden-Baden and Freiburg, and similarly refers to a religious theme. Here Mark Andre explored the aspects of transition present and latent in the resurrection of Christ. Andre, who now resides in Berlin, has a soft spot for German prepositions, the grammatical elements with the function of transition, as illustrated in numerous other work titles such as those of the four chamber music works written between 2001 and 2005: *…durch…, …zu…, …in…, and …als….*

that, despite its considerable differences as to notational surface density, such writing can still be approached through the embodied navigational model and the corresponding interactive tools.

As post-complexity, I define here the relative textural *transparency* of the notation. Standard indicators of complex notation are present in *Contrapunctus*, but they do not necessarily evoke the textural density of Xenakis or Ferneyhough. Such indicators are: the algorithmic stratification of parameters like pitch, rhythm, dynamic, articulation, pedaling etc.; the extremely complex rhythmical structures via nested tuplets; eventually the multiplicity of relations between the above-mentioned elements, organized in *intentionality nodes*. In other words, we are facing a *qualitative* rather than a *quantitative* form of complexity. Mark Andre's polyphony, as evoked in the title of the piece in question, must be understood as a transparent counterpoint rather than as a massive and obscure space to be navigated.

Important works of the last few years include the clarinet concerto *über* written for Jörg Widmann and the SWR Symphony Orchestra, which won the Orchestral Prize at the Donaueschinger Musiktage, as well as the violin concerto *an*, written for Carolin Widmann and premiered at the ACHT Brücken festival. Last season, the composer completed his trilogy of works for ensemble with *Riss I,* which was premiered by the Ensemble intercontemporain. Mark Andre's first opera *wunderzaichen*, which recounts the fictitious journey of the first German humanist Johannes Reuchlin whose present-day alter ego is sent on a trip to Israel, became one of the highlights of the 2013/14 season at the Stuttgart Opera under the baton of Sylvain Cambreling, and will be performed again this season.

Following the successful premiere of his orchestral work *woher… wohin* at the end of the 2016/17 season, written for the Bavarian Radio Symphony Orchestra and performed under the baton of Matthias Pintscher, the 2017/18 season is focused on chamber works. His string quartet *Miniaturen,* written for the Arditti Quartet and also premiered at musica viva in Munich last July, will be given its French premiere at the Festival d'Automne. At the Wittener Tage für Neue Kammermusik, two new works will be performed; a new solo work for clarinettist Jörg Widmann and a harp concerto for soloist Andreas Mildner and the WDR Symphony Orchestra.

Mark Andre is a member of the Berlin Academy of the Arts, Saxon Academy of the Arts and the Bavarian Academy of the Arts, and was honoured with the order of Chevalier des Arts et des Lettres in 2011. In 2012 he was fellow of the Institute for Advanced Study in Berlin. He teaches composition at the Academy of Music in Dresden."

In https://en.karstenwitt.com/mark-andre, accessed 04.03.2018

The question that emerges is then: Why would Mark Andre's music remain incomprehensible without the dimension of embodiment? How does performative embodiment turn into a prerequisite of "inner hearing", despite the clarity of musical notation? And also: How could we root Mark Andre's very notion of *Zwischenräume* (*in-between spaces*) in embodied experience ? Are those compositional spaces conceptual entities ? Or do they also have a pragmatic, performer-specific meaning, which renders them palpable for the analyst and the listener ?

Zwischenräume

The traces of a model of embodied navigation can already be found in Andre's compositional aesthetics, and more precisely in his concept of "in-between spaces". In an interview with the music journalist Björn Gottstein[409], Mark Andre demystifies to a certain degree this elusive concept. Sometimes, Andre designates with this term a certain materialist use of the instrumental medium: For example, an unusual spatial distribution of instruments, originating in the orchestrating art of Mahler and Webern. In this case, *in-between spaces* are conceived in the architectural and acoustic space. In other cases, the concept points towards a deconstructive compositional process in relation to a timeline. Then, the composer speaks of »Ruinen der Struktur«- "ruins of structure". This and similar conceptual metaphors (such as »Atem des Materials« - "breathing of the material" and »Faltung des Raums« - "fold of space") are ubiquitous in Andre's descriptions. They accentuate the dynamic nature of composition as a process, rather than as the generator of a fixed result. Finally, the frequent use of electronics in Andre's music enables disembodied sonic presences, which open up *in*-between spaces in their interaction with acoustic sounds. In any case, *in-between spaces* remain latent and fragile. They are defined by a movement between the Real and the Virtual, the acoustic and the electronic, the physical space and the perceived time, eventually the Embodied and the Symbolic.

[409] http://www.geraeuschen.de/21.html , accessed 07.12.16

They become also an object of analysis in Martin Zenck's contribution[410] on Andre's music theatre, with references to the philosopher Jean-Luc Nancy and the architects Carlo Scrapa and Renzo Piano. In this case, they signify the emergence of architectural and philosophical inter-structures, in relation to Andre's opera *Wunderzeichen.* As such, they are pointing towards an interdisciplinary perception of the term on the basis of intermedia.

Let us at this point compare the above description of *Zwischenräume* to the following definition of embodied navigation, as presented in part two:

Embodied Navigation signifies the perpetual movement *in-between* embodied structures of the immobile score-space. This movement produces a new and infinitely malleable space. The movement functions *between* learning and performance, *between* detailed and global aspects and *between* the continuity of performance and the resistance of decoding. The qualities of navigation, such as directionality, speed, viscosity etc., define what can sound out of the initial, incomprehensible and / or unplayable image. Interpretation is then this diachronic movement, instead of the repetition of a fixed sound-image.

It might become clear, that the production of latent, fragile and transitory spaces in Mark Andre's compositional aesthetics can be extended into the *de facto* interactive aesthetics of the performer. Through the notion of *in-between spaces*, we can describe both the virtual and the real physical movement that enables the embodied processing of notation. The results of this processing remain provisional and are updated during a diachronic learning trajectory.

[410] http://www.musikwissenschaft.uni-wuerzburg.de/fileadmin/04070000/Allgemein/Tagungen/studientage/imaginaer/MZ_U__ber-u-Zwischenra__ume.pdf accessed 17.04.2018

Given the above definitions, how are those inter-structures relevant for the early composition for solo piano *Contrapunctus* (1998/1999)? The work was algorithmically generated and didn't feature any of the above-mentioned media - *spatialization*, electronics and mixed music, architectural aspects and music theatre. How can we relate the composed in-between spaces to the navigation of affordances by the performer?

3.2 Grasping Transitoriness

In what follows, I analyze the macro- and micro-structures in *Contrapunctus* through the embodied navigational model. At a first stage, I focus on the relations of three co-articulated embodied layers to form: The global form of the work corresponds to the arm-layer, the phrase-structure to the grasp-layer, and the micro-structures to the finger-layer.

These correspondences are traced along four sections, which articulate the timeline of the piece:

1) Bars 1-27: This section is characterized by a contradictory relation of the co-articulation layers: The arm- and grasp-layers remains static, while the finger-layer is mobile.
2) Bars 29-72: The introduction of a third voice in the middle register (bar 28) interrupts the opening situation through the activation of the arm-layer. The finger-layer density is now matched by register leaps for the accommodation of the third voice. The grasp- layer remains static.
3) Bars 73-116: The return to a two-part structure (bar 73) marks the return to the initial static character of the arm-layer. Due to the presentation of the initial material in the form of chords, the finger-layer is now also inactive, as opposed to the activation of the grasp-layer.
4) Bars 117-150: In the context of a general diffusion of the activity, all three layers are now static. Mark Andre's concept "ruins of structure" becomes here palpable. The transition inside the piano for the preparation of the extreme strings of the instrument (bar 117) marks the poetic transcendence of time and timbre through an unusual physical action.

A. Embodiment Of Global Form: Arm-Layer

Contrapunctus' first 27 bars constitute a solid thematic entity. Structural features of the material in the pitch and rhythm domains are the first reason for this perceived unity. The second reason is the tension produced by the juxtaposition of a static arm-layer to a mobile finger-layer. This feature is enhanced through the physical distance of the hands, which occupy the extremes of the keyboard. This distance evokes similar passages in Beethoven's later sonatas, Galina Ustvolskaya's piano music, or even the opening movement of Brian Ferneyhough's *Opus Contra Naturam* from the opera *Shadowtime.* The acoustic void from such arrangement constitutes a literal *in-between* space, which is intensified by the physical stretching of the performer over the keyboard, with his/her arms fixed. The tension is heightened even more through an action *before* the beginning of the piece: The silent depression of a chromatic cluster, which is then to be held with the middle *sostenuto* pedal of the instrument. This silently depressed cluster adds an *aura* of sympathetically vibrating strings in the lower region of the instrument to the overall sound.
In the following video you may watch a performance of those 27 bars (0'00" – 0'58"), including the cluster action in the beginning.
https://www.youtube.com/watch?v=Bba_RwWOsW4 accessed 26.04.2018

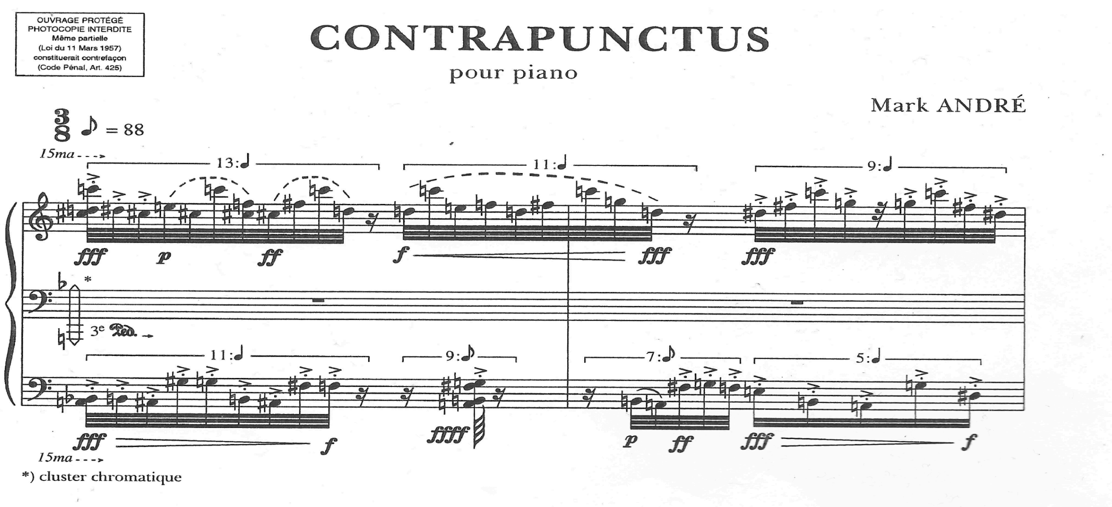


Figure 108: *Contrapunctus*, bars 1-2

The introduction of a third voice in bar 28 (Figure 109) is opening up a new space, still transparent in terms of texture, but now articulated through rapid arm-

movements. The third voice in the middle staff is not intended only as an acoustic, but also as a visual and kinesthetic event:
https://www.youtube.com/watch?v=Bba_RwWOsW4&t=58 (0’58”-01’00”)

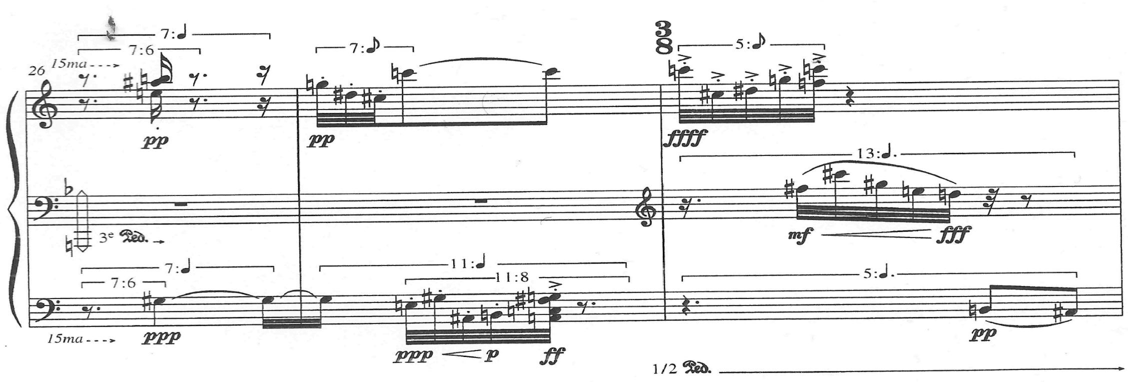


Figure 109: *Contrapunctus,* bars 26-28. A third voice is entering in the middle staff of bar 28, requiring the activation of the arm-layer

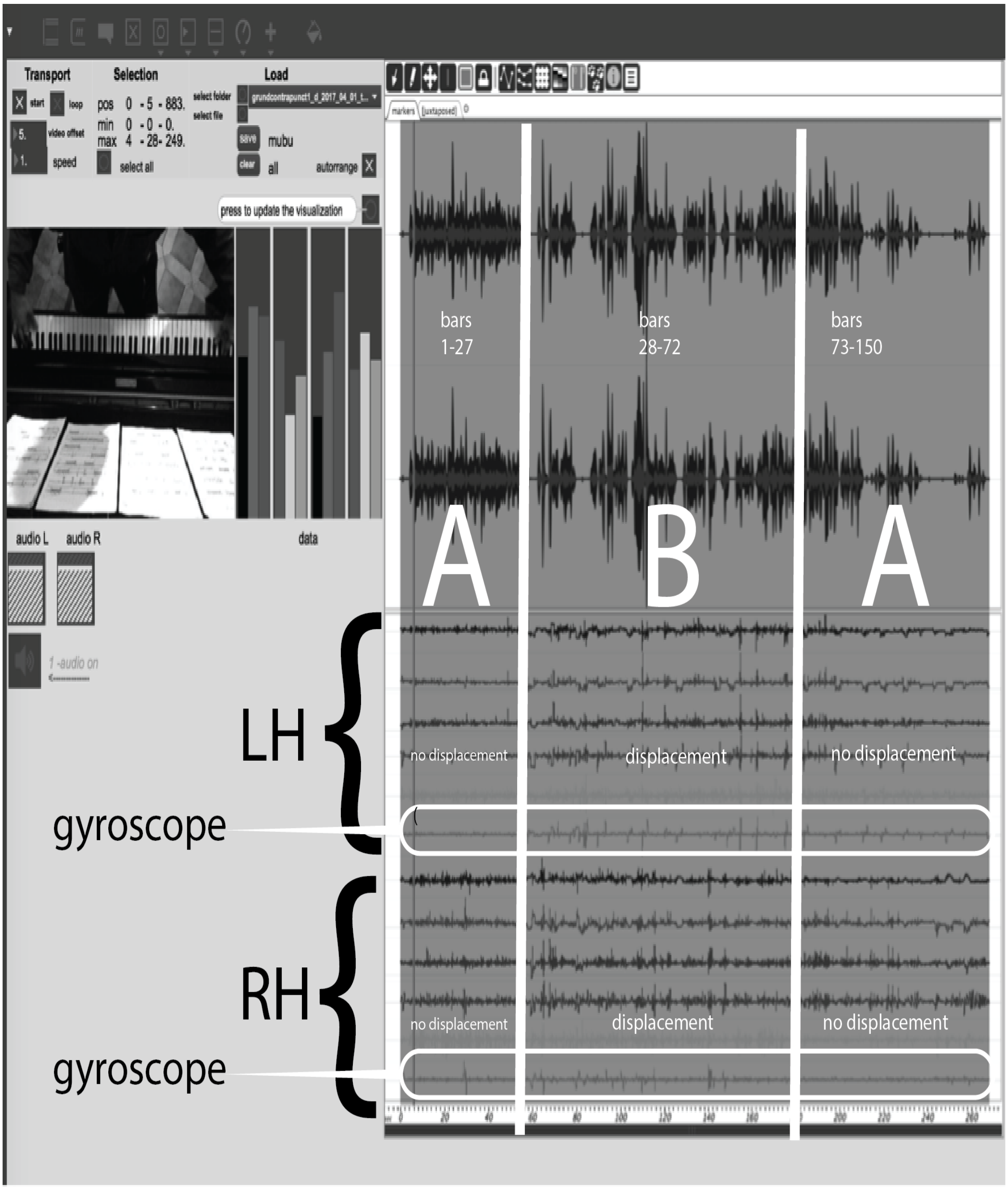


Figure 110: Representation of *Contrapunctus*' macro-form through multimodal data. In the first and third sections A, bars 1-27 and 73-150 respectively, the gyroscope signals indicated remain inactive. Their activation at Section B, bars 28-72, indicates the activation of the arm-layer as a result of a three-part texture.

In Figure 110 you may see a representation of the arm-layer's activation in the form of multilayered data for a given performance. The bar in question, bar 28, has been annotated as the beginning of section B in the macro-form of the work. In terms of gesture signals, please notice the annotated gyroscope signals for the right and the left hand respectively: The section B of the work (bars 28-72) features heightened activity in these signals, which indicate the horizontal displacement along the keyboard. On the contrary, in sections marked with A (bars 1-27 and 73-150), those gyroscope signals remain almost inactive. The important point here is: A structural, higher-order characteristic of the piece becomes visible in lower-order, physical movement data. In this way, patterns in physical energy can be correlated to patterns in the symbolic notation. Another important feature of this representation is its concise character: It gives a bird's-eye view of the whole piece and its manifestation in physical energy, as opposed to symbolic representations.

The passage at bars 55-60 (Figures 111, 112) features the climax of section B. During a notated *metric modulation*, the arm-layer activation is challenged by an impossibly fast tempo and by its interaction with very soft dynamics. The metric modulation takes the form of a succession of irrational time signatures: 3/12 (bars 55-56) – 3/15 (bar 57) – 3/18.75 (bar 58) – 3/23.4375 (bar 59) – 3/29.296875 (bar 60). Each shift indicates an acceleration. The relation of the tempi is given by the ratio of the time signature denominators: 15:12 (bar 57 in relation to 56), 18.75:15 (bar 58:bar 57), etc. The calculation of these ratios show an acceleration of 5:4 for each successive bar, so that the sequence of the tempi, given the initial tempo 132 BPM at bar 55: 132*5/4= 165 BPM (bar 56); 165*5/4=206.25 BPM etc. as shown in Figures 106 & 107. The coupling of arm movement with this tempo makes the passage impossible to perform. On top of that, the soft dynamics do not allow for physical movements of high energy – what Cox 2002 would describe as "energetic striving": The touch has to remain light and each attack has to be approached with care. In this way, the parameter of dynamics functions counter-intuitively to the climactic characteristics of the passage. This function cannot be described in terms of a fixed sound result, but only in terms of interaction and in terms of indeterminacy.
In the following video you may see a performance of this passage:
https://www.youtube.com/watch?v=Bba_RwWOsW4&t=110 (01'50"- 01'56")

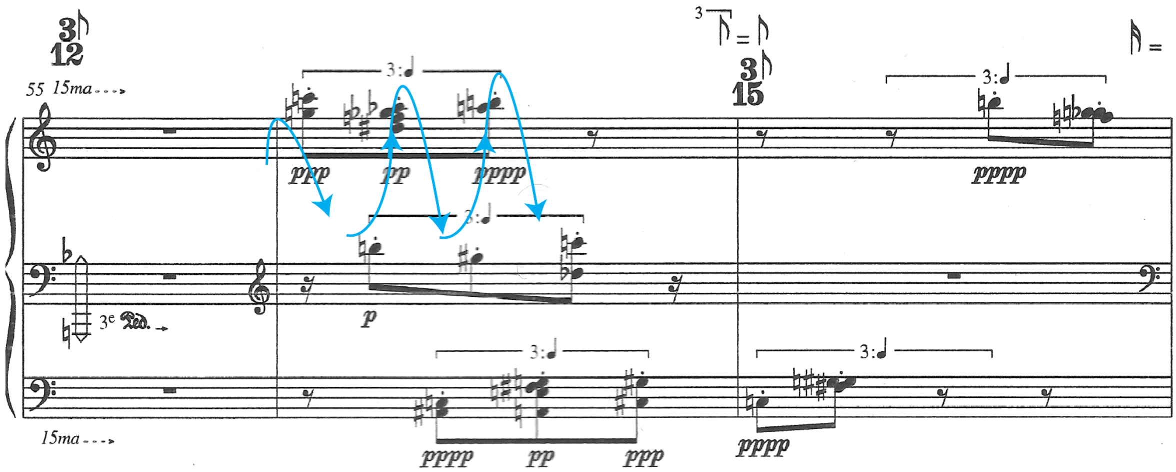


Figure 111: Acceleration through metric modulation in tempi ratios 12:8, 15:12, (132, 165 BPM) or bars 55-57. The blue arrows show the activation of the arm-layer for the right hand.

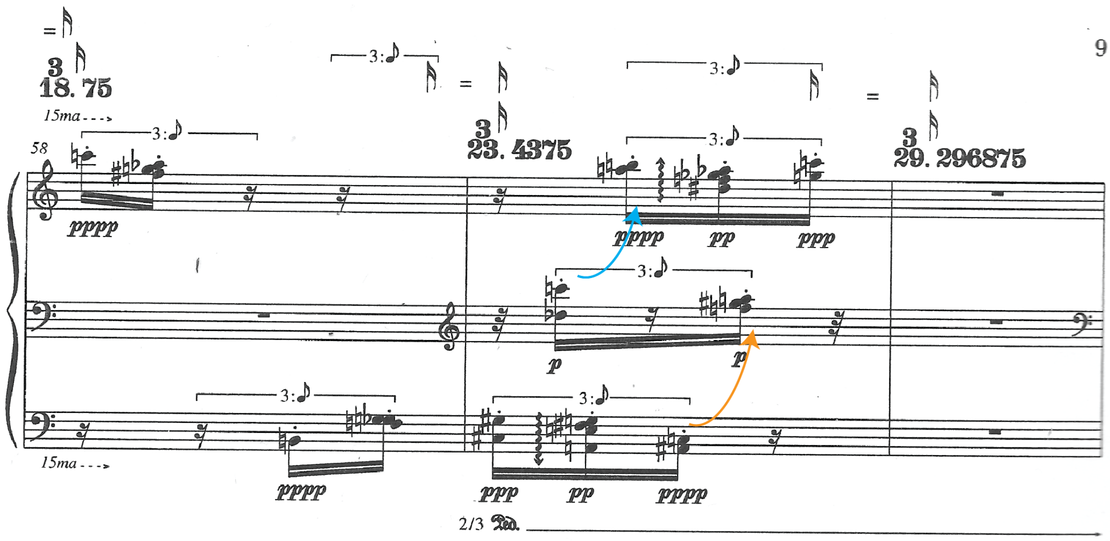


Figure 112: Acceleration continues by 18.75:15, 23.4375:18.75, 29.296875:23.4375 (all 5:4, or 206.25, 257.8125, 322.265 BPM), bars 58-60. Blue and orange arrow for the activation of the arm-layer in the right and left hands respectively.

The “heavy” return to the original two-part texture with chords marks a new deactivation of the arm-layer (bar 73, 2’13” in the video[411]). This is visible as return of

[411] https://www.youtube.com/watch?v=Bba_RwWOsW4&t=133

section A in the data of Figure 110. At the same time, the physical articulation in grasps becomes more palpable.

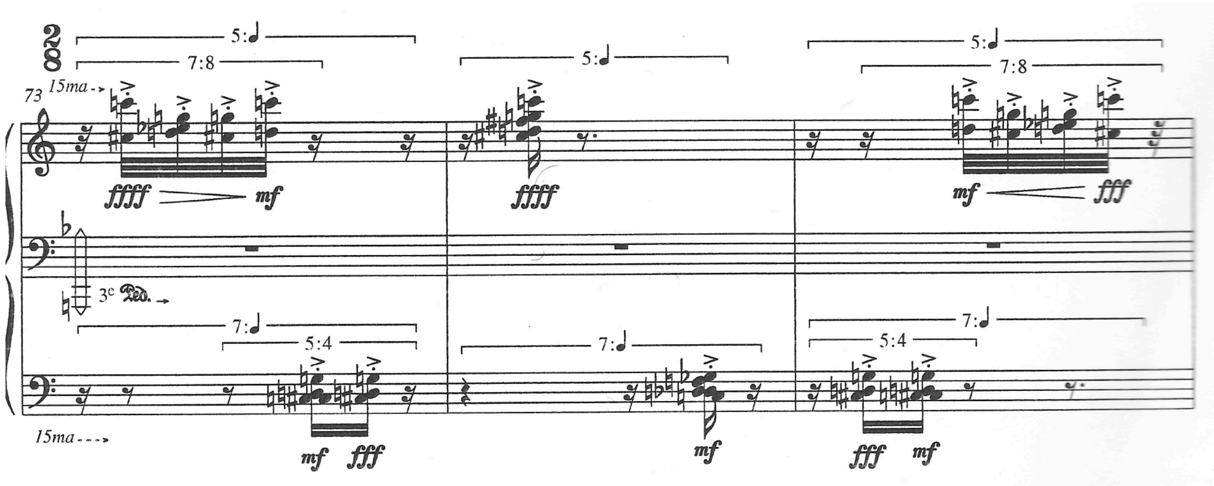


Figure 113: Return to two part-texture with chords

From now on, the general tendency of the piece will be the gradual move towards silence and the transcendence, so to speak, of the listening act. Intensity is released not only in terms of sonic features, but also in the gradual deactivation of the three embodied layers. In the following image, you may see a characteristic example: The *metric modulation* of bars 55-60 is now repeated in reverse (as deceleration) and with the texture having reached a new level of transparency in both horizontal and vertical dimensions (what Mark Andre would call “ruins of structure”). Please notice in the video how I start counting the fast tempo with my head at 2’43”. The passage lasts until 2’49” (bar 102):

https://www.youtube.com/watch?v=Bba_RwWOsW4&t=163

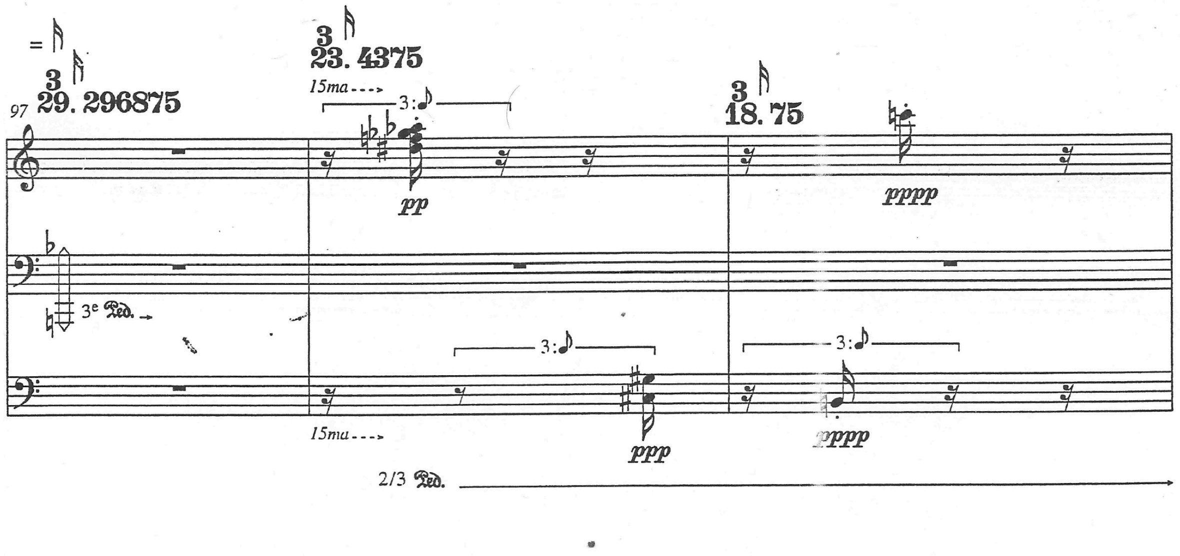


Figure 114: “Ruins of structure” in the re-exposition of the metric modulation

The passage to the last section (bars 117-150) becomes visible through another unusual action, such as the beginnings silent cluster. It is an action of preparation of the extreme strings of the instrument with rubber, in real-time, as shown in the following video (3’15”-3’31” for the left hand, 3’35”- 3’46” for the right hand) :
https://www.youtube.com/watch?v=Bba_RwWOsW4&t=195
This action adds a moment of corporeal tension on the part of the interpreter because the preparation is happening in real-time. The result of the action, a non-pitched timbre transformation of the outer strings, is functioning as a *lacuna* which is transcending the piano’s usual timbre, in moments like 4’-04” (left hand) and 4’06” (right hand) of the video. A rather interesting question concerning the embodiment of the very last bars, in tempo 40 (measure 117-150), is exactly the embodiment of horizontal, time voids or “ruins”: If and how could someone project the elaborate rhythmical structure, with two extreme variations, whether almost conducting it or in absolute immobility (3’15” to end). In this specific performance, I was not very determined about this aspect, mixing moments of “conducting” (for example, 4’35”-4’41”) and standing still waiting for the next expressive gesture (4’41”-4’46”).

B. Navigation Inside The Arm-Layer

The navigation inside the inactive arm-layer can be demonstrated in the first five bars of the work. On the one hand, I present the manipulation of complex nested rhythms. This aspect requires a finger-layer analysis. At a second stage, I show the interaction of rhythm with articulation, dynamic and other groupings, using the representation of music parameters as intentionality nodes. As analyzed in part two, this representation is inspired by connectionist architectures.

Mark Andre's basic mechanism for the production of a highly polyphonic texture despite the register limitations of the first five bars is the juxtaposition of non-coinciding polyrhythms. The frame for this process is a strict macro-rhythmical structure filtered ("ruined") by rests. The symmetrical structure of two plus two 3/8 measures (bars 1-4) is broken at the end with a fifth 3/32 measure. This basic group juxtaposes three groups of subdivisions of 13-11-9 of a quarter-note in the right hand against four groups (11-9-7-5) in the left hand (measures 1-2). This relation is followed by the retrograde form 9-11-13 against 5-7-9-11. The result is a highly symmetrical albeit far from simple structure of proportionate deceleration and acceleration, whereas the relationship between the two hands remains irrational.

The geometrical simplicity of the horizontal sequences does not relieve the incomprehensibility of polyrhythms such as 13:11.. We can certainly understand, that two different streams of notes are differently subdivided between the two eighth notes, but their exact relation remains irrational. Why? Because, if we wished to have an exact, imagined and representable rhythmic relation between the two voices, we would need to subdivide the duration of a quarter note in 13*11=143 parts. Such computation is not pragmatic for human intelligence. The pragmatic solution is instead to navigate through the passage using mediation techniques. Mediation techniques allow for an approximation of the rhythmical relations. This navigation is embodied. Why so? Because the choice of the proper heuristic depends on the relevant embodied layer of the co-articulation, providing the appropriate resolution for the rhythmic task. In this specific example, we can evenly distribute the 13 and 11 attacks respectively over two eighth notes (pulse-based approach). In this way, we can know that the second eighth must arrive after the seventh note in the case of the 13-tuplet and after the sixth note in the case of the 11-tuplet; but this approach works well only with one-handed structures, or differently put, the eighth note resolution is coupled well with the hand-grasp layer.

For the relation between the hands, we must notice the sequence note per note, which becomes possible through the technique of proper positioning (decimals.) But attention: During the actual performance, none of the above-mentioned techniques is in itself sufficient: One is aware and navigates between both points of focus, both the alternation of attacks in the finger-layer and the homogeneous distribution in the grasp-layer. In other words: One explores this complex relationship in an embodied and enactive way; one navigates the rhythm as a manifestation of physical co-articulation.

Eventually, in terms of physical movement, this very complex architecture is proven astoundingly simple. Each note in the left hand is essentially played *after* the one in the right hand (except for the moments when they coincide): *Punctus contra punctum*. Please remember here the notion of *inter-complexity* as opposed to *intra-complexity*: Situations which are complex on paper may be very simple in terms of interaction. The rhythmic structure of Andre's bar 1-5 is a good example of this distinction.

C. Intentionality Nodes

Inter-complexity increases, when we consider the further subdivision of the 13-tuplet in three different dynamic and articulation groups against a continuous diminuendo in the left hand. Since all these parameters are fusioned in singular ensemble of physical accelerations, it is logical to suppose that their correlation, the interaction between rhythm, dynamic and articulation, becomes visible in the gestural data.

How are structural and embodied features inter-related, when the ensemble of musical parameters must be taken into account? What sort of model could describe this interaction? To this purpose, we have developed the notion of *intentionality nodes*, as the points of crossing of several parametrical layers, as displayed in the next illustration (Figure 115). We have annotated the following parameters:

Simultaneous attacks of the hands (red frames), eighth beat (brown beams), finger-layer as decimals of the pulse (decimals under each note), modulations of articulation (orange square) and dynamics (green crescendo and diminuendo symbols), modulations of speed (nested tuplets, blue signs), all that with the same symbols for both the symbolic score and for the multimodal representation (audio and gesture).

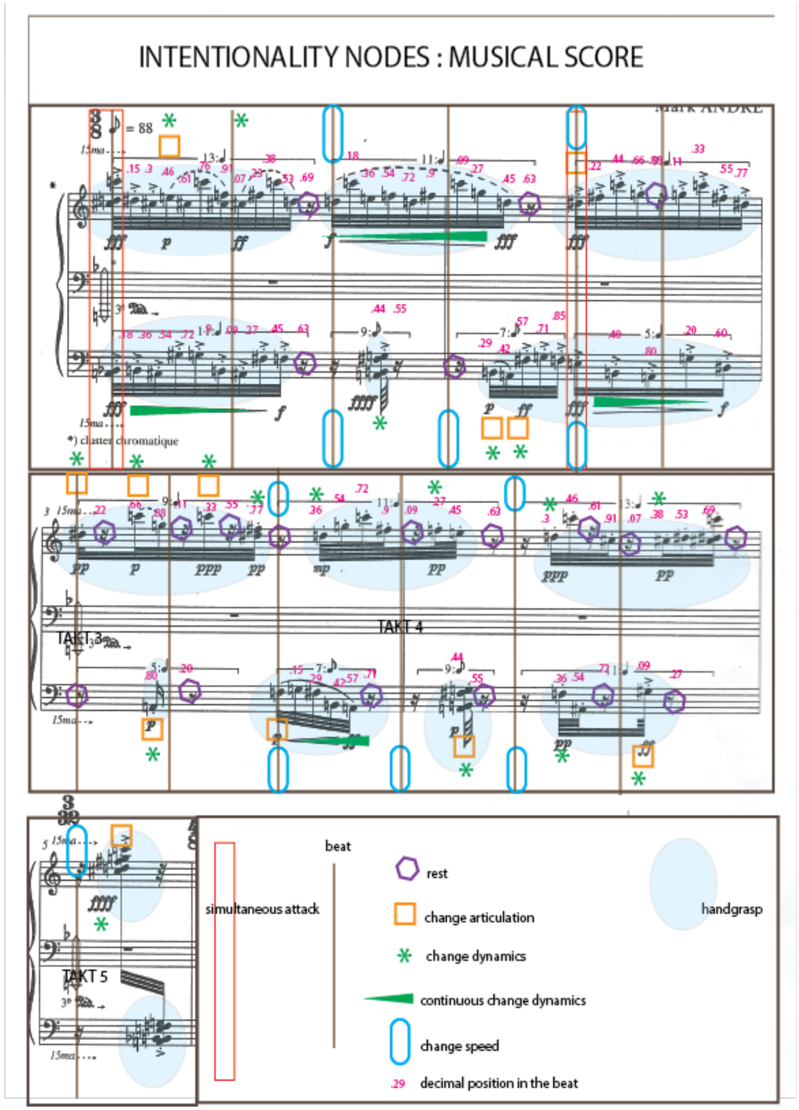
Please note how simple and ergonomic is the correspondence of figures to the grasp layer (blue ellipses) but at the same time how complex is the articulation of the finger-layer through the alternation of all parameters, which invites a navigational model of embodied interaction. Note also the decoupling between the amplitude of sound and the amplitude of gestures, which becomes indicative of articulation. For example, in bar 4, the discontinuity of the staccato in the right hand does not correspond to the soft dynamic of the music (high amplitude in the gesture, low amplitude in the sound).

The complex structural relations, which invite navigation on the part of the performer, become visible in the following figure (Figure 115).

Further work with interactive systems opens up the possibility of different prioritisations during the learning and the performance and the representation of sensorimotor learning. One communicates with the composer through corporeal articulations and not simply symbols, in an analogy to Leman's model of corporeal articulation between performers and audiences. The embodiment of the symbols is navigational and explorative.

In the following video, you may see a scenario of navigation of *Contrapunctus*' intentionality nodes, pertaining to the third dimension of learning, that of resistance and refinement. Two video views are provided: One from above (kinect video, until 2'36") and one from the right-hand side (2'36" until the end). You may notice the insistence on certain fingers and relations, towards the sculpting of the final albeit provisional sonic result. The score of intentionality nodes is also provided in the video.

https://www.youtube.com/watch?v=SRZO0sJZzgY , accessed 01.05.2018


INTENTIONALITY NODES : MUSICAL SCORE
TAKT 3
TAKT 4
TAKT 5
*) cluster chromatique
simultaneous attack
beat
rest
change articulation
change dynamics
continuous change dynamics
change speed
.29 decimal position in the beat
handgrasp

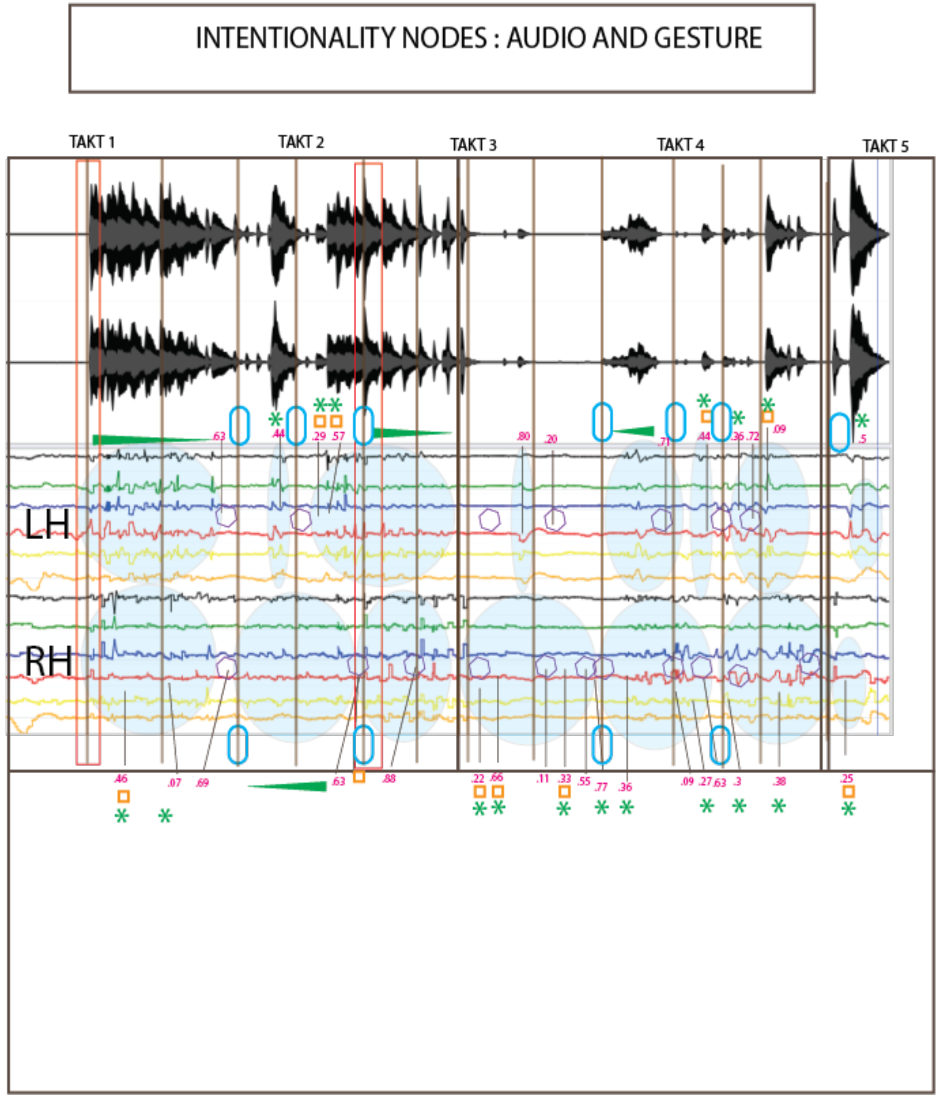

INTENTIONALITY NODES : AUDIO AND GESTURE
TAKT 1
TAKT 2
TAKT 3
TAKT 4
TAKT 5
LH
RH

Figure 115: Intentionality nodes in *Contrapunctus*, indicated on notation (left) and data (right) for bars 1-5. Each note is the convergence point of multiple parametrical layers, which are indicated in different colors.

3.3 Conclusion

We proposed the interpretation of the notion of *in-between spaces* through the model of embodied navigation in Mark Andre's *Contrapunctus*. The interaction of rhythm, articulation and dynamic on the micro-level of fingers and grasps, but also the global structures, participate in the dramatic pacing of the piece. At all levels of the musical form, embodiment plays a definitive role. The conclusion from the comparison of data to score opens the possibility for different focal points and can be controlled interactively through the sensor environment *GesTCom*. This offers an example of mediation between symbolic signification, action-oriented descriptors and physical energy.

4. Physical Theatre Emerging From Notational Complexity: Wieland Hoban's When The Panting STARTS, For Solo Piano

4.1 Introduction

Wieland Hoban[412]'s *when the panting STARTS* for solo piano is the third case-study of this dissertation. It merges the first and third axes, notation and performativity, of complexity embodied. Notational complexity is conceived as an overlayering of independent actions on the keyboard and the pedals of the instrument. The actions themselves are often unidiomatic, non-ergonomic and physically extreme. Their defamiliarizing effect is further enhanced by their coarticulation in mostly conflicting ways, so that both their aural and visual outcome is indeterminate. Such deconstruction of the performer's reflexes to complex notation generates a form of physical theatre, and far from incidentally: The title of the piece makes explicit reference to a motif in Samuel Backett's *How it is*[413], the recurring phrase "when the panting stops". The piece was composed during 2002-2004 for the British pianist Ian Pace, who premiered it at Transit Festival, Leuven, on 23.10.2004.

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[412] "Wieland Hoban was born in London in 1978. He began studying music and German at the University of Bristol, then studied composition at the Frankfurt Academy of Music and Performing Arts with Isabel Mundry, Hans Zender and Gerhard Müller-Hornbach. He has won various German composition prizes. In addition to his work as a composer he is also a freelance translator, primarily of writings in the fields of music and philosophy, including several books by Theodor W. Adorno and Peter Sloterdijk, as well as numerous essays for collections and journals; he has also published musical analyses and other theoretical texts. He has been a regular interpreter at the Darmstadt International Summer Course for New Music since 2000 and the Donaueschingen Music Days since 2011.", in https://wielandhoban.wordpress.com/, accessed 04.03.201

[413] Samuel Beckett, *How it is*, ed. by Edouard Magessa O'Reily, Faber & Faber, London, 1994 ; first edition in French, *Comment c'est*, Les Editions de Minuit, Paris, 1961

In what follows, we explore the composer's intentions, as conveyed in performance and programme notes; we look closer at the techniques employed, individually and in juxtaposition; we trace their dynamic transformation in the piece's dramaturgy; and we explore the link between notation and its multimodal content, both in studio recordings of my learning process and in different concert performances. The objectives here are: First, to affirm the inadequacy of abstract comprehension in tackling the challenges, as opposed to the embodied navigation of notational affordances; second, to show how the embodied navigation paradigm and multimodal recordings contribute to the performance of this uniquely challenging work.

4.2 The Composer's Intention

A. Background

Wieland Hoban is a British-German composer, whose output constantly engages with questions of embodied interaction and notational complexity. He formulates this engagement as follows:

"In his music, Wieland Hoban strives to create a multi-layered discourse and experience. He examines questions of context and re-contextualisation, of flow and stasis, and looks for ways to find differentiations between parameters and states in all aspects of the music. A central principle in this music is that differentiation requires many different conditions: complexity results not from surface density alone, but from probing different levels of density; timbral diversity comes not from focusing purely on extended playing techniques, but from exploring different modifications and negations of playing technique, focusing on individual parameters. Fixed structure and freedom, similarly, are in a dialectical relationship; neither state is considered desirable on its own, and the discourse results from the interplay between them. Though occasionally incorporating ideas from other arts or extra-musical areas, Hoban's aim is to create a music whose qualities of flux, differentiation and self-reflection mirror and express the nature of consciousness itself."[414]

Hoban's preoccupation with multiple layers of parametrically constructed musical states in constant dialectic interaction, as an act of self-reflexivity, echoes the central themes treated by *New Complexity* figures, such as : Brian Ferneyhough, whose idiosyncratic *somatics* we explored in the first part ; or Claus-Steffen Mahnkopf's

[414] In https://wielandhoban.wordpress.com/bio/ , accessed 20.04.2018

Komplexismus, also cited in our opening definitions of complexity A more particular affinity of interests is shared between Hoban and Franklin Cox. They both work with parametrical polyphony of decoupled actions on string instruments and their representation through tablature writing, as in Figure 116. This affinity is vividly demonstrated in Hoban's own analysis of his cello piece *Bakensammler*[415] or Cox's cello piece *Recoil*[416] (Figure 116), whereby scales of embodied parameters reflect different degrees of clarity and distortion, in the attempt to structure fragile and indeterminate sound results. We remind here Cox's important assertion, that such techniques

"open the possibility of a new sort of 'embodied' thinking transcending means/ends oriented training (for example, of traditional virtuosity) [….] and value that which is so consistently denigrated in Western philosophy-the physical body and physical motion- without fetishizing the physical domains in expense of the mental/ideal".[417]

The indisputable pioneer behind such techniques is Klaus K. Hübler, whose reformulation of string technique[418] through parametrical decoupling has already been analysed in a dedicated chapter (part one, 2.2.h)

[415] Wieland Hoban, "Towards the Semantification of Instrumental Technique", in Claus-Steffen Mahnkopf, Frank Cox, and Wolfram Schurig, eds., *Polyphony & Complexity*, Hofheim: Wolke Verlag, 2002, pp.223-232

[416] Cox, 2002, pp. 120-121

[417] Cox, 2002, p. 129

[418] Klaus K. Hübler, "Expanding String Technique", in Claus-Steffen Mahnkopf, Frank Cox and Wolfram Schurig, eds.: *Polyphony and Complexity, New Music and Aesthetics in the 21st Century*, i. Hofheim: Wolke Verlag, pp. 233-244.

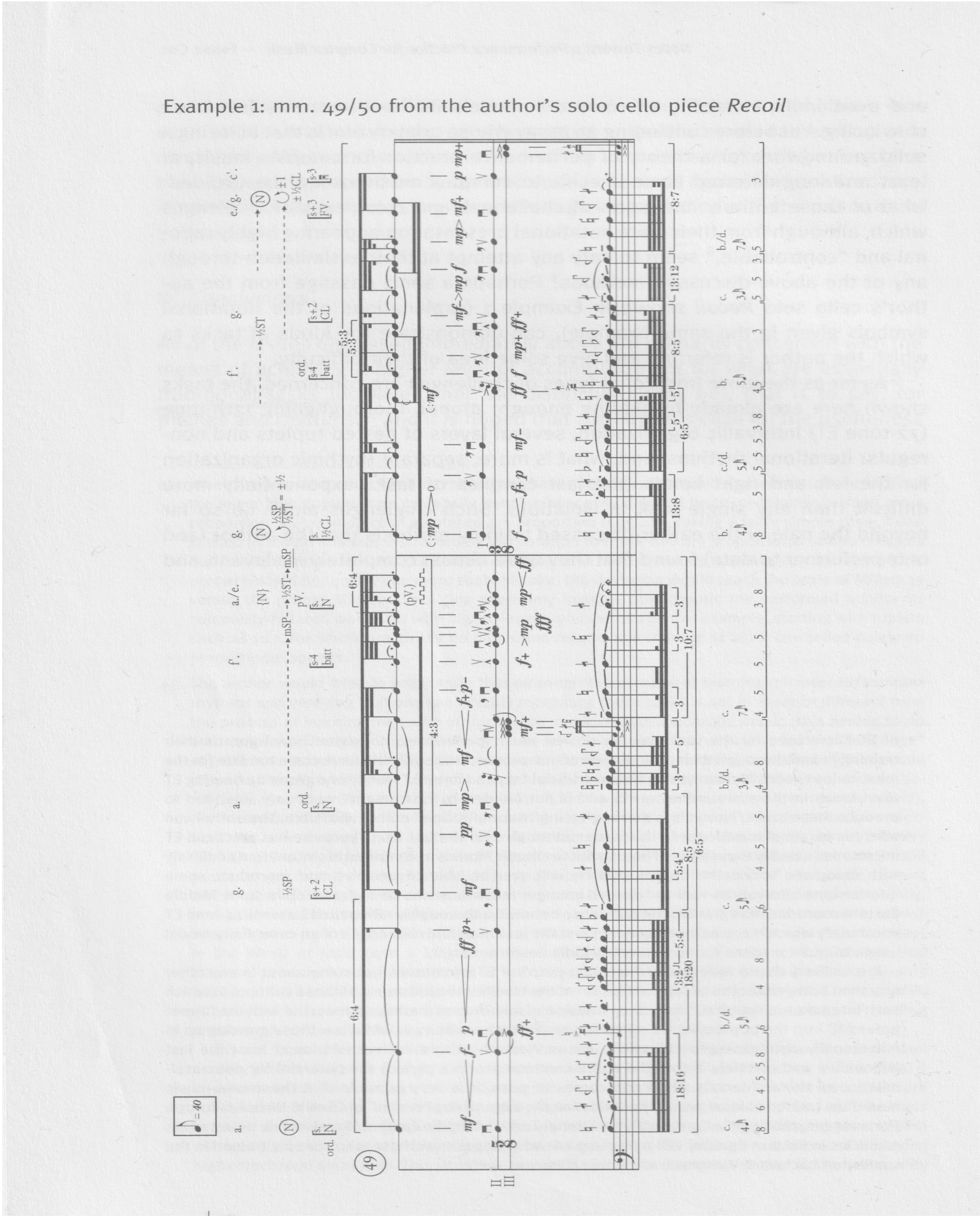

Figure 116: Franklin Cox, excerpt from the cello piece *Recoil*. The lower staff and indications below it apply to the left hand, whereas the middle line(s), upper staff and all indications above it apply to the right hand. Reprinted with kind permission by the author and editor. Originally in Cox, 2002, p. 120

B. A Beckettian Tablature

when the panting STARTS is an explicit attempt for the transfer of tablature notations indicating independent actions from the realm of string technique to that of piano playing. The deconstruction of physical reflexes takes here the simple but powerful form of writing for ten fingers rather than two hands. Each finger represents an instrument or voice in an ensemble :

"The technical aspect of writing separately for the pianist's ten fingers, as an ensemble rather than a unity [..], while imposing bizarre restrictions on the music's fabric, revealed otherwise inaccessible possibilities. This decision was inspired by the playing of Ian Pace, in which the precision and sensitivity of action and touch suggest precisely this: ten fingers rather than two hands."[419]

The privileging of each individual finger as the main carrier of meaningful musical information is reflected in the use of 10 plus 3 staves (one for each finger and pedal) for the notation. Another two staves are added later in the piece, to represent further actions. As specified in the following performance note, the notational decoupling of the finger from considerations of natural coarticulation and ergonomics serves well the eruption into physical theatre, in not always controllable ways :

"when the panting STARTS involves a notation that assigns an individual stave to each finger and each pedal. In some cases, the specification of fingering may appear superfluous, or even inappropriate. It must be borne in mind, however, that –beyond all contrapunctal requirements, which would often be impossible to meet without the notated fingering- certain fingerings have been chosen in order *to influence the actions* required to play the corresponding passages, in some cases very audibly, in others primarily physically / visually. Trills between fingers 4 and 5, for example, are intended to exploit the awkwardness of this action, and should always be played as fast as POSSIBLE, not as fast as can be rendered fluently ; the movement should be *faster than controllable*. Equally, there are passages where the fingers *interfere* with each other by striking the same keys almost simultaneously, or *crossing* each other in such a way as to interfere considerably with the respective rhtyhms / figures. The resulting entaglement is vital to performance. NO attempt should be made while learning the piece to achieve true fluency of execution in such passages, or to play the aforementioned trills as perfectly as conventionally-figured ones. Either practice has to be limited accordingly, or the speed of trills must be increased beyond what is digitally feasible. In other cases, illogical fingerings are specified without any such reason; here, they serve the preservation of a particular hand-position, which should remain fixed as long as the notation suggests ; while this can sometimes be justified in practical terms within the larger context of a passage's textures and fingerings, it sometimes serves a purely physical / visual purpose, underlining the *frozen or*

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[419] Wieland Hoban, programme note for the author's performance at SARC, Queen's Universcity Belfast, January 2018

mechanical state associated with the work's character and many of its restraints. From bar 321 until the end, the notation is modified somewhat. Below the staves for the right hand fingers, there is one marked 'all fingers' and one marked 'heel' ; the former contains rhythms for simultaneous attacks with all right-hand fingers, superimposed upon their individual rhythms is the staves above. The latter indicates rhythms for the white-key clusters played with the heel of the hand, as present throughout the work. Below these staves are those for all three pedals, rather than only the left and the right. While the tempo and the rhythms of all parts in this final section at times exceed feasibility, the pianist should attempt to keep up with them at all costs, sooner sacrificing attacks than lowering the tempo. The tempo here, and also all grace notes repetitions, *could be taken as faster than possible*. In the final moments of the piece, the sound of the pedals must drown out that of the keys ; depending on the instrument, the respective diminuendo and crescendo of the hands and the feet should be calibrated accordingly. It is vital to the ending's expressive character that the pedals are intensely noisy, not giving the impression of a pitchless residue, a skeletal trace left over after the fingers' withdrawal, but rather of an overpowering and transcedence of the finger / key / pitch dimension. *when the panting STARTS* requires a slight preparation of the undamped upper register of the piano. Blu-tak or a similar light adhesive gum should be attached to the bridges in such a manner as to ensure no loss of pitch content, but rather a tone as close as possible to that of the other strings."[420] (my italics)

Intentionally impossible actions, finger entaglement, hand fixation, overlayering of actions with the addition of more staves, loss of control, the Schumannian "faster than possible" mentality and the dramatic overpowering of the hands by the feet, are just some of the techniques in Hoban's list. While learning the piece, I have informally called them "voodoo piano techniques". Such techniques are intentionally alienating the pianist from the instrument and could even be harmful physically. Their result is a desperate virtuosity of failed attempts, without the gratification of improvement and with a bleak inevitable ending[421].

The composition of a Beckettian endgame for the piano on the basis of artificially imposed performance constraints is not irrelevant to the theatralization of musical acts and the objectification of the performer's body in quite a few post-war composers. These tendencies are actively questioning the theatrical conventions of Western Art Music concerts. Hoban's response offers though a somewhat inverse image:

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[420] Wieland Hoban, *when the panting STARTS*, unpublished score, Performance Notes, p.1-2

[421] The allusion to Beckett's well-known phrase "Ever tried. Ever failed. No matter. Try again. Fail better", from *Worstward Ho*, 1983, is here too obvious to miss.

“During the last few years, I have reached the conclusion that for me, a solo performance is implicitly an act of theatre. While a greater number of performers on stage can more readily allow the music to be the sole focus of attention (though their interaction can also be seen as a form of theatre), the situation of a soloist on stage strikes me as that of a protagonist involved in a monologue. This monologue can conform to the expectations of the context by adopting the meta-personal style of the genre, where the artificiality of the circumstances is passed over. Or it can thematicise this. The latter option has been explored in depth by such composers as Schnebel, Kagel, Holliger or Globokar; my interest, however, is in a purely musical formulation of this ideal. How can the work develop and convey a consciousness of its own artificiality and erode this to acquire an autonomous expression? How can the tension between acceptance and rejection of expressive norms become productive in an aesthetic and semantic sense? [….] If the piece can be said to have one overriding aesthetic aim, it is to transcend the negation of language – including its own – to reach a form of meta-language reconstructing the individual's search for meaning. [….] The title is a reference to Samuel Beckett's prose work *How It Is*. While that work's authorial voice begins its many attempts at narrative 'when the panting stops', i.e. once it has gathered its breath, it is precisely this state of speechlessness that constitutes the point of departure in *when the panting STARTS*.”[422]

Rather than bringing into attention the implicit theatrical nature of the performer’s monologue by extra-musical devices and actions, Hoban attempts to reveal it at the “molecular” level of music notation, by reformulating the basics of sound production on the keys and the pedals. Instead of extending the instrument or augmenting the performer’s acts into theatre, he attempts to elicit expressive out of effective gesture, questioning their very distinction. Thus, theatre is emergent rather than imposed, a physical theatre, to be sure, still structured as language, even though beyond panting, as the limit of speechlessness induced through physical constraints.

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[422] Wieland Hoban, programme note for the author’s performance at SARC, Queen’s Universcity Belfast, January 2018

In what follows, I will present in greater detail the dramatic evolution of this Beckettian piano tablature, in both traditional and multimodal representations; I will discuss the implications of Hoban's notation for direct perception and embodied navigation; and I will provide multimodal documentation of the preparation phase and video documentation of a live performance, offering a longitudinal study of its *ontogenesis* in performance.

4.3 Towards A Meta-Language Of Piano Technique

A. "Voodoo" Techniques

Hoban's employment of alienating and potentially dangerous ("voodoo") techniques follows a carefully planned dramaturgy leading to escalation. One of the "strange attractors" in their dynamic evolution is the constant attempt to escape a *frozen or mechanical state*[423]. This state is literally embodied in the form of static polyphonic passages, as the following in the opening section (bars 1-15):

https://www.youtube.com/watch?v=d2_Eca2UQiY accessed 29.04.2018
(0'00"-0'48")

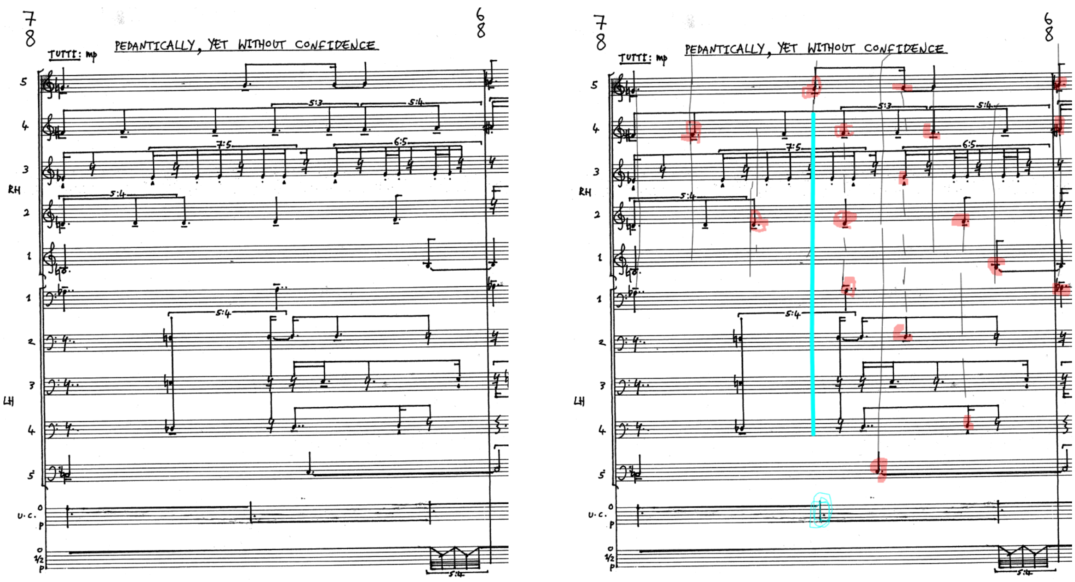


Figure 117: wtpS (when the panting STARTS) standard polyphony: "Frozen" hand position, different articulation for each finger, complex rhythms and percussive

423 Hoban's expression from the performance note cited above

pedaling, bars 1-3. Vertical lines stand for eighth-note beats, red noteheads indicate notes on the beat or in simple relations to it. Blue vertical lines indicated the onset of the *una corda* pedal. 0’11”-0’17” in the video above.

In Figure 117, a closely spaced chord is held for long, featuring inner movement in the form of individual fingers differentiated by means of rhythm and articulation and slow pitch-shifting. In my hand-written annotation (right side), vertical lines stand for eighth-note beats, red noteheads indicate notes on the beat or in simple relations to it. Blue vertical lines indicated the onset of the *una corda* pedal. The chord is further punctuated by right pedal rhythms, a material to be significantly developed later.

Other forms of punctuation, including *white-note clusters with the heel of the hand* (Figure 118) or *pedal vibrato* (a gesture foreshadowing a literal panting in gestural and sonic terms, Figure 119) leads to a first mobilization of the initial handgrasp (bars 16-31, Figure 120 showing bar 16, the whole passage lasts from 1’34”- 2’02” in the video). During this passage, the right hand plays arpeggios differentiated in rhythm, dynamics and articulations, over a static and punctuated background.

A real breakthrough from fixation arrives in b.32-33 (Figure 121, 2’03”-2’11” in the video), which features the first impossible overlayering of independent actions: The index fingers in both hands play solo melodies including one-finger *acciacaturas* – imagine a single finger playing a black and white key almost simultaneously in a *glissando* snap movement; the thumbs contribute a third line, featuring tremoli and more acciacaturas; while the outer fingers play punctuated chords and the heels of the palms contribute clusters. The simultaneous presentation of the actions is unstable, both in terms of repeatability of execution and subsequently in terms of sound result.

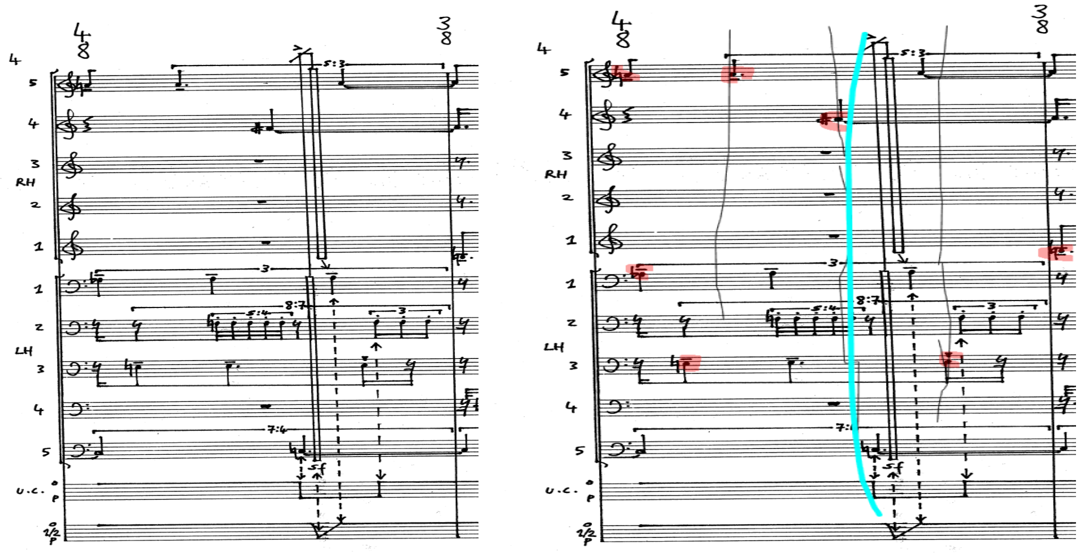


Figure 118: white-note cluster with the heel in both hands while stopping notes with the fingers, bar 4

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=52

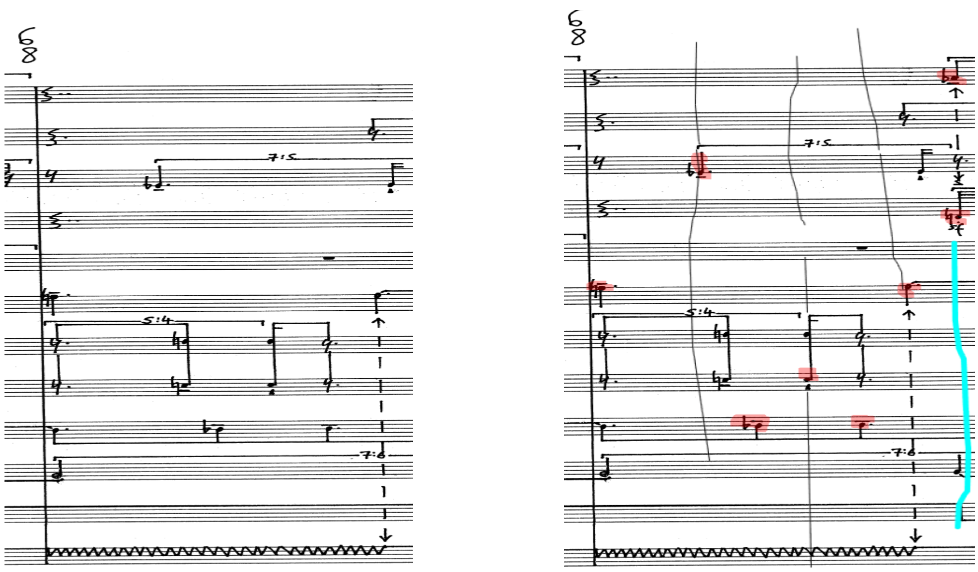


Figure 119: pedal vibrato, bar 11

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=68

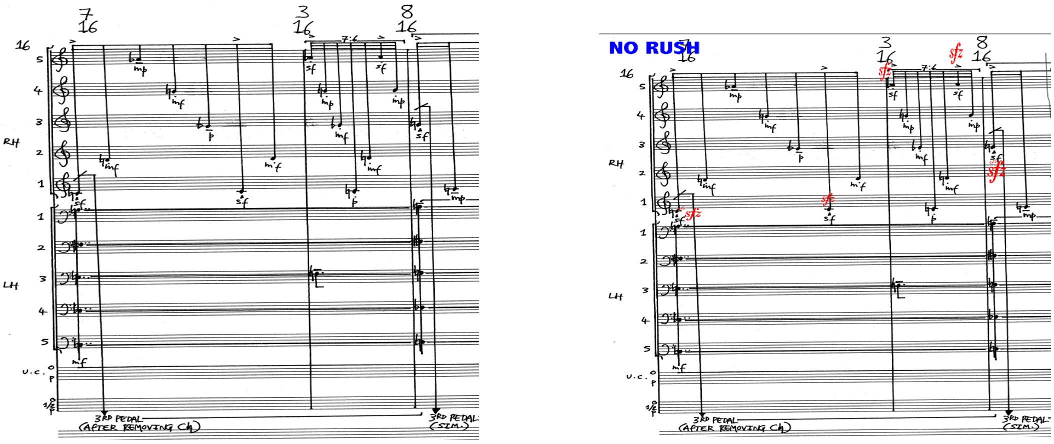


Figure 120: Mobilization with arpeggios and use of the sostenuto pedal for the left hand, bar 16

https://www.youtube.com/watch?v=d2 _Eca2UQiY&t=89

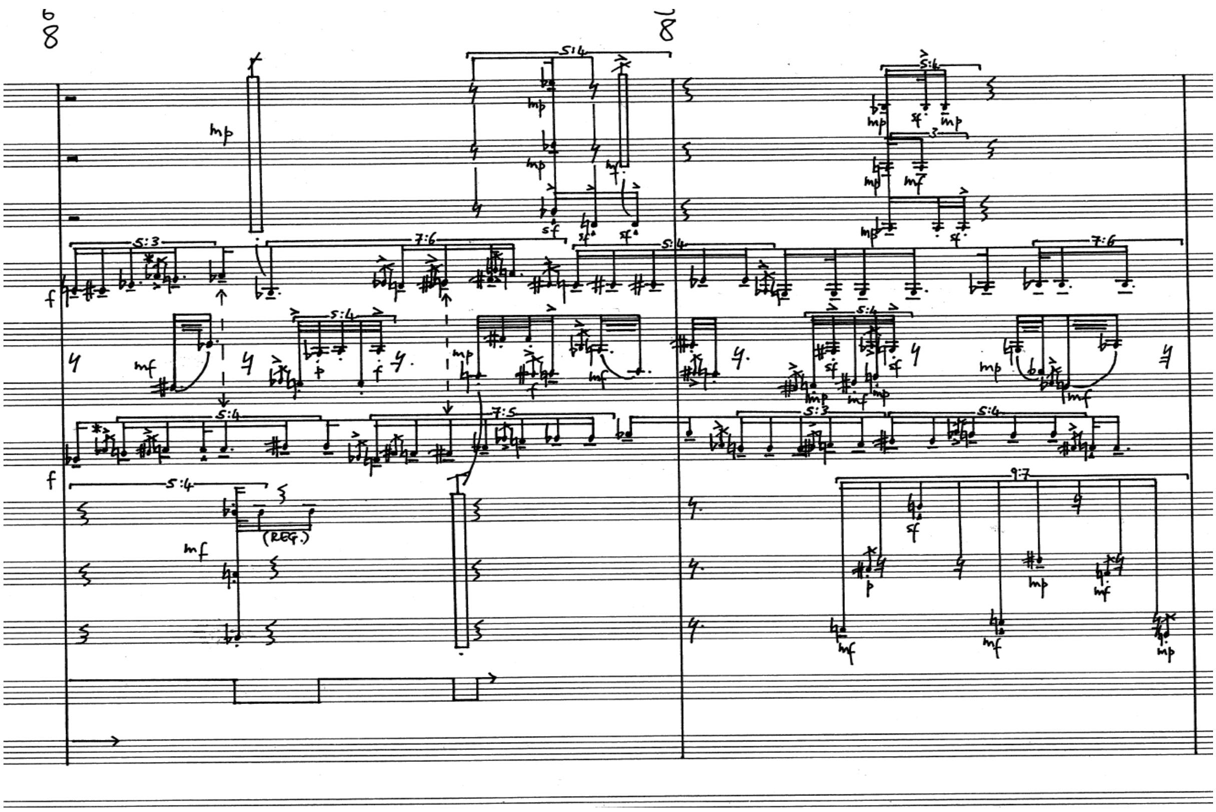
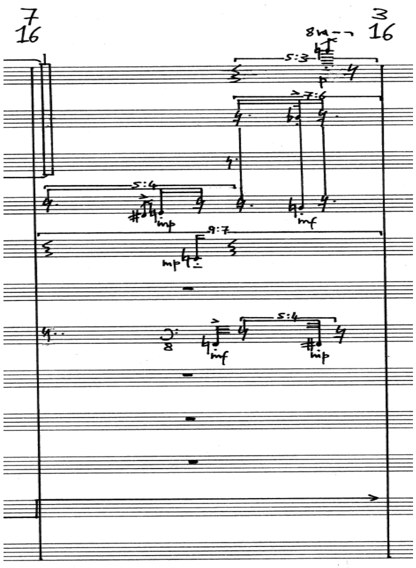


Figure 121: complex polyphony, including multiple one-finger melodies with acciacaturas, tremoli shared between the thumbs, heel clusters and chords

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=123, 2’03”-2’11”

The continuation of the piece as to unidiomatic techniques features the alteration of the previous two states, frozen and impossible polyphony, in variations and occasional dramatic attempts out of the stagnation of fixed hand positions -for example, in a blues-like upward leap or a heavy chord passage with pointillistic acciacaturas:



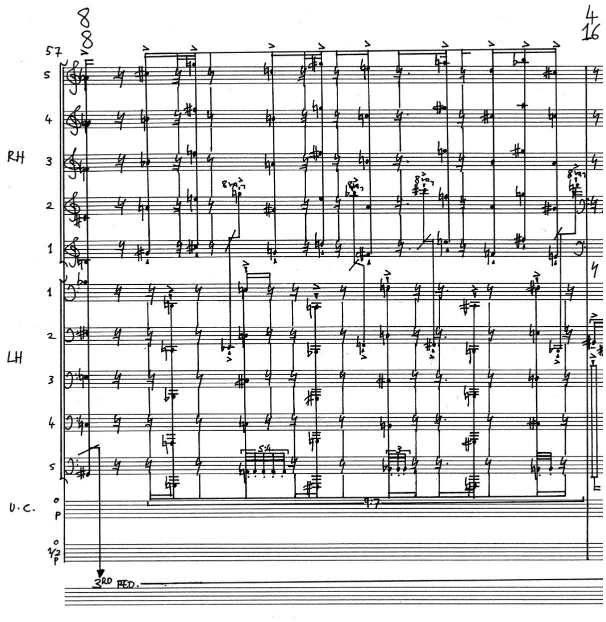


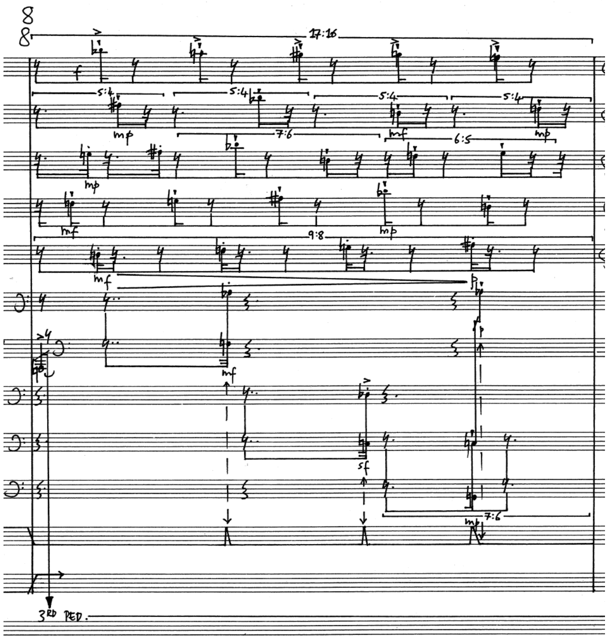
Figure 122 (left): blues-like attempt to break out of a frozen state, bar 35,

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=151 (2’31”-2’35”)

Figure 123 (right): block chords with pointillistic acciacaturas,

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=215 (3’36”-3’45”)

The next breakthrough arrives in bar 84, with non-sensical finger entanglements, right before a -by now typical- bar of right hand impossible coarticulation of three independent layers (Figure 119-120):



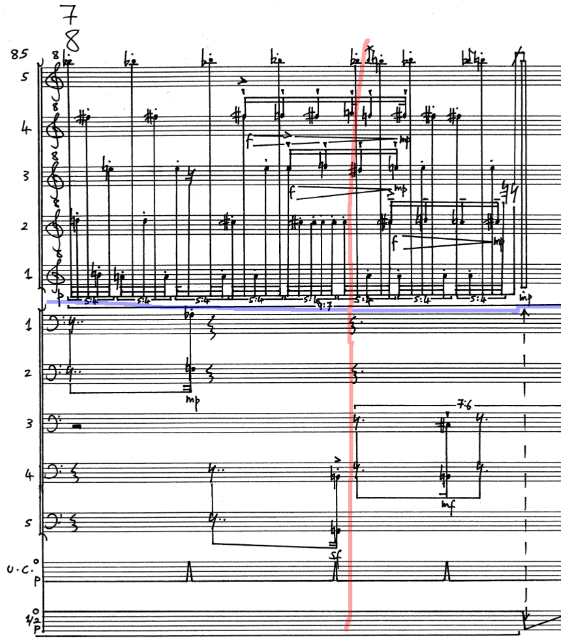


Figure 124 (left): Non-sensical finger entaglement in the right-hand, bar 84
https://www.youtube.com/watch?v=d2_Eca2UQiY&t=307 , 5’08”-5’14”
Figure 125 (right): Impossible polyphony, bar 85
https://www.youtube.com/watch?v=d2_Eca2UQiY&t=316 , 5’16”-5’19”

In bar 123, a new impossible action is introduced. It is the first evocation of what Hoban characterized in the performance note as the “awkward” trills with fingers five and four, not to be practiced or smoothened out but rather to be played in a jerky, desperate way, as fast as possible (Figure 126):

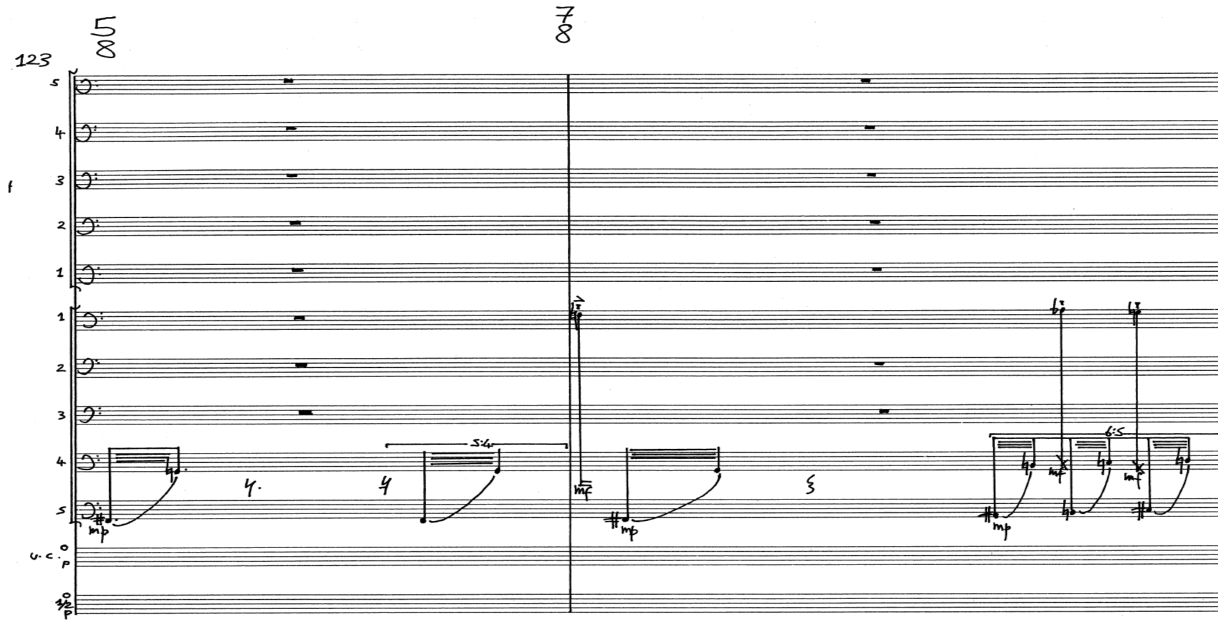


Figure 126: trills 4-5, bar 123

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=420 , 7’00”-7’06”

This passage, as well as the following passage (Figure 127) of irregular, even if much more feasible, tremoli, leads to the “emotional centre” of the piece, the iteration of the melodic motif over a trill at the lowest region of the instrument (Figure 128, bars 137-151). Not incidentally, this moment marks the middle of the piece and the beginning of an at large developmental section, until the finale, with the introduction of additional staves for slapping clusters on the right hand and violent pedal attacks, eventually overtaking the sound on the strings. The finale summarizes and culminates the notion of decoupled independent layers of actions.

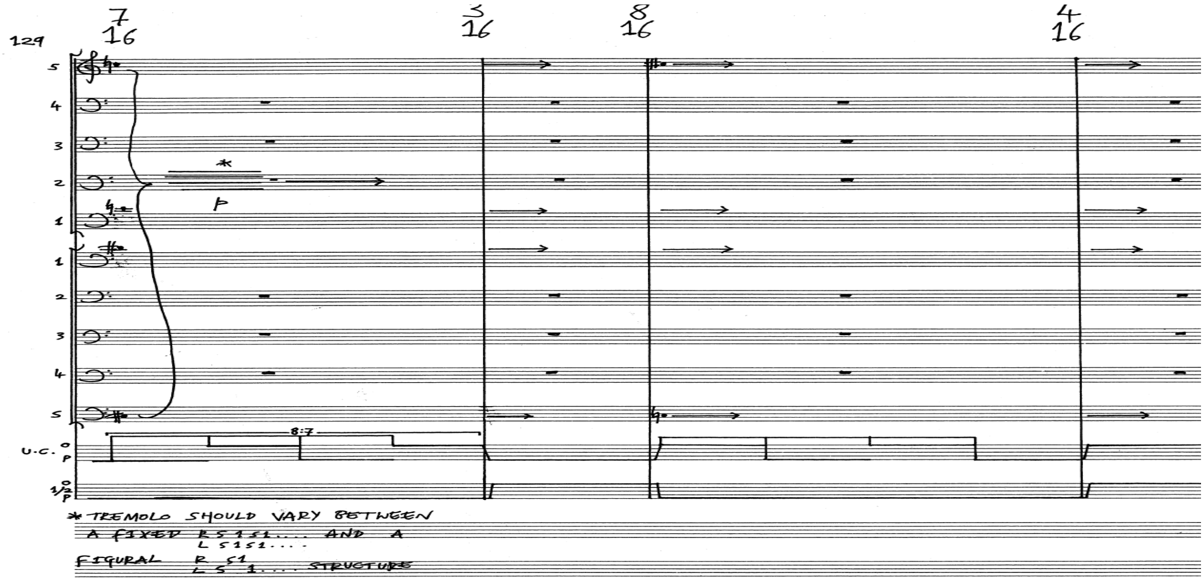


Figure 127: Variable tremoli, bar 129

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=436 , 7’16”-7’38”

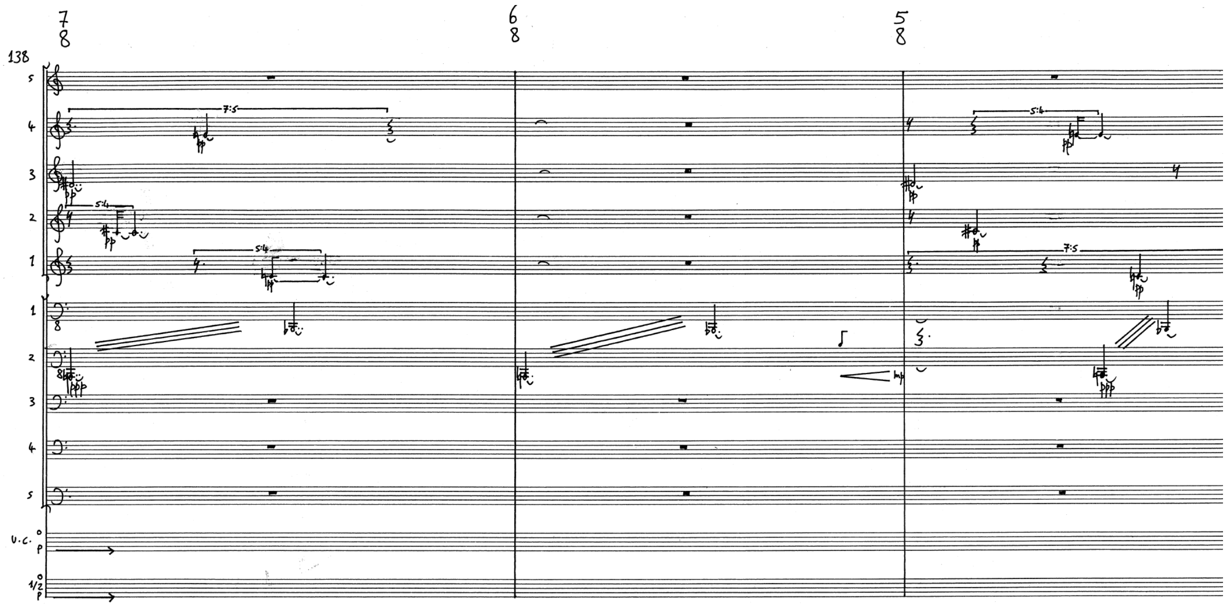


Figure 128: melodic motif over a low trill, bar 138

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=459 , 7’40”-8’32”

A few special moments in this development: Fast double “panting” pedal tremoli, white cluster tremoli, multiple (painful) acciacaturas (Figure 129, bars 155-165, 8’52”-9’00”);

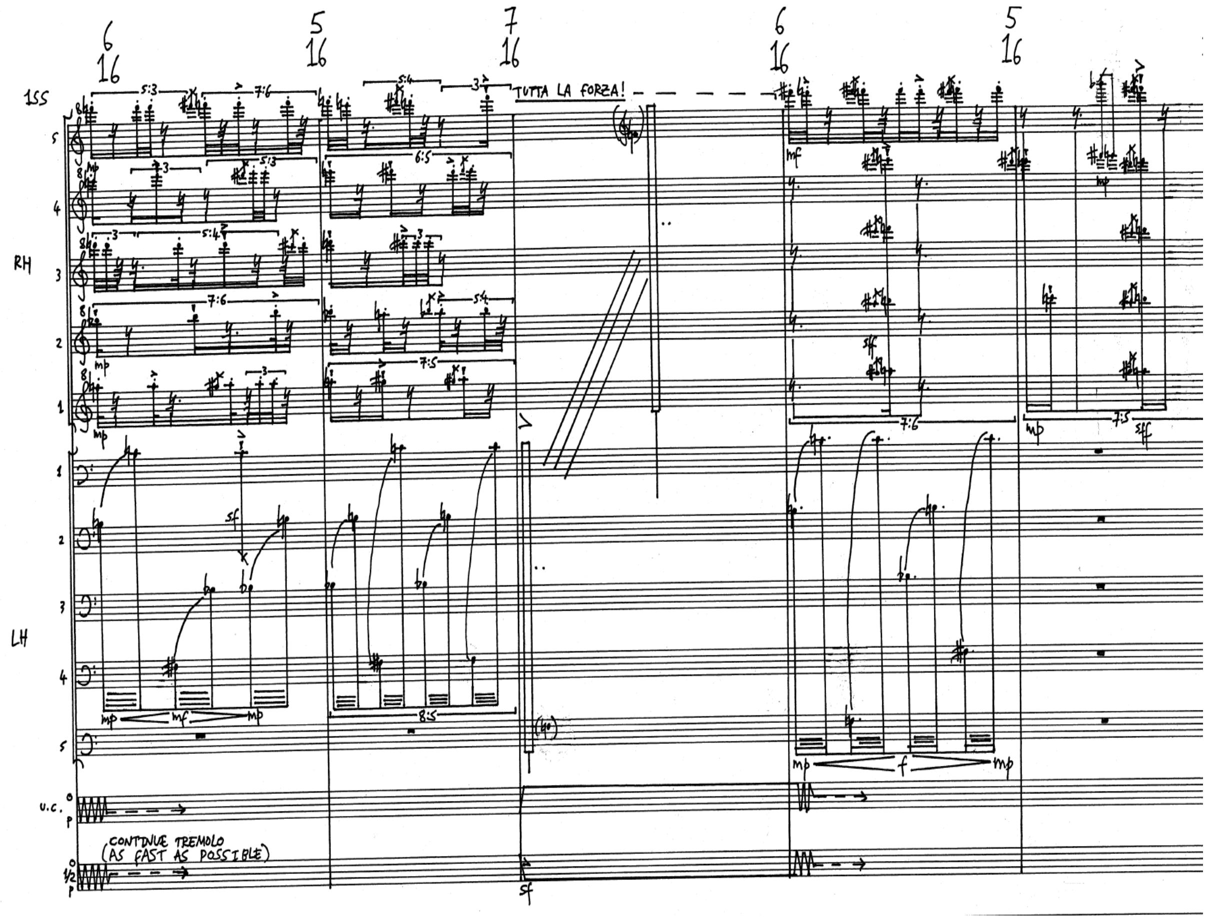


Figure 129: Double pedal tremolo, white-cluster tremoli, multiple acciacaturas, bars 155-165, 155-159

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=531 , 8’52”-9’00”

Alternating fingers in a single trill (Figure 130):

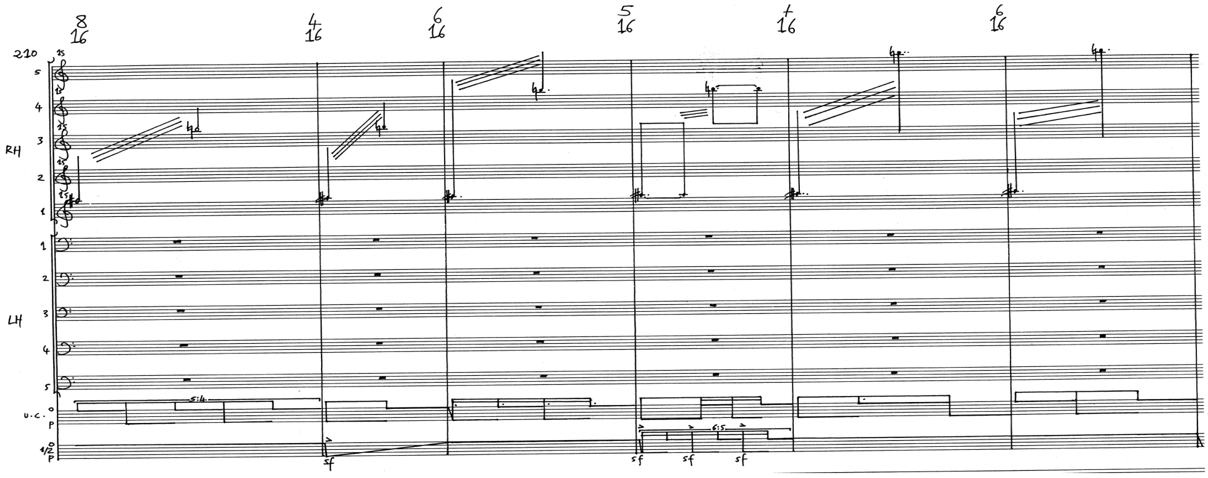


Figure 130: Trills with alternating fingers, bar 205-222, here 210-216

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=662 ,11’02”-11’34”

and what Hoban terms the “chicken dance” (bars 223-240, 11’34”-12’02”): a passage, whereby the pianist is constantly playing micromelodies of 4-5 trills in both hands, while simultaneously rotating the hand outwards around the axis of the trill, in order to play with the thumb notes that are higher (lower for the left hand) than the trill. In the annotation below (Figure 131), in purple circles the twisted notes. The necessary outward contortion of the elbow at the moment of the thumb crossing under the fingers four and five lends to this technique its sensational name.

Further cases of very uncomfortable finger entanglement (bars 295-306, 15’39”-16’00”) and a fantastic polyphonic passage (bars 317-320) leading to the grand finale of the piece. As already underlined, the addition of more staves for the right hand serves the addition of more layers of independent actions in the form of white and black clusters that interfere with the finger actions. The increasing activity of the feet, in the form of snap attacks, overtakes the string sound (bars 321-330, 16’55”-17’24”)

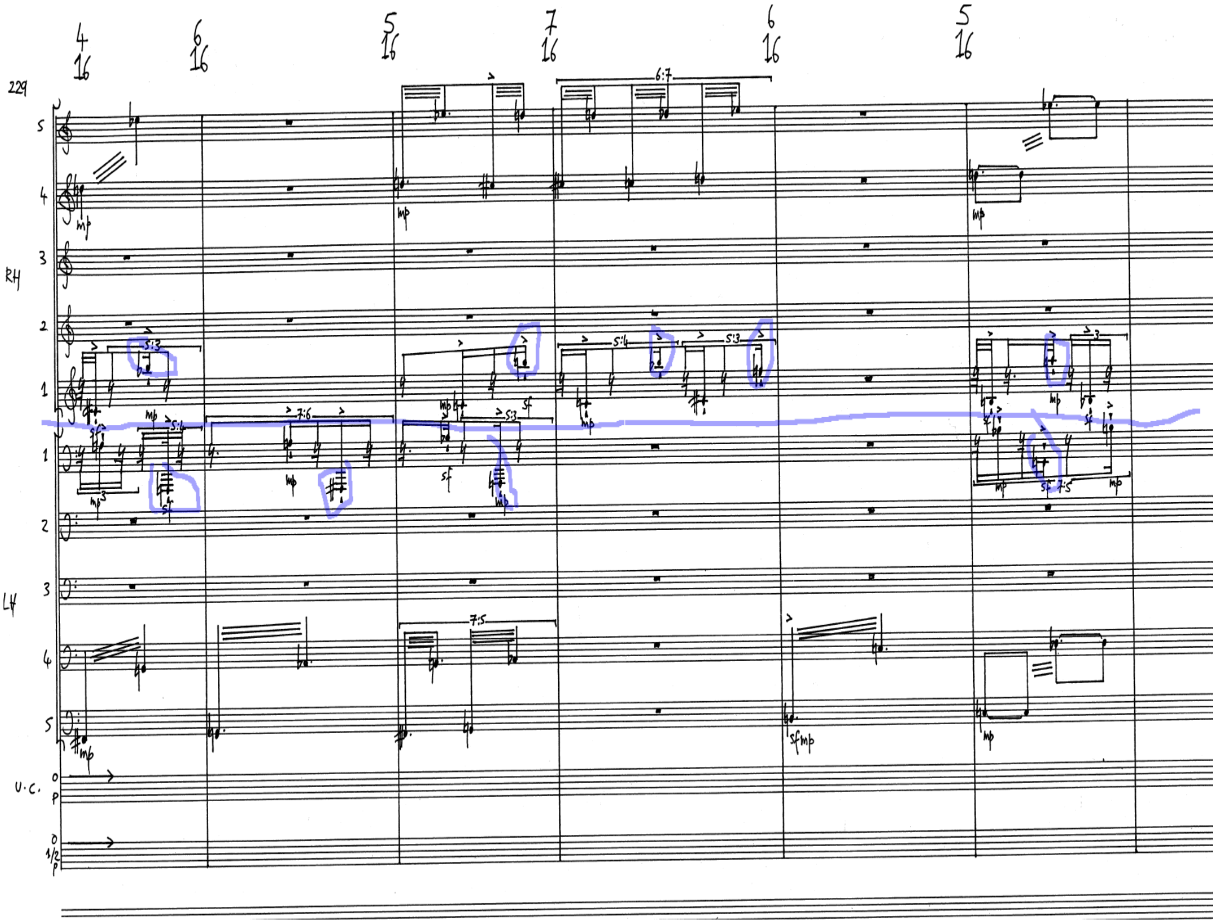


Figure 131: The "chicken dance", bars 223-240, here 221-226

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=692 11’34”-12’02”

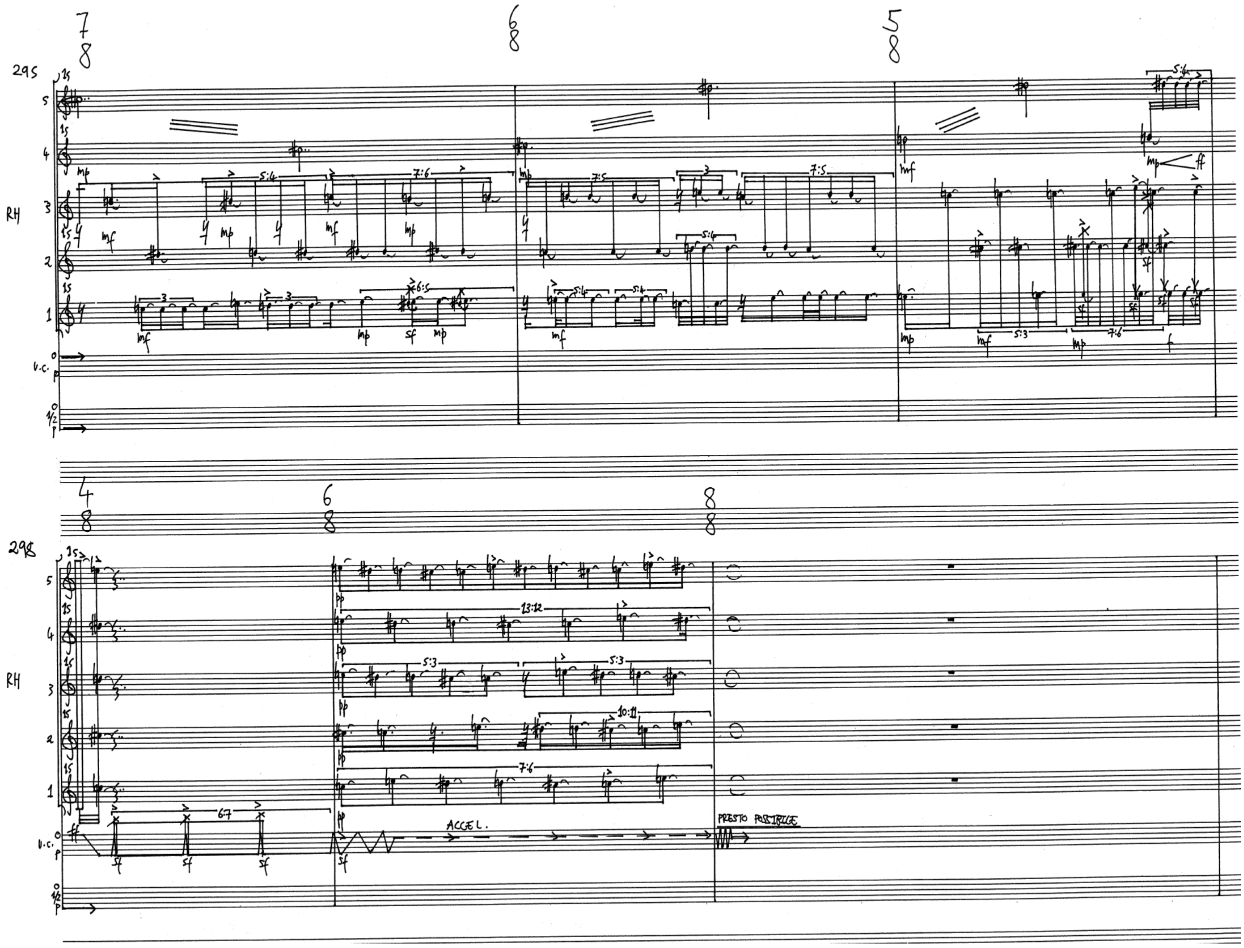


Figure 132: Finger entaglement in the right hand, contorted and fixed elbow position, bars 295-306, here 295-299

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=938 , 15’39”-16’00”

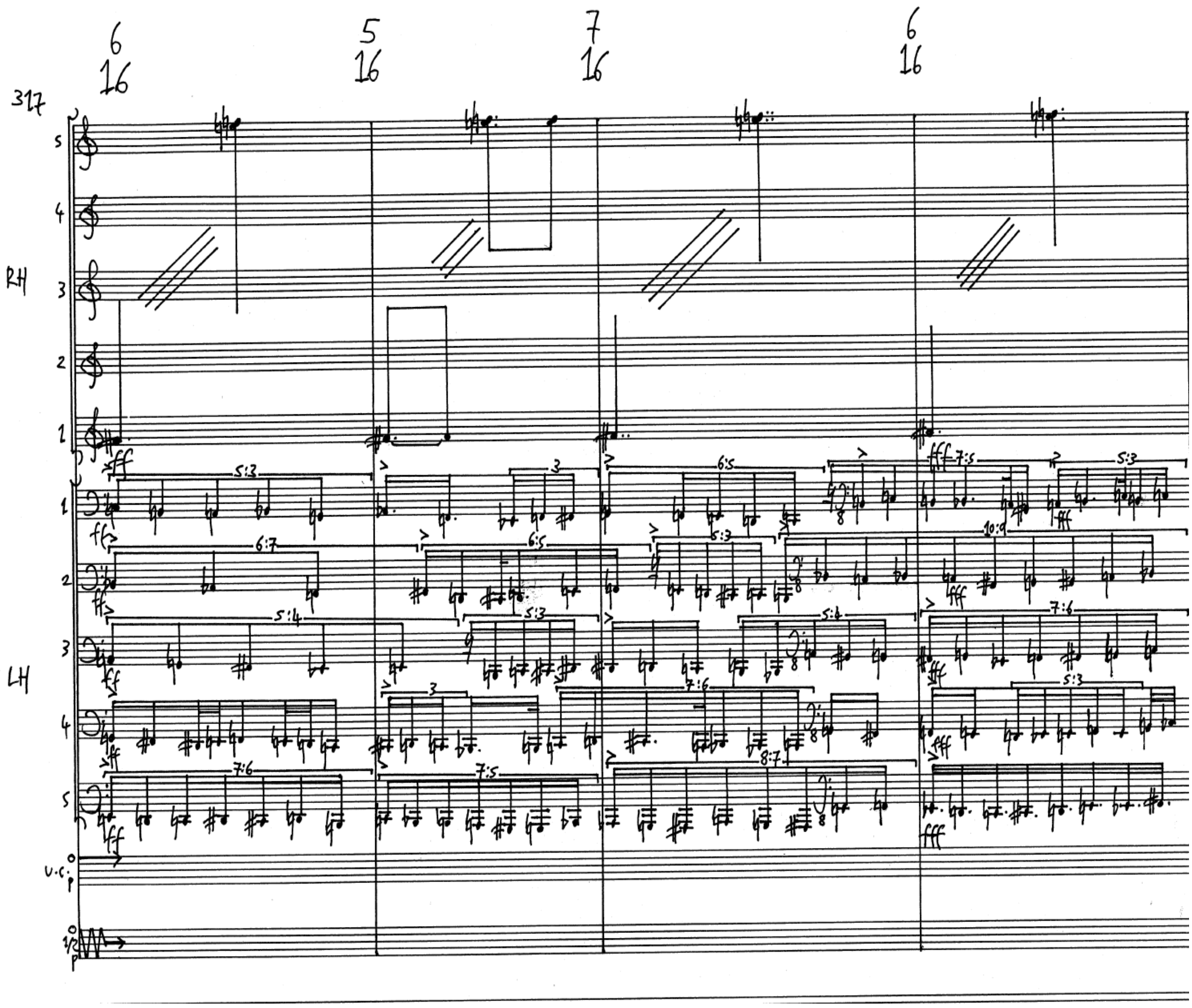


Figure 133: Left hand polyphonic cadenza before the finale, bars 317-320

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=1006 16’48”-16’55”

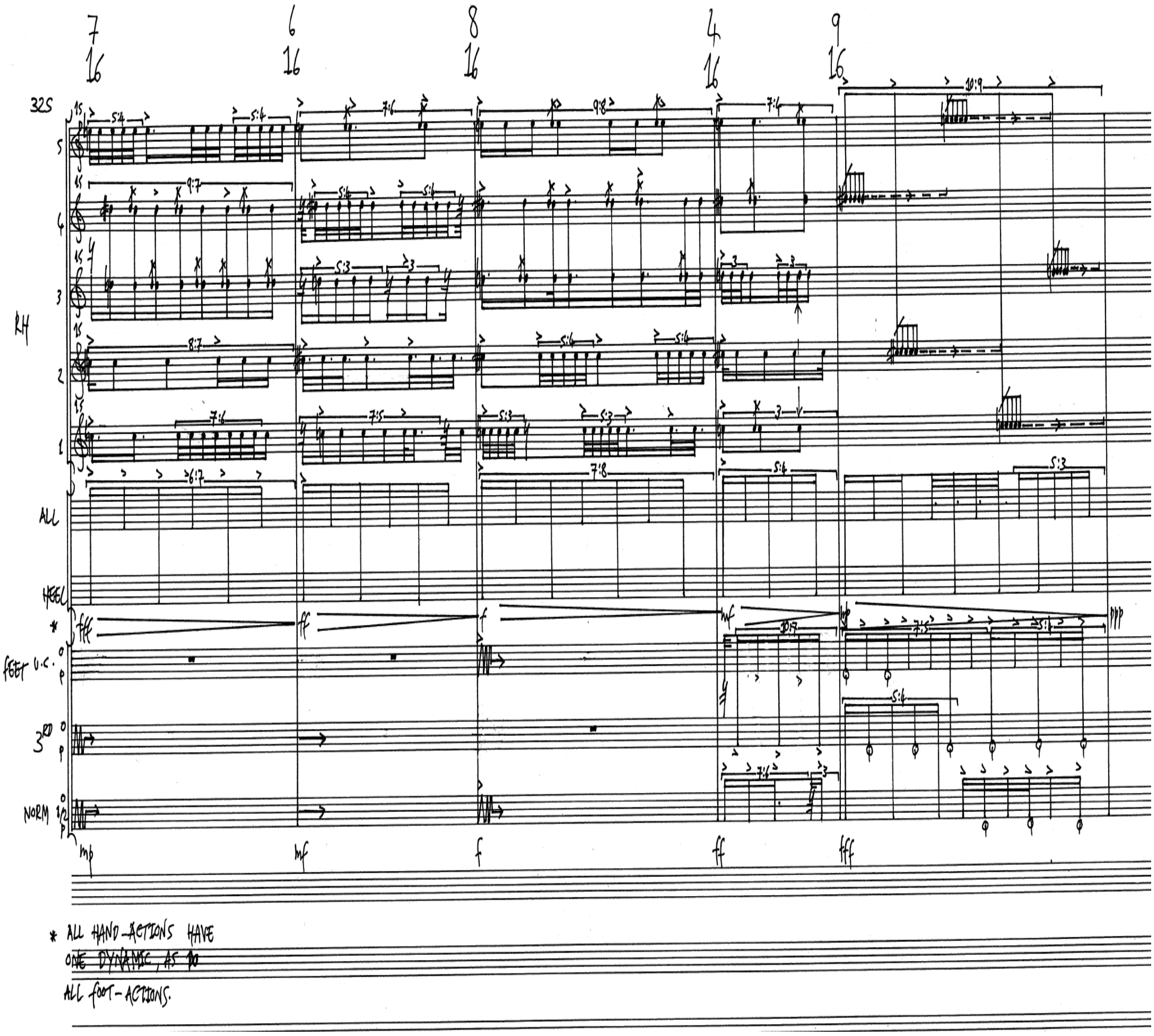


Figure 134: Finale. Note the addition for two staves in the right hand (“all”, “heel”), the counter-intuitive decrescendo of the right hand over the double tremolo of the pedals and the overwhelming pedal snap actions of bar 326, at which point the piano sound must be drown, bars 321-330, here 325-329

https://www.youtube.com/watch?v=d2_Eca2UQiY&t=1014 , 16’55”-17’24”

Here is also a comprehensive list of all the techniques:

- Frozen state
- One-finger acciacaturas
- Pedal tremolo
- Overlayered actions

- White-note heel clusters
- Finger entaglements
- Impossible trills
- Hand rotation and elbow contortion (chicken dance)
- Slapping actions on the keys and snap effects on the pedals

Concluding: Wieland Hoban achieves a dramatic discursive form through the employment of unstable and fragile actions, both in themselves and even more in their unpredictable and highly personalized interactions. The expressive power of the work is elicited not only from the surface effects of these highly alienating actions, but even more importantly through their coarticulation in space as overlayering and in time as causality and eventually meaning, a form of language after the end of language itself.

B. Embodied Navigation And Interactive Systems

In terms of embodied navigation, Hoban's tablature notation should be assumed to render the finger-layer transparent, by assigning a staff to each finger and reserving the two bottom staves for the pedals. Such layout makes indeed palpable the composer's analogy to "an ensemble for ten fingers", allowing for a maximum of parametrical differentiation of each individual finger. In terms of readability though, it sabotages direct perception, especially in passages where the same hand position is not retained. The reflex of relating sparse notational information into coarticulated discursive wholes and of assembling topokinetic into morphokinetic properties is confused, due to the spread of the staves over the whole page and the necessitation of diagonal reading. As shown in my annotation, complex rhythm in itself requires a good amount of deciphering, which accentuates the (by default) pronounced topokinetic properties.

In the case of independent action polyphony, my primary personal reflex was to restore the direct perception of handgrasps and eventually arm trajectories, often with extensive score annotation and automatic rewriting, rather than try to mentally simulate the compositional stratification, by, for example, learning the individual voices. Since each of these actions is inevitably going to affect the rest, an initial strategy based on muscular interdependence and restoration of the coarticulative unity allowed me to later strive towards a maximum of individual differentiation. In this respect, Hoban's polyphony did not elicit an approach much different than the usual top-down one, despite its idiosyncratic notation and aesthetic targeting.

The fragility of impossible iterative actions, such as the 4-5 trills and the "chicken dance", equally activated reflexes towards topokinetic learning and securing morphokinetic trajectories, before allowing for the actual attempt of an inevitably unstable performance. Considerations of macrostructural properties and of an initial grasping of the global aspects allowed for rapid readings towards establishing the morphokinetic properties with air-gestures and handgrasp successions. Such embodiment of macro-form was important for another reason, namely the stamina requirements of the piece. Given the extremity of actions, energy-saving was for me as important as energy expenditure. The locus of such energy-saving is always the body as environmental information. This is information of body schematic processes: How smaller muscles are supported by large ones (muscular interdependence), how to counterbalance unbalanced situations (for example during the double tremolo passages, where I would support my body with one hand), etc.

Ergonomicity cannot be totally abolished and natural reflexes distorted, despite any compositional and aesthetic programme. On the contrary, counter-intuitive actions are to be based on a very clear gestural ground, which is established in the dynamicity between notation, movement and instrument. Instability emerges naturally out of such interaction.

The multiplicity of potential trajectories of rhythm desciphering or dynamic and articulative "sculpting" cannot interfere with the requirement of forward movement. The *faster than possible* indication is telling as to this fact. Again, such considerations are counterbalanced by the *pedantically, but without confidence* expressive instruction in the beginning of the piece. No concrete strategy or *a priori* interpretative decision can quite substitute for the dialectic movement in-between structures, the exploration of affordances and limits of the notation, the counter-balancing of what seems intelligible and conceptual but must be re-inscribed in terms of embodied intelligence.

The difference in duration between my two recorded live performances of the piece are telling concerning the dialectic between *a faster than possible* and a *pedantically, but without confidence* approach. My first performance of the piece in Berlin[424] has a rather pronounced leaning towards the pedantic aspect, as opposed to the stormy and much shorter Belfast performance cited in all cases above, 7 minutes faster than the first one.

In the following video https://www.youtube.com/watch?v=RVfKF--nusk (accessed 29.04.2018) you may see a practicing session of a few voodoo techniques in a stratification scenario: Frozen state, overlayered actions, “chicken dance” and an entangled finger passage, in a multimodal representation and automatic rewriting for the first three examples, which relieves the readability issues of the original notation. Please compare to the original notation for a measure of the readability effect.

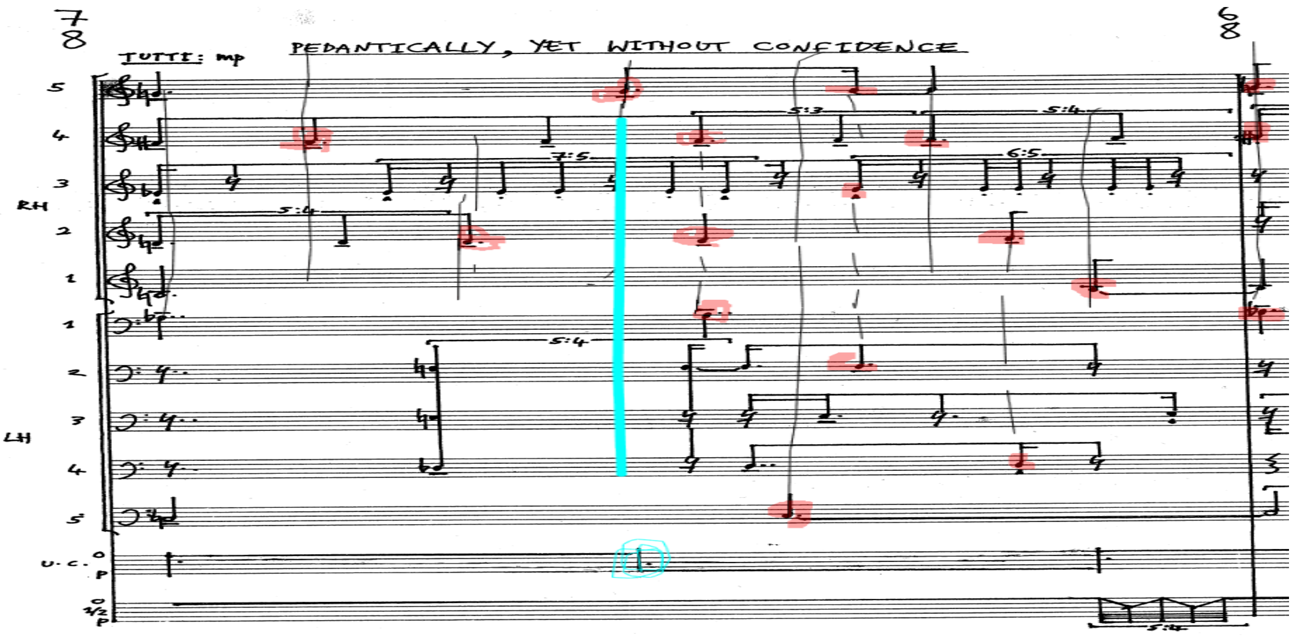


Figure 135: Frozen state, bars 1-2, original annotated notation

[424] https://www.youtube.com/watch?v=tHU8rKRg-RQ&t=1 accessed 28.04.2018

Figure 136: Frozen state, bars 1-2, reduced proportional representation generated by the MIDI file

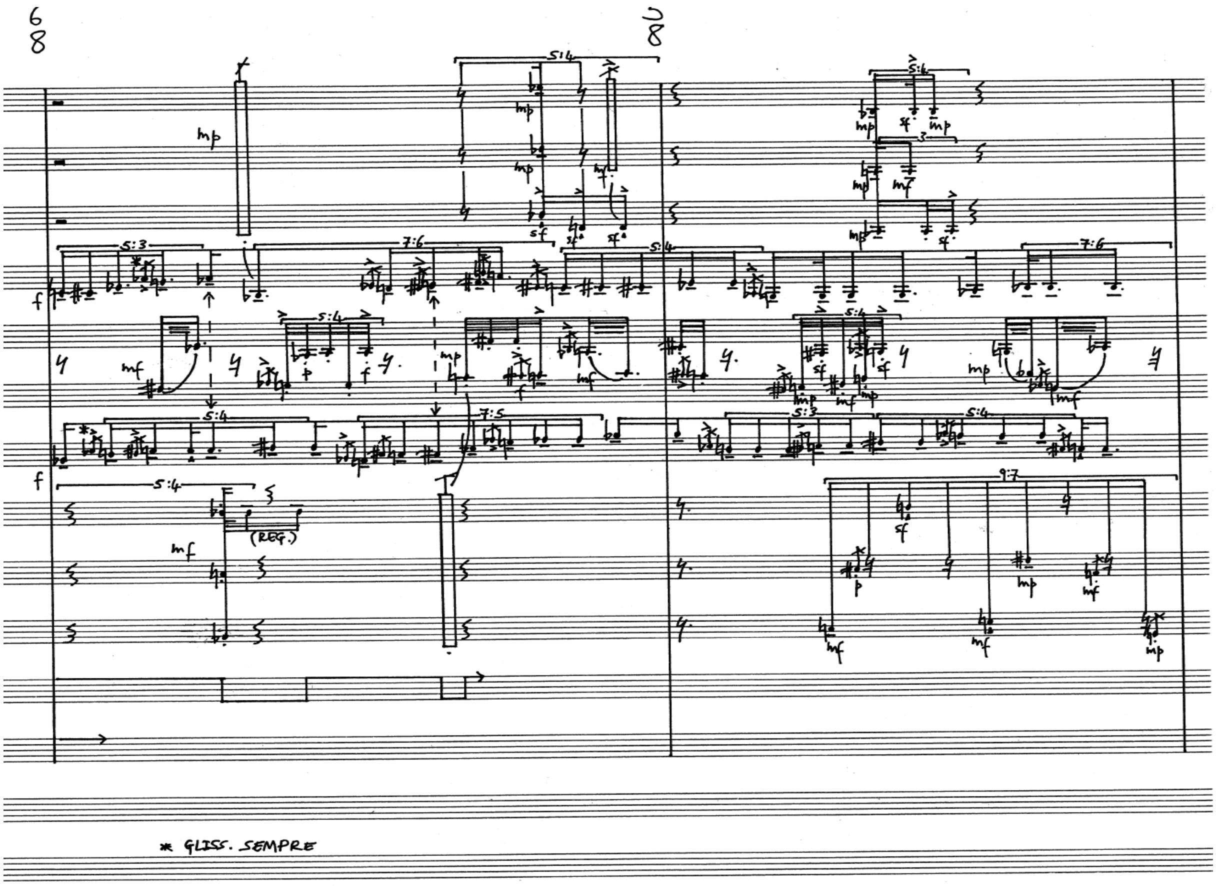


Figure 137: Overlayered actions, bars 9-10, original notation

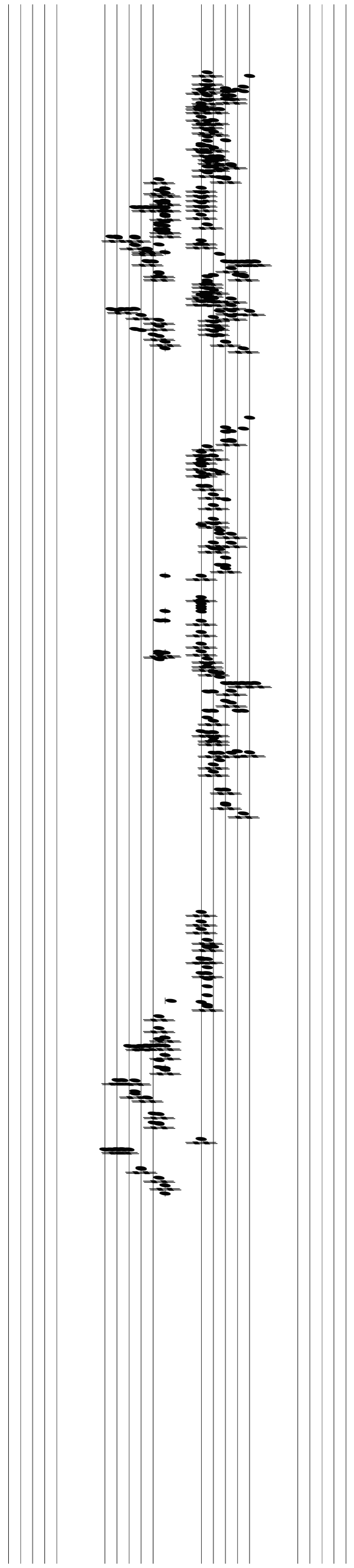


Figure 138: Overlayered actions bars 9-10, reduced proportional representation for right hand, left hand and both hands, corresponding to the three chunks from left to right

Figure 139: Chicken dance, bars 225-228, original score

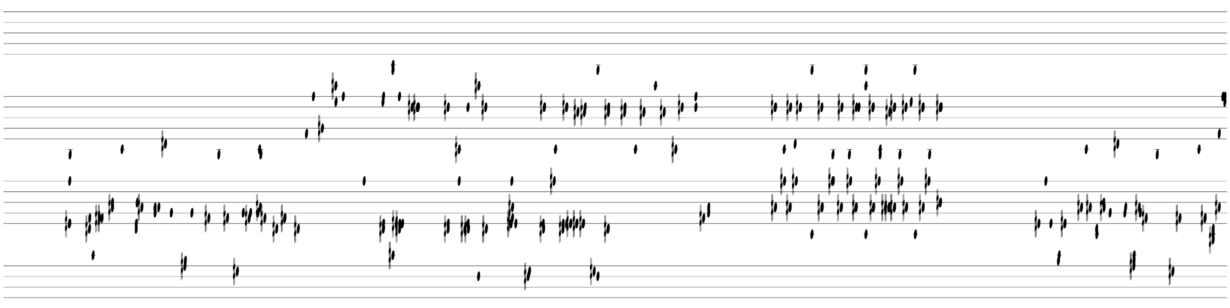


Figure 140: Chicken dance, reduced proportional notation generated by the MIDI file, bars 223-234

4.4 Conclusion

Hoban has developed a multitude of techniques, which allow for the problematization and transcendence of a universalized notion of technique, in a way which is both systematically discursive and purely physical. Such techniques defy any notion of understanding before performance and reveal the experiential navigation of affordances of the instrument, the body and the notation as the only pragmatic solution. In terms of notation as interface, Hoban elicits an expressiveness, which at times contradicts ergonomicity, flow and utilitarianism. The latter qualities can be partly restored through the rewriting of the piece in performance, in the form of multimodal data and output notations. As with the ubiquitous awareness of biomechanical constraints and body schematic processes as a counter-balance to the voodoo techniques, such rewritings are never to be thought as an *Ersatz* of the original notation, but rather as an outline of a performance space to be navigated.

5. Amalgamation Of Textual Complexity, Physical Theatre And Live Electronics: Nicolas Tzortzis' Incompatible(S) V For Silent Piano And Live Electronics

5.1 Introduction

Nicolas Tzortzis[425]' *Incompatible(s) V* for silent piano and live electronics assumes a central position in the exploration of works that make the case for embodied navigation. Not only does it represent a highly developed form of intra-notational complexity, in the sense of polyphony, texture and rhythm; but it also raises questions in relation to the sound and time control of the electronic medium; and questions about performativity emerging from the interactions between the textual and electronic elements. In other words, *Incompatible(s) V* touches upon all three axes of complexity embodied, intra- as well as inter-notational.

In what follows, we will explore those three axes in a reverse order, starting with the third, performativity, defined by the composer as interaction between:

a) sound and image
b) electronic and acoustic sound
c) human and machine

These prerequisites generate compositional choices as to the use of the electronic medium (second axis) and as to their codification in traditional notation and in programming languages – *Max / MSP* patches and *Antescofo* (first axis).

5.2 Interactive Aesthetics

The following passage from the work's programme note is briskly summarizing

[425] http://nicolastzortzis.org/ accessed 11.05.2018

Tzortzis' complex network of aesthetic programmes and tools in this ambitious work:

"Action decoupled from result, image decoupled from sound. A new approach to complex polyphonic writing. An instrument whose sound constantly varies. An open-form determined by the computer. Parasitic sounds revealed thanks to technology. Orchestration through microphones. The machine seeks to devour the human" (programme note, my translation)[426]

At the centre of the piece lies the radical decoupling between visual perception of the pianists' actions on the instrument and their audible outcome. The composer claims that this intuition originated in a dream:

"I dreamt of a pianist on stage playing very dense and virtuosic textures, only that the sound would not be originating in the instrument, but rather anywhere else in the hall. One would listen to noises of the piano amplified to the maximum and sometimes one would hear nothing at all, even when the pianist continued to play"[427] (Tzortzis 2012, my translation)

This vision of a disorienting physical theatre defined the means of sound production. Those include both a real (*Yamaha Silent Piano*[428]) and a virtual (*Pianoteq*[429])

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[426] « Action dissociée du résultat, image dissociée du son. Nouvelle approche de l'écriture polyphonique complexe. Un instrument dont le son varie constamment. Une forme ouverte décidée par l'ordinateur. Des sons parasites révélés grâce à la technologie. Orchestration par microphonie. La machine cherche à dévorer l'homme ». Programme note from the premiere, 08.06.2012, at Espace de Projection, Ircam, Festival Manifeste. Piano : Pavlos Antoniadis

[427] « J'ai rêvé d'un pianiste sur scène qui jouait des textures hyper denses et virtuoses, sauf que le son ne sortait pas de son instrument, mais de partout ailleurs dans la salle. On entendait les bruits du piano amplifiés au maximum et parfois on n'entendait rien du tout, même si lui, il continuait à jouer ». Nicolas Tzortzis, *Vers une musique autogérée:(In)compatibilités, Réseaux, Intuition et Processus*, PhD thesis at the Université de Montréal, 2012, p. 54

[428] The *Yamaha Silent Piano* allows for a seamless alternation between the acoustic sound of the instrument and its digital sampling: "When the silencing function has been engaged and keys are struck, hammer shank stoppers move into place to prevent the hammers from striking the strings. While the piano is outwardly silenced, the movement of the keys and other performance information are picked up by optical sensors and converted to digital data by a tone generator. Digitally sampled acoustic sound is then sent to stereo headphones for the player to enjoy in complete privacy."https://usa.yamaha.com/products/musical_instruments/pianos/silent_piano/index.html , accessed 18.04.2018. The switch to silent mode was in this case effectuated via a lever placed under the keyboard.

instrument, as well as contact microphones, which capture the so-called "parasitic" sounds, that is the noises of the piano mechanism. The title of the piece is then rooted in this *incompatibility* between action and sound. The Roman numeral "V" indicates that this work for silent piano and electronics is part of a further series of "incompatible" works. The provisional "(s)" in the title (*Incompatible(s) V*) alludes to open-form generating multiple versions of the piece.

Tzortzis' aesthetic foundation enjoys multiple origins and influences that he explicitly cites[430]. It crucially also evokes the *parametrical decouplings* thematized by Klaus Karl Hübler (see part one), which are here extended into the domain of interaction with electronics. Further commenting on parametrical decoupling, the composer writes:

"It consists in creating events which are not sensed as coexistent, of nature often contradictory, and in working with juxtaposed layers which do not communicate in an always evident manner. […] Given the choice of the instrument and the presence of the electronics, there is an in-depth work on the possible relations between the acoustic and electronic sound, questioning and rethinking the relationship between musical silence and scenic action." (Tzortzis 2012, p. 54-55, my translation)[431]

The interaction between image and sound and the interaction between acoustic and electronic sound constitute thematic elements of the piece, but so does the more general theme of human-machine interaction. In this domain, Tzortzis articulates a critique against canonic forms of interaction, for example in Philippe Manoury's classic *Pluton*, for piano and live electronics : As the machine is acted upon but not

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[429] The *Pianoteq* is based on physical modelling and allows for the real-time control of a variety of physical parameters of the piano sound. In that way, Tzortzis was able to avoid the one-dimensionality of the silent piano built-in MIDI piano sounds, creating what he calls « le nouveau piano preparé » . https://www.pianoteq.com/ accessed 18.04.2018

[430] The music of Iannis Xenakis, Helmut Lachenmann, John Cage, Philippe Manoury, Brian Ferneyhough, to mention just a few, becomes point of reference and constructive critique.

[431] « Comme son titre l'indique, la pièce traite la notion de l'incompatibilité. Il s'agit de mettre en place des événements qui ne sont pas censés coexister, de nature souvent contradictoire, et de travailler avec des couches juxtaposées qui ne communiquent pas de manière évidente. Dans cette pièce, un des défis était de dissocier les actions du musicien de leur résultat sonore, créant ainsi un décalage entre son et image. Vu le choix de l'instrument et la présence de l'électronique, il y a un travail approfondi sur les rapports possibles entre le son direct et le son traité, remettant également en cause le rapport entre silence musical et action scénique. », Tzortzis 2012, p. 54-55

really reacting *in unpredictable ways*, there is for Tzortzis no interaction but mere "triggering". In this sense, his notion of interaction aspires towards a "new open form", whereby the machine would determine and indicate to the pianist in real-time, which part of the score is to be played - thus the notion of the "machine devouring man", given the inhuman difficulty of the task[432].

Eventually, Tzortzis defines intra-notational complexity as a source of further interactive possibilities, through the exploration of new modes of touch and triggering ; rhythmic complexity, which develops Xenakis' idea of the arborescence and questions the nested logic of Ferneyhough's rhythmic complexity ; and the exploitation of all sonorous resources of the instrument, albeit not through negating its traditional tropes (as in Lachenmann), but in a technologically enhanced way. All those points are also linked to the logic of the electronic treatments, a form of writing in itself.[433] And all those points, so is our thesis, question performative embodiment and extend the model of embodied navigation to the interaction with electronics.

5.3 Embodied Interaction

From a performer-specific perspective, Tzortzis' aesthetic agenda raises a series of important questions concerning the agency of the performer; the relationship between body image and body schematic processes; the reaction to live-generated open-form; eventually the notion of accuracy in relation to textual aspects and score-following, effected through the *Antescofo*[434] software.

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[432] The ten different versions of the piece consitute a revision of usual open-form devices : Rather than preparing and playing a singular path (such as in "classic" open form works, like Boulez' *3ème sonate* and Stockhausen's *Klavierstück XI*), the performer needs to react to real-time changes of the score, which the machine decides according to performed parameters.

[433] « Sur le domaine de l'écriture instrumentale, j'ai voulu me baser sur des modes d'articulation peu habituels et sur une écriture rythmique novatrice qui prolongerait la logique de Xenakis et remettrait en cause la logique de la complexité de Brian Ferneyhough, pour créer des liens entre le jeu pianistique et les traitements électroniques, tout en exploitant l'ensemble des sources sonores de l'instrument, mais pas dans leur contexte familier de l'école post-lachenmaniènne. » p. 55

[434] http://forumnet.ircam.fr/product/antescofo-en/ accessed 19.04.2018

A. Agency And Control Of Alienated Sound Production

"The silent piano allows to have an instrumentalist who plays on stage, without necessarily listening at all times to the sound of her instrument. Equiped with headphones, the pianist listens at all times what s/he plays, but the sound diffused in the hall can vary between direct sound, electronic sound and the variable mix of the two. This allows for radically decoupling actions and sounds, offering thus a different degree of freedom to the electronic medium, which does not stay attached to the instrument but rather exists autonomously. The pianist changes also roles throughout the piece, as s/he alternates between soloist, generator of noises for the electronics, accompanist, or even mime, when the acoustic sound is completely cut off."[435]

The alienated experience of the pianist, due to the headphones, problematizes in new ways the ecology of movement, sound and touch, as often experienced in both acoustic and electronic music performance. Simply put, the performer acts and listens to the digital output of her action, that is the built-in samples of the *silent piano*, but is at the same time aware, that this output is nothing but the bare skeleton of the real acoustic experience, taking place elsewhere. Such experience is inversely proportional to the asserted alternation of the performers' roles as "soloist, generator, accompanist, mime". The latter relates primarily to the composer's manipulation of the performers' actions as compositional material and to the listeners' perception of such multidimensionality, rather than to the pianist's sense of agency. The performer's experience should rather be described as one of induced claustrophobia and sensory deprivation, and as such, it bares distinct psychological and semiotic overtones.

This state of play *per se* is certainly not new in electronic music performance, as it has been reviewed in part two of the current. Performers of electronic instruments

[435] « Le silent piano permet d'avoir un instrumentiste sur scène qui joue, sans qu'on entende tout le temps le son de son instrument. Équipé d'une paire de casques, le pianiste, lui, peut entendre ce qu'il joue, mais le son diffusé dans la salle peut basculer entre son direct, son électronique et le mixage variable de deux. Ceci permet de complètement dissocier les actions des sons, offrant ainsi une toute autre liberté à l'électronique, qui n'est plus obligée de rester « collée » à l'instrument, mais exister avec plus d'autonomie. Le pianiste change de rôles tout au long de la pièce, car il est en alternance soliste, générateur de bruits pour l'électronique, accompagnateur, ou quasiment mime, une fois coupé le son direct. » Tzortzis 2012, p. 66

routinely outsource agency to composers and sound engineers, both in respect to sound control and in respect to timing, as in the case of fixed media. The ingenious twist in Tzortzis' case is that, rather than compositionally and technically attempting to restore agency, he instead invests in its loss, objectifying performance as a mostly disconnected layer of the sensory stream.

A notable exception to this general principle comes at work in the third part of the three-partite version that we presented at Ircam, starting around 14'05" of the video documentation.[436] Here, after having removed the headphones and switched to the acoustic sound of the instrument using a lever under the keyboard, I could, for the first time during the performance, actually listen to the real sound of the instrument and to the electronic treatments in the hall around me, breaking, so to speak, out of the confinement experienced during the first two parts. This switch bears distinct dramaturgical and symbolic energy, grounded on the restoration of the normal ecology of sound, movement and touch.

Returning to the incompatibility state, questions are raised as to how the awareness of sensory deprivation affects embodiment and performance. My personal responses to the impoverishment of the auditory feedback were: an increased reliance on kinesthetic and haptic feedback, even though I was aware that the latter was not perceivable in the hall through the auditory channel ; the alternation between uncanny concentration, in the form of an accentuation of body schematic, motoric processes, and moments of almost desperate communicative attempts, where I would become momentarily aware of my body's semiotic properties, in the sense of body image and gesticulation; and the absorption in the virtual space of the score, which, given the automated page-turning and the "amputation" of the real acoustical space, was transformed in some sort of real-time signal, driving the performance as much as sensory feedback itself, in an experience of direct perception. A nice example of this interplay between body schematic and body image processes is the excerpt between 3'22" and 3'40" of the video above[437]: After 3'30", the relationship between the physical gesture and the sound output is utterly decoupled, only to be

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[436] https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=845 accessed 20.04.2018

[437] https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=202 accessed 20.04.2018

restored in the dramatic return around 3'38". At that very moment, an unusual expressive exaltation, driven by a momentary cadential moment in the writing, is to be seen and also heard, due to the return of the link between gesture and sound.

Tzortzis recognises Cage's *4'33"* as a major source of inspiration for the decoupling between action and result . The surprise of the listener, who is disoriented due to the lack of an immediate link between sound and gesture, becomes highly valued, a form of manipulation of both listener and performer. It constitutes an example of compositional appropriation of several of the issues related to live electronic performance. Instead of trying to address the problems, Tzortzis thematizes them and turns them into compositional material, in the same way Boulez or Ferneyhough or Hübler thematize impossibilities in their own way. In this way, physicality as presence becomes in itself a significant source of material, either irrespective of its own sounding results, or through unexpected couplings with the electronic sound.

Remembering here Erika Fischer-Lichte's radical definition of presence[438], as energy circulation triggered by the spectator's perception of the performer's embodied mind, one could even claim that Tzortzis achieves a *diffusion of bodily energies* in multiple directions. He is allowing for the simultaneous perception of bodily actions, parasitic piano sounds and spatialization effects in the hall, next to the rich overlayering of different electronic treatments. A fragmentation and simultaneous augmentation of the body of the performer into several streams of sonic super-structure takes place, while he or she remains grounded to an almost mundane, transparent bodily presence.

B. Constant Textual Complexity As Determinant Of Embodiment

One of the most directly apperceptible characteristics of the piece is the constant notational density of the two outer movements (a: start to 7'44"[439], b: 14'05"[440] to the end of the video). We claim that this degree of notational complexity is quintessential

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[438] Refer to part one, 2.4b. of the current

[439] https://www.youtube.com/watch?v=Mw_WKNNC-rE accessed 20.04.2018

[440] https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=845 accessed 20.04.2018

to the interactive aesthetics described above: Through the extremity of actions and the energy-saving requirements it invites on the part of the performer, such notation paradoxically facilitates embodied transparency and confinement, rather than expressive projection, as would otherwise have been the case[441]. The performative body disappears in a constant flow of physical movement, with no time to perceive itself (body image) other than in terms of forward movement (body schema).

Interestingly enough, Tzortzis thematizes this forward flow by describing the diverse textural types employed in terms of a fugue[442]:

"Every situation, every object, every texture appears only briefly, turning these measures into some sort of a fugue stretto, as if this beginning was in reality nothing more than the culmination of a process that has already started long ago."[443]

The situation and objects which the composer refers to are rather loosely defined in terms of textural entities: micro-canons, repeted notes, rapid chords, trills and tremolo, dense polyphonies etc, and several unidiomatic modes of articulation, notably cluster glissandi, keynoise attacks and extreme key releases, as in the following examples of notation and videos (all examples at the beginning of the video excerpt):

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[441] In the following video, you may experience a live performance of the piano part without the electronics and the network of interactive aesthetics described above. The difference as to expressive and communicative aspects are striking. https://www.youtube.com/watch?v=SPrl3C1vgY4 accessed 19.04.2018

[442] Remember here the etymology of *fugue* from the Latin *fuga*, "a running away, act of fleeing", from *fugere*: "to flee".

[443] « Chaque situation, chaque objet, chaque texture n'apparaît que très brièvement, faisant de ces mesures une sorte de stretto de fugue, comme si ce début n'était, en vérité, que l'aboutissement d'une pièce, d'un processus qui avait déjà commencé bien avant.» ibid., p.95

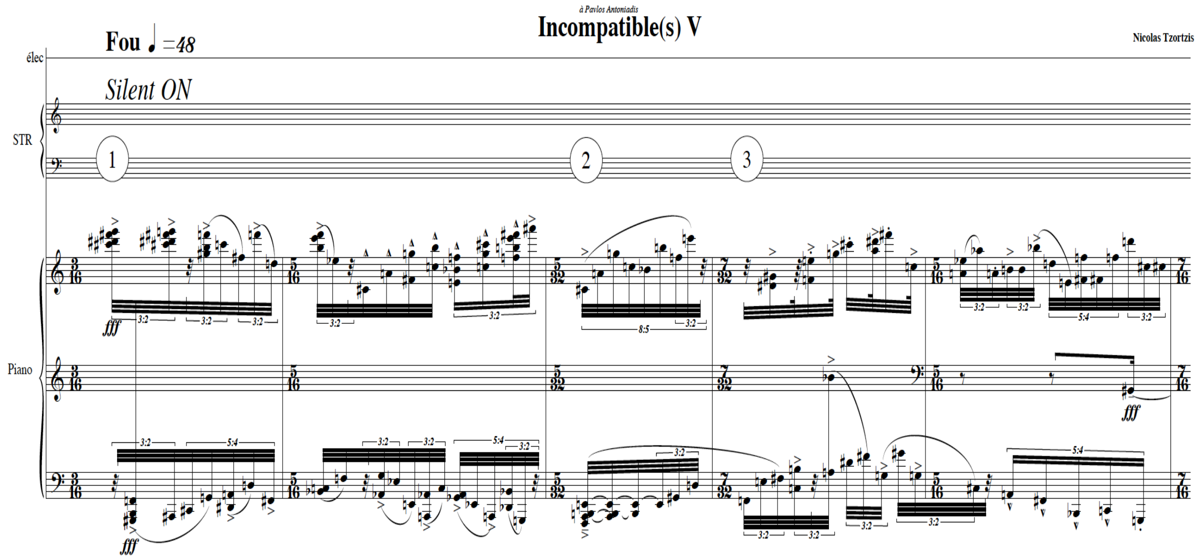

Figure 141: Original notation, bars 1-5, initial signalling gesture and two-part polyphony

Video of performance with electronics:
https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=38
Video of performance without electronics:
https://www.youtube.com/watch?v=SPrl3C1vgY4

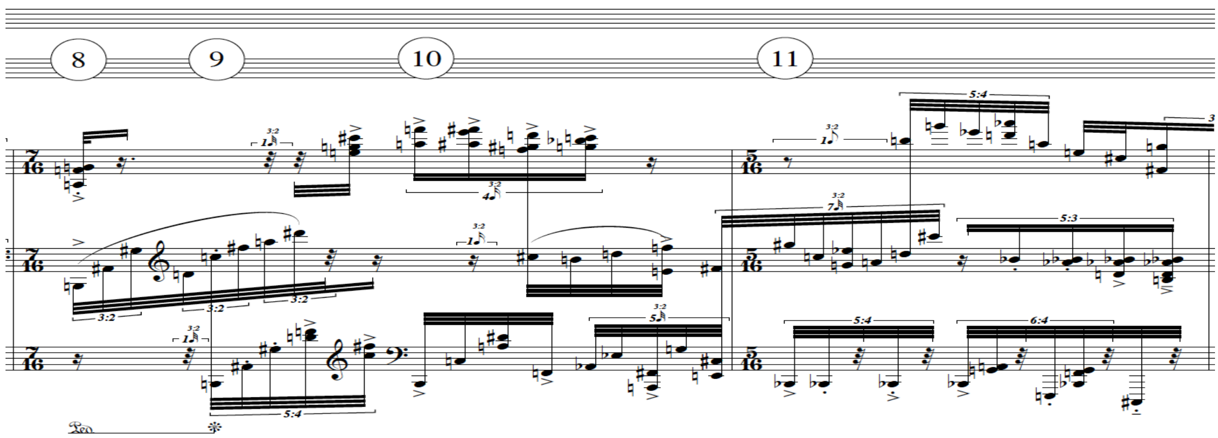

Figure 142: Micro-canons, bars 10-11

Video of performance with electronics:
https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=55
Video of performance without electronics:
https://www.youtube.com/watch?v=SPrl3C1vgY4&t=30

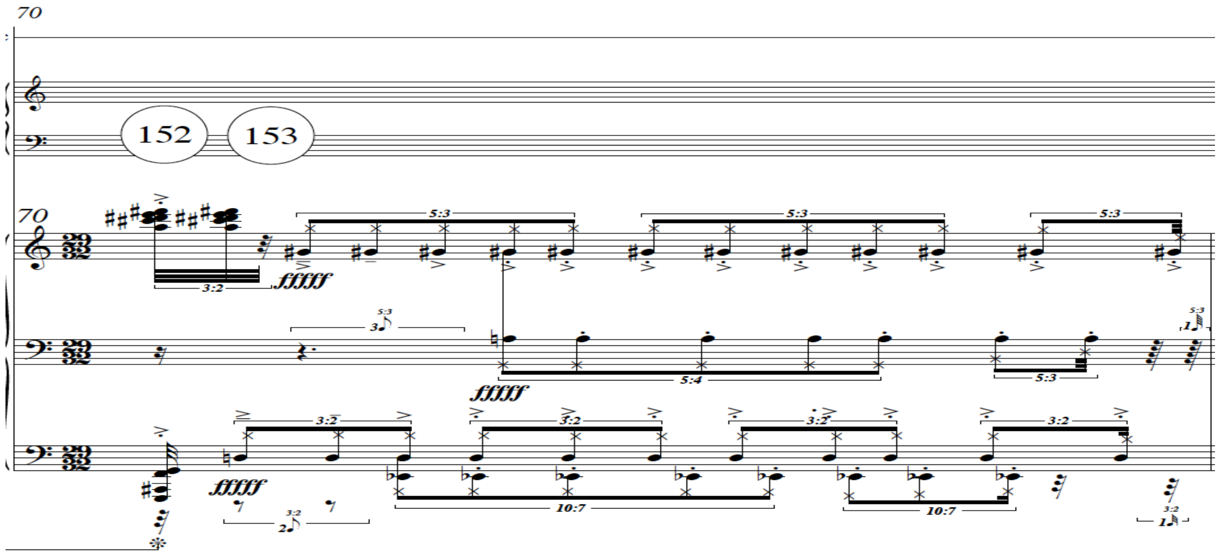

Figure 143: Key-noise attacks, bar 70

Video of performance with electronics:

https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=244

Video of performance without electronics:

https://www.youtube.com/watch?v=SPrl3C1vgY4&t=205

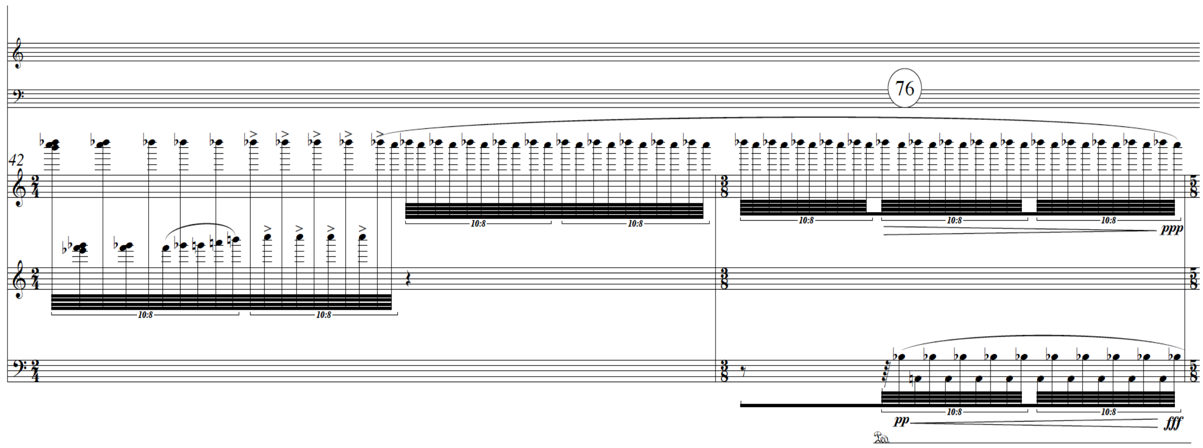

Figure 144: Trills and tremolo, bars 42-43

Video of performance with electronics:

https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=98

Video of performance without electronics:

https://www.youtube.com/watch?v=SPrl3C1vgY4&t=123

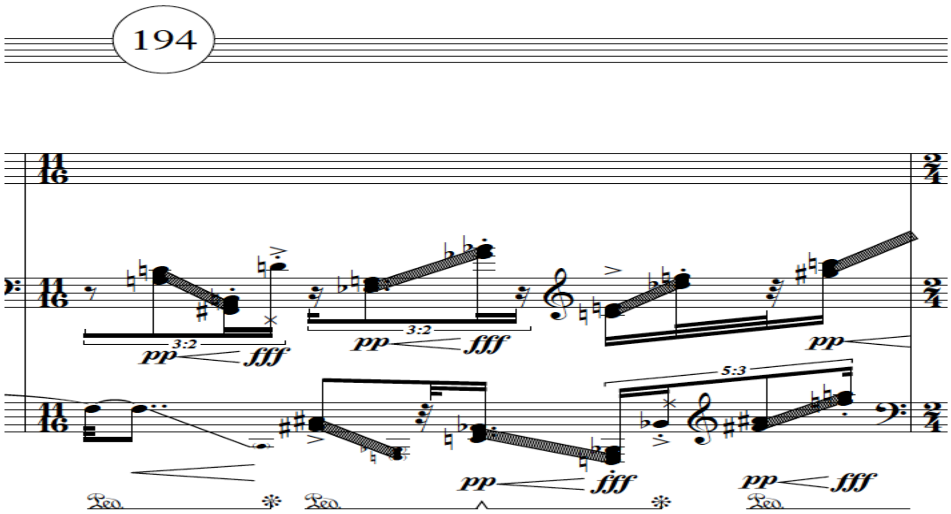

Figure 145: cluster glissandi, bar 85

Video of performance with electronics:

https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=292

Video of performance without electronics:

https://www.youtube.com/watch?v=SPrl3C1vgY4&t=250

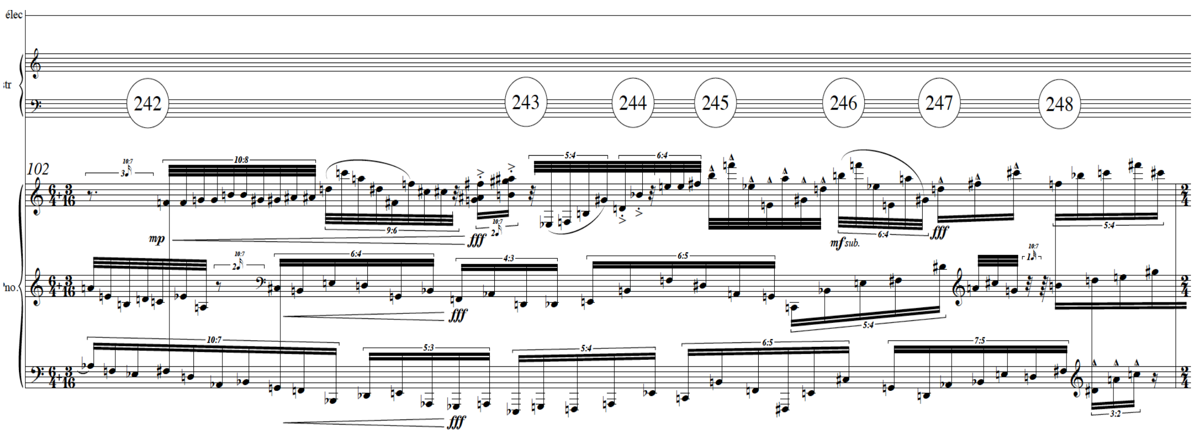

Figure 146: Three-part writing, bar 102

Video of performance with electronics:

https://www.youtube.com/watch?v=Mw_WKNNC-rE&t=349

Video of performance without electronics:

https://www.youtube.com/watch?v=SPrl3C1vgY4&t=301

Such thematization of the parameter of texture, in the context of a fugitive form tending towards *developing variation*, equals unmistakeably a thematization of performative embodiment and flow, articulated by distinct albeit brief gestural profiles.

The subsequent privileging of morphokinetic (as opposed to topokinetic) qualities of physical movement is not however to be taken for granted: Tzortzis' rhythmic language does not allow for easy solutions of the *energetic striving* type[444], due to both quantitative and qualitative characteristics. Tzortzis' novelty lies in his intentional avoidance of closed rhythmic spaces (such as nested tuplets), while privileging arborescent structures of broken or extended tuplets starting in any point of any grid, for which he has developed special notation.

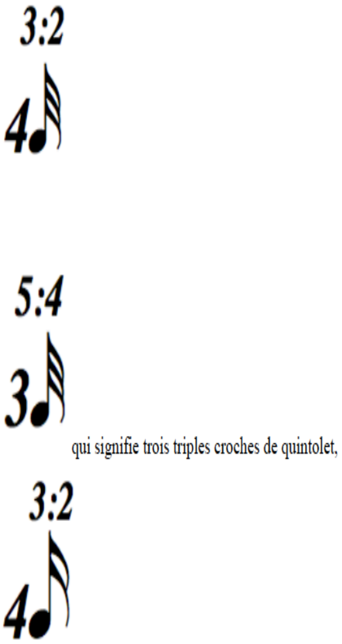

Figure 147: New rhythmic notation for non-nested durations, from top-down: 4 triplet 32nds, three quintuplet 32nds, 4 triplet 16ths etc.

[444]Energetic / intuitive as analyzed in Cox, 2002, p. 79-80

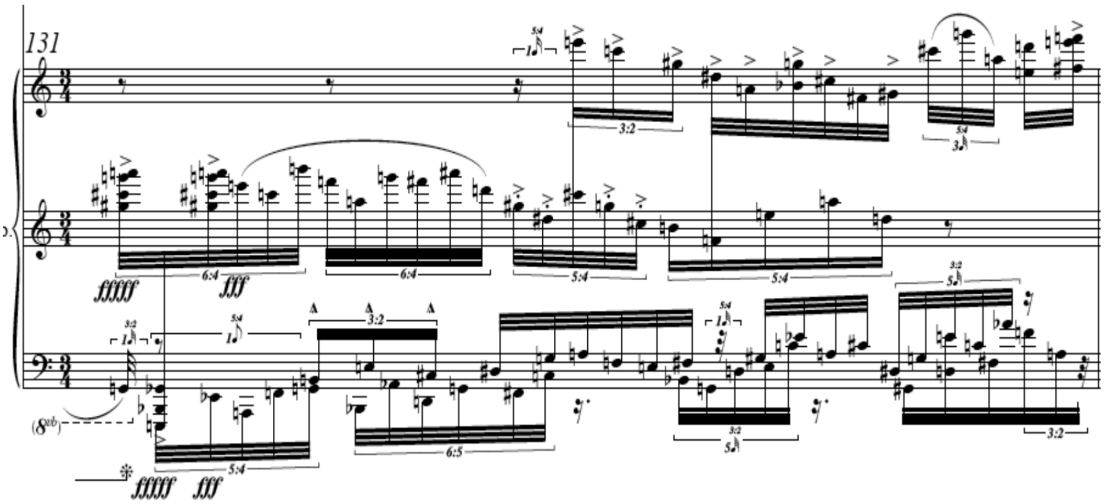

Figure 148: Excerpt with new rhythmic notation

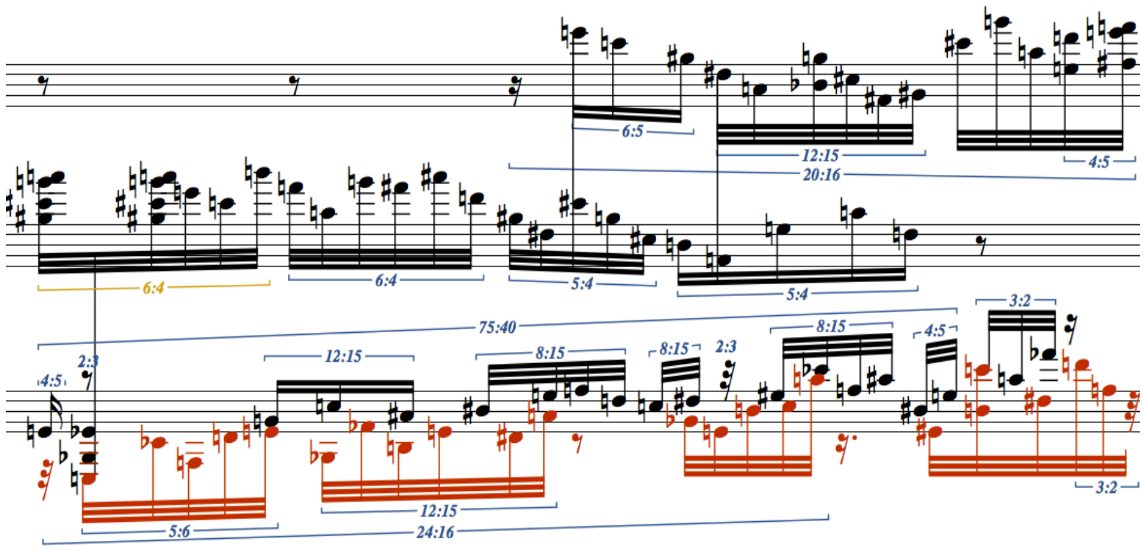

Figure 149: Same as above with traditional notation. The complexiy would be mind-numbling.

This anarchic branching-out of new lines and streams (which he terms *musique autogérée*) is not irrelevant to the sense of forward flow, but constantly counterbalanced through the painstaking deciphering of the learning process. As for the performer, the rhythmic novelty claimed by Tzortzis does not change much:

Those tasks are not significantly different to the ones explored in other case-studies, since they can be tackled through mediation techniques, as navigation of coarticulated entities around a basic beat.

C. Accuracy In The Light Of Impossibility And Score-Following

While the notational characteristics cited above invite multimodal integration into intuitive, forward-moving gestures (save the complex rhythm deciphering), the presence of an advanced score-following system, used to trigger electronic treatments and automatically turn the pages, makes urgent the question of accuracy.

Antescofo is based on scripts representing the symbolic score, as shown in the following example:

```
TRILL ( 9100 8900 8200 2900 ) 1/12 bar109-ev269
page-num 23
TRILL ( 2900 9100 8900 8200 ) 0.0167
CHORD ( 9100 8900 8200 3300 ) 1/15
CHORD ( 3300 8700 ) 0.0334
CHORD ( 8700 3900 ) 1/20
NOTE 3900 1/20
CHORD ( 4800 4200 ) 1/12 bar109-ev270
CHORD ( 4800 4200 5100 ) 7/416
CHORD ( 5100 3800 ) 1/15
CHORD ( 3800 5400 ) 0.0334 bar109-ev271
CHORD ( 5400 4400 ) 1/20
CHORD ( 4400 6200 ) 1/20
CHORD ( 6200 4900 ) 1/30
CHORD ( 4900 6700 ) 0.0667
CHORD ( 6700 4600 ) 0.0166
CHORD ( 4600 7100 ) 1/12 bar109-ev272
CHORD ( 8000 5200 ) 1/12
CHORD ( 5200 7200 ) 7/416
CHORD ( 7200 5500 ) 1/15
CHORD ( 5500 7800 ) 0.0334
NOTE 7800 1/20
CHORD ( 8900 4500 ) 1/12 bar109-ev273
CHORD ( 8900 4500 8500 ) 1/96
CHORD ( 8500 5100 ) 7/96
CHORD ( 5100 8300 ) 1/48
CHORD ( 8300 5500 ) 1/16
NOTE 5500 1/32
NOTE 6400 3/32
CHORD ( 5800 3600 ) 3/32 bar109-ev274
CHORD ( 5800 3600 6800 ) 0.0157
CHORD ( 6800 4100 ) 5/64
CHORD ( 4100 7900 ) 1/32
CHORD ( 7900 3400 ) 1/16
CHORD ( 3400 7400 ) 3/64
CHORD ( 7400 4600 ) 0.0469
NOTE 4600 1/16
CHORD ( 6100 5100 ) 5/64 bar109-ev275
CHORD ( 6100 5100 6900 ) 1/32
CHORD ( 6900 5800 4900 ) 0.0468
CHORD ( 5800 4900 6700 ) 1/16
CHORD ( 6700 5400 ) 0.0157 bar109-ev276
CHORD ( 5400 7200 ) 5/64
CHORD ( 5400 7500 ) 1/64
CHORD ( 7500 6200 ) 1/16
CHORD ( 6200 8200 ) 0.0469
CHORD ( 8200 5600 ) 1/32

CHORD ( 5600 7300 ) 0.0782
CHORD ( 5600 7600 ) 1/64
CHORD ( 7600 5800 4800 ) 1/16
CHORD ( 5800 4800 8600 ) 1/16
CHORD ( 5800 8600 ) 1/64
CHORD ( 5800 8100 ) 5/64
CHORD ( 5800 9200 ) 1/32
CHORD ( 9200 5500 ) 3/64
CHORD ( 5500 8700 ) 5/64
CHORD ( 7900 6500 5200 ) 1/10 bar109-ev277
CHORD ( 7900 6500 5200 9000 ) 1/10
CHORD ( 6500 8300 8100 7400 ) 1/12
CHORD ( 8300 8100 7400 6800 6600 5900 ) 0.0167
CHORD ( 6800 6600 5900 ) 1/10
CHORD ( 6800 6600 5900 8900 7800 ) 1/20
CHORD ( 8900 7800 6700 6100 ) 1/20
CHORD ( 6700 6100 ) 1/10
CHORD ( 6700 6100 8000 ) 0.0167
CHORD ( 8000 6400 6200 ) 1/12
```

Figure 78 Incompatible(s) V, version 1.1 mes 109 script antescofo

Figure 150: Sampleof Antescofo script

Given the fact, that the resolution of the system reflects the note-to-note resolution of the original notation, one is faced with the following dilemma: The system might perfectly function in situations where performance is in itself a more or less perfect reflection of the musical score, what happens though in situations, where a perfect performance is impossible or even undesired, as is here the case?

This consideration became hard-wired during my learning process of the piece, fueling an extreme prioritization of pitch accuracy and topokinetic considerations of movement, than would have otherwise been the case. The need to release the requirement for topokinetic accuracy in search of morphokinetic freedom had always to be calibrated against the very real possibility of *Antescofo* not being able to follow anymore, which could result in electronics not triggered, or even worse, pages not turning.[445]

The system (and I) performed eventually satisfactorily, although the question of score-following in such situations remains open: Could a system like *GesTCom*, based primarily on motion-following rather than score-following, perform better in situations where score accuracy is compromised due to complexity? While the first phase of its use shows that *GesTCom* can account for a wide range of variations of nested movements (and thus potential inaccuracy in relation to the score), the question is only speculative, as it has never been tested for score-following proper, as opposed to the sophisticated *Antescofo*.

Score-following should thus be considered as another constraint, this time in terms of timing control, in addition to the original constraint cited concerning sound control. While those two aspects are usually functioning in trade-off terms, in this particular instance they constitute a double constraint, shaping the "island" psychology and embodiment of the performer.

D. Navigating Electronics?

The compositional handling of electronic treatments remains close to the gestural nature of the instrumental writing. Here is a clarifying description by the composer:

"In order to amplify, for example, a rapid horizontal movement, one may process it through a granulator, that functions like a shadow, follows the trajectory and exaggerates the contour. The

[445] In reality, the manual triggering by the composer was also possible, so that this danger remained only virtual.

output of the granulator can later on be slightly transposed or fed into a ring modulator or frequency drift, so that a line is transformed into a thicker texture, a mass that moves with the piano"[446]

Such materialist description, a process of thickening the instrumental contour, hints towards a common spectromorphological grounding of both acoustic and electronic sound on the same bodily roots. This shared morphological identity is counterbalancing the aesthetics of incompatibility and partly restores the sense of agency and liveness.

Tzortzis claims that this double identity of the electronics, decoupled through the *silent piano* and at the same time embodied through the morphology of the instrumental gesture, opposes the traditional triggering (*déclenchement*) aesthetics:

Normally, given that the computer cannot process sounds that it has not yet received, the expectation is for the instrumentalist to play something that is immediately picked up, in processed or reproduced form, by the electronics. In this piece, on the contrary, one can expect the response of the machine, followed by the action that provoked it, since the sound of the piano can be completely decoupled. The roles change, the electronic is not confined to always following or responding, but rather appears to lead in real time, without at the same time resorting to readymade audio files, which would constrain the interpretation of the pianist. One could also expect the perception of only electronic treatments, since the sound of the instrument can disappear. Every treatment (ring modulation, filtering, granulation, frequency shifting, harmonization etc), as well as the possible combinations between the treatments, are brought to the foreground, liberated from the weight of pure instrumental sound. That, which normally is perceived as secondary or accompanying, assumes the protagonistic role. While playing the score on the piano keyboard, the pianist plays also the treatments, a passage in granular synthesis which has the same contour as the instrumental writing, plays a transposed sound, without the original being present, a filtered chord which is harmonised ; s/he does not just play the piano, but at the same time projects / reveals the mechanism that works behind, the sceleton of the instrument which never has the occasion to reveal its sonic richness.[447]

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[446] « Pour amplifier, par exemple, un mouvement rapide horizontale, on le passe à travers un granulateur qui fonctionne comme une ombre, suit la trajectoire et exagère le contour. Ce qui sort du granulateur peut ensuite être légèrement transposé ou passé par un modulateur en anneau ou un dérive de fréquence, afin qu'une ligne devienne une texture plus épaisse, une masse qui bouge avec le piano. » ibid. p. 126-127

[447] « Dans cette pièce, on peut entendre d'abord la « réponse » de la machine, suivie par l'action qui l'a provoquée, vu que le son du piano peut être décalé. Les rôles changent, l'électronique ne fait pas que suivre où répondre, mais paraît mener le jeu en temps réel, sans avoir recours à des fichiers son

While such considerations are valid from a compositional and reception point of view, it has to be stressed, that the ability of the performer to shape the electronics, as described in the passage above, is taking place without his acute awareness of the outcome, but at the most through speculation. The performer is, so to speak, “lending his body” to the cause of shaping the electronics, a shaping which remains a strictly compositional affair.

Considering these remarks from the point of vue of NIMES, it becomes clear that the very notion of the instrument in *Incompatible(s) V* is significantly revised : Next to the usual augmentation of the instrument, what comes into focus is the possibility to reduce the instrument into a controller, or even into an assemblage of machinic parts through the amplification of parasitic sounds. What remains constant, even decoupled from auditory feedback, is body schematic processes underlying all possible manifestations of such an enlarged notion of the instrument. And if in this notion we include the interactive forms of musical notation, both the traditional writing triggering action as well as the Max / MSP patches and *Antescofo* scripts triggering electronics, then we have a rather complete representation of a dynamic system around the human body.

E. Machine Devours Human

From a performer-specific perspective, Tzortzis’ vision for a renewal of the interactive aesthetics through live-generated open-form is intriguing. The quantitative aspects of

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préfabriqués, qui contraindraient le pianiste à une interprétation moins flexible. On peut même ne faire entendre que les traitements, en faisant disparaître la partie purement instrumentale. Chaque traitement (modulation en anneau, filtrage, granulation, dérive de fréquence, harmonisation etc.), et les combinaisons possibles entre ces traitements, se font entendre en premier plan, libéré du poids de la présence du son instrumental. Ce qui, d’habitude, est perçu comme secondaire ou accompagnateur, devient, dans cette logique, le protagoniste. Le pianiste, en jouant la partition au clavier, « joue » aussi les traitements, « joue » en fait un passage en synthèse granulaire qui a le même contour que sa partition, « joue » un son transposé, sans que le son d’origine soit présent, « joue » un accord filtré puis harmonisé, ne joue pas « que » du piano, mais, en même temps, nous fait entendre le piano qui travaille derrière, le squelette de l’instrument qui n’a jamais eu l’occasion de révéler sa richesse sonore. » Ibid., p. 61

the endeavor, about 50 minutes mostly as dense as the material shown in the two outer movements of the video in what he terms the *mega-version*, are haunting. How does one prepare for this mass of music to a degree that would allow real-time responsiveness for an infinite amount of random permutations and with the accuracy constraints of *Antescofo* fully at work ?

In such a situation, the very notion of preparation is to be radically rethought. If preparation equals internalization according to a UTI approach, then the game is most definitely lost or exhausting and the machine will most likely devour the poor performer. The taming of the machine passes through the acknowledgement of the interactive dynamics of the situation, whereby the performer would become accustomed to directly perceiving and realizing the affordances of the notation - in fact: any notation. Impossible tasks like this push the envelope of what is possible, through the reformulation of the underlying performance paradigm. As has been previously stressed, a direct perception paradigm privileges morphokinetic properties and problematizes accuracy. Under this light, the very technological fabric could be rethought, integrating, for example, score-following systems which are more responsive to the relevant performance paradigm.

5.4 Conclusion

Nicolas Tzortzis's *Incompatible(s) V* presents us with a multilayered interactive system. At least four types of interaction are stressed by the composer, namely : image and sound, electronics and acoustic instrument, human and machine, performative body and compositional writing. From the performer's perspective, the interaction can be described as follows : Embodied music notation, in both its morphokinetic and topokinetic features, in pre-arranged or open forms, generates performative actions, often visually decoupled from the actual sonic output, while constantly shaping it, thanks to the *silent* instrument and its extensions. Questions of agency, presence, embodied navigation of different notational and electronic features, score-following and accuracy, are thematized. Tzortzis reverses the classical problem of mixed music : Instead of using the embodied presence of the instrumentalist to guarantee the agency of the electronic sound, he aims at the liberation of the electronics and the alienation of liveness. This *ex negativo* sense of physicality is further enhanced through the sheer features of the instrumental writing in itself : Textural and rhythmic complexities which invite embodied navigation of a *moto perpetuo* in constant flow. The perceived semiotic aspects of performative embodiment become feasible through a model of direct perception and affordance navigation rather than through the investment in an impossible internalization.

Conclusion

This PhD thesis proposes a novel paradigm of pianists' interaction with complex music notation. Its novelty lies in the rethinking of the classic notion of interpretation as interaction. Two features are central for this paradigm: The primacy of performers' embodied experience and the inherent plasticity of music notation. Embodiment is shown to shape constantly the comprehension of the notation and to transform notation in real time.

The focus on complex contemporary repertoire is intentional, in revealing the aporias of traditional interpretation. Complexity is conceived beyond the quantitative aspects of notation. Those aspects were described as *intra-complexity* of the graphic symbols. The multimodal grounding of these symbols gives rise to *inter-complexity*, as complexity of their interaction with the physical realities of performance. In that sense, even simpler graphic notations can give rise to complex interactions and, vice versa, surface complexity may represent simpler interactions. In principle, this distinction should be extendable to any repertoire of notated piano music.

This paradigm is denoted as "embodied navigation of complex piano notation", in an explicit reference to Gibson's ecological psychology. Gibson's ideas on environmental interaction form the basis for a great range of cognitive science theories, often summarized as "embodied cognition". We made an in-depth survey of the field, so as to precisely identify concepts relevant to the interaction with complex notation. The off-loading of notational complexity to embodiment, the articulation of performer-specific discourses based on embodied experience and the dynamicity of the interaction without the need for mental representability, are three examples of such concepts.

The last requirement triggered questions of external representability of the paradigm. In a first phase, we represented embodied navigation in the form of multilayered tablatures. These tablatures showed affordances of the notation and constituted a state-space for the dynamic interaction. At a second step, we upgraded the representations into dynamic ones, using state-of-the-art technology for gesture capture and interactive notation. The result was a sensor-based environment for the processing and control of complex notation: *GesTCom* (*Gesture Cutting through Textual Complexity*).

The theory of embodied navigation and the *GesTCom* system were used for the performance analysis of selected complex repertoire, namely works by Iannis Xenakis, Brian Ferneyhough, Mark Andre, Wieland Hoban and Nicolas Tzortzis. Some of these works explore inter-complexity beyond the composition for acoustic instruments, in the form of electronics and intermedia. In this way, they cover three axes of complexity in relation to embodiment, as surveyed in part one.

Embodied navigation and the *GesTCom* are also inspired by models at the core of systematic musicology today. They materialize dynamics of expressive interaction and communication on the basis of corporeal articulations, as proposed by Marc Leman; and they remain open to research in co-articulation, as proposed by Rolf-Inge Godøy. By merging notation, movement and instrument, they address wider issues in the field of Human-Computer Interaction and New Interfaces for Musical Expression.

The future of this research could be shaped by the following requirements:

Firstly, the dissemination of the proposed methodologies in selected communities of performers, in both research and pedagogical contexts. The current research has been led by the author's personal practice and took the form of an auto-ethnographic study. However, the integration of objective data and the methodological openness of the paradigm attempted a transition from first- to third-person descriptions. Some prototype applications in pedagogical contexts, as overviewed in the Appendix, have been promising. The envisaged dissemination would take the form of user testing of the *GesTCom* by pianists at different levels of expertise.

Second, the extension of the research into mainstream piano repertoire. The notion of inter-complexity can be applied to any notated music. A comparative study of the classic interpretation tropes in relation to the embodied navigation paradigm would be of great research interest. Some first instances of such research were documented during the author's Musical Research Residency at IRCAM. This extension would be important for the democratization of the *GesTCom* through integration in basic piano pedagogy. It would also enable the interaction with traditional music analysis methodologies.

Third, the application of embodied navigation in studies of sensorimotor learning and prediction. We wish to examine how the transformation of the notation, in both static and dynamic ways, changes the documented chunking and feedback processes at the lowest physiological level. We also wish to examine, how and if the findings of predictive processing can be implemented in the probabilistic architecture of the *GesTCom*, allowing for a more targeted navigation of complex notation. We would like eventually to further examine the assertions of the radical embodied cognitive science, as to the contingency of mental representations and as to the algorithmic structuring of predictive models.

Fourth, the extension of *GesTCom*'s applications into the fields of contemporary composition and free improvisation. The system has already been used in the project described in the Appendix 3 with promising results. Physical movement generating notation through the *GesTCom* could serve the exploration of new interactive possibilities in the composition for instruments, electronics or intermedia. It could also be used for the documentation of improvisational practices, as well as a means of music improvisation in itself.

Fifth, the creation of interactive systems that learn along with the human performer. For example, advanced score-following systems today are based on scripts, which invariably relate to the composer's musical score. The plasticity of the musical score enabled by the *GesTCom* shows towards the potential of systems making use of the performer's processing of notation through physical movement. Such systems would address the dimensionality reduction of the big data involved in the performance of complex music.

Sixth, further development of the *GesTCom*, by implementing advances in all stages of the architecture as reviewed before. Particularly interesting is the implementation of machine learning and MIR techniques, which would enable the automatic transcription of the musical score in a variety of representations, on the basis of a few input gestures by the performer.

Seventh, the enablement of web-based collaborative learning. The learning of notated music has always been a solitary endeavor. The potential implementation of *GesTCom* as an online tool could enable users to upload and share gestural data and interactive multimodal tablatures. Such implementation could foster a culture of exchange in the classical and contemporary music scenes.

Eighth, the multimodal documentation of musical performance. The advent of recording technologies in the 20th century changed music-making and notions of the musical work in unprecedented ways. Video documentation of music performance is today ubiquitous. We can imagine a future, whereby the recording of physical movement in a variety of datasets becomes equal part of this documentation. Such proliferation would enable the transfer of expert knowledge in unforeseen ways.

Concluding: Despite the 20th century advances in piano performance and compositional aesthetics, interpretation remains bound to models of the past. The current study has attempted to show, how the latest advances in contemporary music, cognitive science and music technology might be implemented in piano performance of the most demanding repertoire. A vision of embodied interaction as the basis for musical creativity, while still embracing the virtues of symbolic notation, has been driving this study. A vision of dissemination, inclusiveness and collaborative music-making marks the desired future manifestations of this research.

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Appendix 1 : Online gesture analysis and control of audio processing

Frédéric Bevilacqua and collaborators have presented a

> "general framework for gesture-controlled audio processing. The gesture parameters are assumed to be multi-dimensional temporal profiles obtained from movement or sound capture systems. The analysis is based on machine learning techniques, comparing the incoming dataflow with stored templates. The mapping procedures between the gesture and the audio processing include a specific method we called temporal mapping. In this case, the temporal evolution of the gesture input is taken into account in the mapping process. We describe an example of a possible use of the framework that we experimented with in various contexts, including music and dance performances, music pedagogy and installations." Bevilacqua 2011, p. 127

The relevance of this work for the *GesTCom* project is crucial, as the *GesTCom* methodology is tailored according to the methodology and systems developed for audio control, but with the significant adjustment that in this case we are talking about *notation control* in lieu of *sound control*.

Bevilacqua et al. are citing as prerequisites for the development of motion following the embodied and enactive approaches to music cognition and technological advances in the form of cost-effective sensors and interfaces. This work is regularly reported by the NIME community and stands at the core of both the embodied navigation model and the relevant interactive systems.

The central question in modeling a gesturally controled audio system is the question of the relationship between the incoming gesture and the output sound. By analogy, the crucial question for developing systems for the gestural control of notation is the relationship between gesture and notation. This relationship is conceptualized as the *mapping* between the input and output parameters, with several approaches, featuring both low-level features (raw energy) and higher-order, semantically important syntactical properties. Generally speaking, one could argue that mapping is in itself an art of interpretation of raw data at several levels, or the filtering of the data and the modeling according to customized uses and user expectations.

Another reported problem in existent research was the lack of methods, which would address the real-time evolution of this relationship between gesture and sound. Modeling in general is claimed to privilege statistical methods over buffered (stored) data (the *bag of words approach* referring to gesture, and the *bag of frames* referring to audio descriptors), which are seen as fit for classification of already recorded examples, but less appropriate for being integrated in interfaces for online, real-time uses.

In the suggested by Bevilacqua et al. methodology, the crucial aspect is the consideration of the temporal evolution of the gestures, or their consideration as *multidimensional temporal profiles*, as opposed to their spatial characteristics upon completion of the gesture. This approach, termed temporal mapping as opposed to spatial mapping, insists on the temporal character of the relationship between gesture, sound and musical structure.

***Gesture follower* architecture : gesture capture, processing, mapping, audio processing**

The general architecture of the gesture follower is described in four stages: Gesture capture, gesture processing, mapping to sound and audio processing. One of its main advantages is that it is supported by a set of software libraries that greatly facilitates its design and rapid prototyping, such as for example the *MuBu* library, featuring in the *GesTCom* project.

As far as the first stage (capture of data) is concerned, the authors accentuate the heterogeneity of the possible systems and corresponding data, which can be : Acceleration data captured from accelerometers, gyroscopes and magnetometers, that is inertial sensors ; 3D spatial data through motion capture systems ; image analysis parameters from video capture ; gesture data obtained from sensors such as FSR (Force Sensing Resistor), bend, strain gauge, piezoelectric, Hall, optical, ultrasound sensors ; tablet and multitouch interfaces ; sliders and potentiometers ; MIDI interfaces ; sound descriptors derived from sound capture ; and any combination of the above. The common denominator which unifies these vast potential sets of data is their consideration as multidimensional temporal data, that is their very evolution in time. It is not an exaggeration to claim, that from this specific engineering standpoint, the term “gesture” refers to any physical quantity changing in time. The exact physical quantity is depending on the relevant capture system.

The second stage, that is the processing of the data, involves two steps. First, in a pre-processing step, the data is formatted as a temporal stream of vectors x(t) of dimension M, regularly sampled over a time interval Δt. To this purpose, several techniques such as filtering, re-sampling, data fusion and dimension reduction, normalization and segmentation may be used in the stream of raw data. Thus, the preprocessed data can be seen as series
x1 , x2 , ..., xn. A recorded gesture from t = 0 to t =(N-1)Δt is stored in a matrix G of dimension N x M.

The main processing of those multidimensional temporal profiles is based on machine learning techniques and thus takes place in two phases. In the first phase, called the learning phase, the system is trained on the basis of an existend data-base. In the second phase, called the following phase, the system is used during performance, that is in real-time.

For the modeling of the gesture, Bevilacqua et al adopted a hybrid approach between methods such as *Hidden Markov Models (HMM), Dynamic Time Warping (DTW)* and *Linear Dynamic Systems (LDS)*. Their main requirements, which led to such a solution, were a) the consideration of temporal profiles at multiple time-scales, in accordance with the nested nature of musical structure, thus a fine-grained or high-resolution modeling system and b) the ability to train the system with one single example, thus allowing to work “on the fly” with the practical requirements of very idiosyncratic performers, as is the case in musical and dance applications.

Coming to the techniques which are used as reference for the development of the *Gesture Follower* : Dynamic Time Warping (DTW) is characterized by its invariance to speed variations of the gesture, thanks to the use of dynamic programming techniques for the comparison and alignment of a reference and a test gesture. The same crucial requirement of speed invariance is also covered by the use of Hidden

Markov Models (HMM), although the latter may suffer from coarse time modelling.

In general, the basic features of time-scale invariance, finely-grained time warping and the use of a simple template or reference example to be compared with the incoming gesture are adopted from the DTW, presented though through the HMM formalism for profiting from the conveniences provided by probabilistic approaches, namely the open-ended nature of gesture temporally speaking, as opposed to a constraint of DTW, which is the operation on complete, spatially defined gestures.

The gesture template is structured as a succession of states, each of which is associated to a probability density function, setting the observation probability of the data.

This structure can then be associated to an HMM

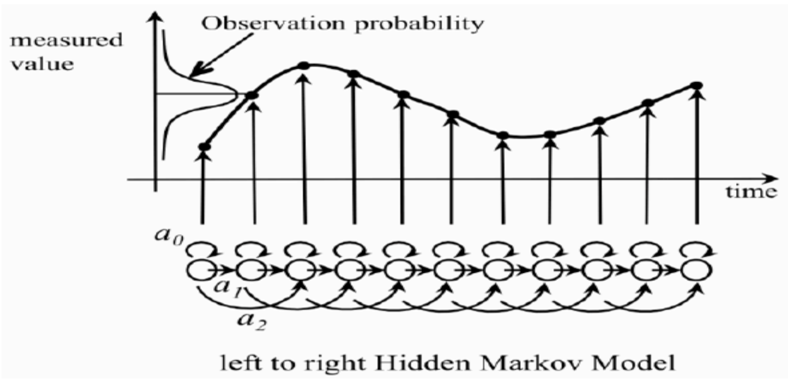

Fig. 8.2 HMM structure associated to a gesture template

Figure 151: Hidden Markov Model structure associated to gesture. Reprinted from Bevilacqua et al. 2011, p. 132 with kind permission.

The fact that the sampling rate is regular simplifies the learning procedure. In this case, all transition coefficients of the same type between states (a0 =stay, a1 =next, a2 =skip, etc) must share identical values, which can be manually set using prior knowledge. The learning procedure consists simply of recording at least one gesture, stored in a matrix G (NxM). Each matrix element is associated to the mean μ_i of a normal probability function b_i, corresponding to the observation probability function. Using several gesture templates corresponds to recording and storing of an array of G_k matrices.

The value of the variance can also be set using prior knowledge. For example, prior experiments can establish typical variance values for a given type of gestures and capture systems. A global scaling factor, which operates on all the variance values, can be manually adjusted by the user.

As soon as the template gesture has been recorded or « learnt », we come now to the second phase, that of the online processing or *following*, the term adopted by probabilistic methodologies used for *score-following*[448].

The gesture follower computes in real-time two parameters : *Time warping* and *Likelihood*.

The first is the temporal differentiation of the new, live gesture, in relation to the already recorded gesture, which is defined as *time warping* (distortion or twist), as presented in the following image :

[448] Schwarz, D., Orio, N., Schnell, N.: Robust polyphonic midi score following with hidden markov models. In: Proceedings of the International Computer Music Conference, ICMC (2004), Cont, A.: Antescofo: Anticipatory synchronization and control of interactive parameters in computer music. In: Proceedings of the International Computer Music Conference, ICMC (2008)

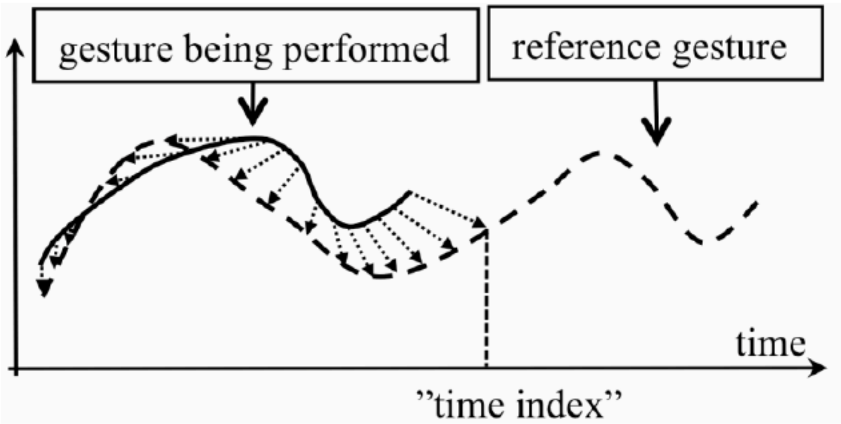

Fig. 8.3 Online time warping of the gesture profile

Figure 152: Online time warping of the gesture profile. Reproduced from Bevilacqua et al. 2011, p. 133 with kind permission.

Please note the following important distinction : In the case of the *Gesture Follower*, the Markov chains are built on the basis of an ontologically similar property, that is on the basis of the time index of an already performed gesture. On the contrary, in the case of score following, the basis for building a probabilistic model, defining the variance etc. is rather the *symbolic music score*, appropriately transcribed for use by the relevant score following system.

The second value, *Likelihood*, is a measure of the similarity of the performed gesture to the recorded one, or the probability that the new gesture is being generated by the recorded one. Since the likelihood parameters are being computed in real-time, they can also operate on open-ended gestures or achieve gesture recognition *before* the completion of the gesture. In a typical situation, the incoming gesture is simultaneously compared to multiple templates, so that additional recognition tasks may be achieved : Not only *if* one template generates the gesture, but also *which* template generates the gesture.

The process of mapping the gesture upon audio features differentiates also between two distinct techniques, known as *explicit* or direct and *implicit mapping*. In the first case, the relationship between gesture and sound, input and output, is mathematically designed and directly controlled by the user. In the second case, implicit mapping is achieved through machine learning techniques during a training phase, so that in the actual performer has only indirect control over the learnt mapping.

The *Gesture Follower* uses both types of mapping, with an emphasis on the implicit mapping thanks to the use of the time index created during the learning phase. In simple terms, the mapping is the synchronization of two parameters, one refering to gesture, the other to sound, based both on continuous alignment (since the computation is real-time, outputing time-index values in a continuous way) and discrete, based on cues or time events which will trigger certain processes.

In the following example, the two parameters in question are audio loudness and hand acceleration. Notice a typical decoupling, whereby a constant increase in audio loudness requires two cycles of hand acceleration.

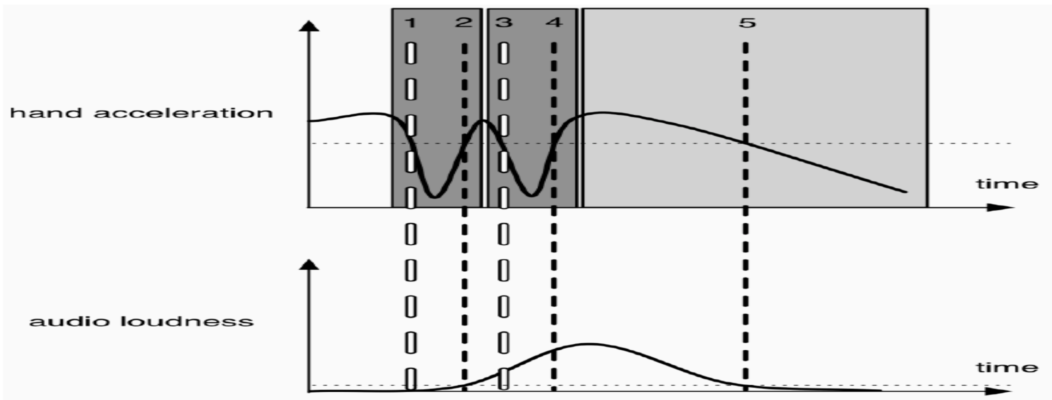

Fig. 8.4 Toy example of temporal mapping between hand acceleration audio loudness. Mapped gesture data is composed of three phases: one first phase (dark grey), a repetition of this first phase (dark grey) and a third different phase (light grey). Vertical lines indicate similar gesture values.

Figure 153: Temporal mapping between hand acceleration and loudness. Reproduced with kind permission from Bevilacqua et al., 2011, p. 136.

The processing of the audio ouput was achieved through the use of an advanced phase-vocoder system, so that gesture may be used for controlling the playback speed of a recording. In a given “conducting scenario”, the player may stretch or compress the audio during the following phase, given that she has recorded the gesture template while listening to the original recording in the learning phase.

Appendix 2 : Pedagogical applications of the *GesTCom*

Pedagogical applications of the system *GesTCom* have been an object of communication on several occasions, including invited talks, demonstrations of the system and workshops with pianists at dfferent levels. A complete listing of those events is provided in the list of communications.

This short report summarizes the main reactions, criticisms and experiences pointing at potential future applications and improvements of the system.

A recurring theme after every presentation of the *GesTCom* for classical music pedagogues was an almost universal detachment from issues of archiving, representability, external processing, reproducibility and communicability of learning and practicing rituals. In particular, a common situation would be the following: Most people would be able to follow very well the operations of piano learning I was referring to, for example the reduction of pitch content in a complex composition so as to reflect the different embodied layers; or the exploration of different prioritization filters shaping interpretation and being tested with the *motionfollower*. A stereotypical response would be “yes, we already do that, so why use technology for it?”. In a published review, someone praised the virtues and sophistication of the system, to resume that “it was used for tasks which would still be manageable with pen and paper”.

Such responses are quite characteristic of the existing gap between music technology as a rapidly growing field, very often in active dialogue with music composition, but not at all with music performance, whether classical or new, and its pedagogy. Classical music education in particular seems to be permeated by a certain technophobia and reluctance to deal with new media, mostly expressed by “digital primitives” over the age of 40 rather than the “digital native” students, whose responses were very encouraging.

My response to general critique questioning the use of technology for fulfilling tasks, which could also be fulfilled in a traditional way, would point at different fields of technological advancement. So I would ask if the participants would be willing to return to writing letters and hand-written dissertations rather than e-mails and electronic documents. Then I would point to the advantages of those technologies as to how they facilitate communication, reproducibility, representability, external processing and meta-data or archiving features, and would point to potential future applications of *GesTCom* in that respect, in particular:

1) The consistent archiving of the learning trajectory in terms of meta-data and with self-monitoring possibilities through the augmented multimodal feedback offered by the data visualization. In that respect, the long practicing sessions typical of classical musicians could become more efficient and leave a trace in the form of data, rather than exclusively depend on some sort of inner development.
2) The augmentation, externalization and representation of traditional practices, such as score-annotations and learning diaries and logbooks. Self-monitoring devices have already been in place with ancient technologies, and those new technologies constitute extensions and augmentations rather than replacements of the latter.
3) The idea of radical externalism as opposed to learning as internalization seems to be one of the most resistant when talking to classical music educators. The idea that certain features can be outsourced to the environment, allowing for greater efficiency in tasks which are otherwise supposed to be contributing to the students' long-term development, could be even judged as harmful.
4) The idea of communicability of practice, for example through a platform for online learning of a piece by several participants around the world or for group lessons of musical instruments from a distance, seemed also quite shaking for the norm of classical music education, in the form of one-to-one tuition and solo practicing instead of collective practicing.

Another critique, especially as to applications of the *motionfollower* for allelomimetic learning, would be the degree of personalization that the tools enable. Many people were afraid that the recording, analysis, modelization of physical movement could lead to some sort of mechanical reproduction of movements, which would defy the inherent performative idiosyncracies. In such critiques, I should always point out the tools' accommodation of personal performative needs and features, their highly customizable nature, as well as the fact that such applications are on the contrary helping to define the limit between universal biomechanical constraints and personal expression. To give a telling example, concerning the PADR envelope: Despite the very personal touches of attacking or ways of displacing, or even the ergonomicity or not of certain fingerings, all pianists will need to resort to coarticulation of some sort of upper arm participation, in order to play non-linear materials, in short leaps. There is a limit to personality and expression and analyzing how they emerge out of the mentioned constraints is a worthwhile endeavor.

Students' responses to the technologies were very promising. In more than one occasions, people were able to sight-read complex materials, such as music by Xenakis or Ferneyhough, and then compare their original reading to alternative representations, which were generally found simpler to read. In other cases we used the *motionfollower* for the allelomimetic study of difficult passages: The teacher would demonstrate the top-down learning process and record it, and the student would imitate it in their own idiosyncratic way, with the system following or not as a measure of the main segmentation being retained. Some people chose to perform traditional repertoire and test the *motionfollower* with interpretational variations of a more traditional type, for example tempo rubato. Finally, there were interesting cases of improvisation, whereby the multimodal recording of a long improvisation allowed for the *a posteri*ori recognition of gestalts in all modalities, that the pianist would have during the performance neither intended nor perceived.

Appendix 3 : Composition and Improvisation applications of the *GesTCom*

An artistic application of the *GesTCom* was explored in the context of a long-term project with the London-based composer and improviser Panos Ghikas.

The initiation of the project, on the occasion of the Music and / as Process conference in Bath University (2016) bore the title *Open Cycles: Embodied Navigation of Unreal-time improv*.

http://panosghikas.com/unrealtime/#PAVLOS_MENU
accessed 09.05.2018

Open Cycles is a joint project that combines Panos Ghikas' concept of *Unreal-time Improv* and Pavlos Antoniadis' concept of *Embodied Navigation of Complex Notation*. The former approaches improvisation and composition as interchangeable and complementary strands of music-making through audio timeline navigation; the latter explores a similar fluidity between the realms of gesture, notation and sound in piano performance. Having already explored the concept within the context of performative collaboration, one of the further aims is to refine its technological application by focusing on the potential for both processing and generating fixed compositional works.

In this collaboration, the Unreal-time improve methodology will be utilized as a technique, but with a new starting point: Fixed composition will be subjected to a process of progressive transformation through an improvisation-notation-performance cycle. The intention is that this will yield a series of variations on the original composition, whereby the development is derived by a sequence of re-improvisations and re-notations.

So far, the recording process and the performance interface have technologically materialized this cycle. Pavlos Antoniadis' contribution in the domain of performance extends the mediation at the domain of notation to a wider investigative sphere, where the sequence of actions within that cycle are challenged, bringing into question whether notation remains the salient defining element that differentiates improvisation from composition.

The resulting performance of this cycle will attempt to challenge temporal perceptions by offering a new gestural syntax to both the composer/performer and the audience.

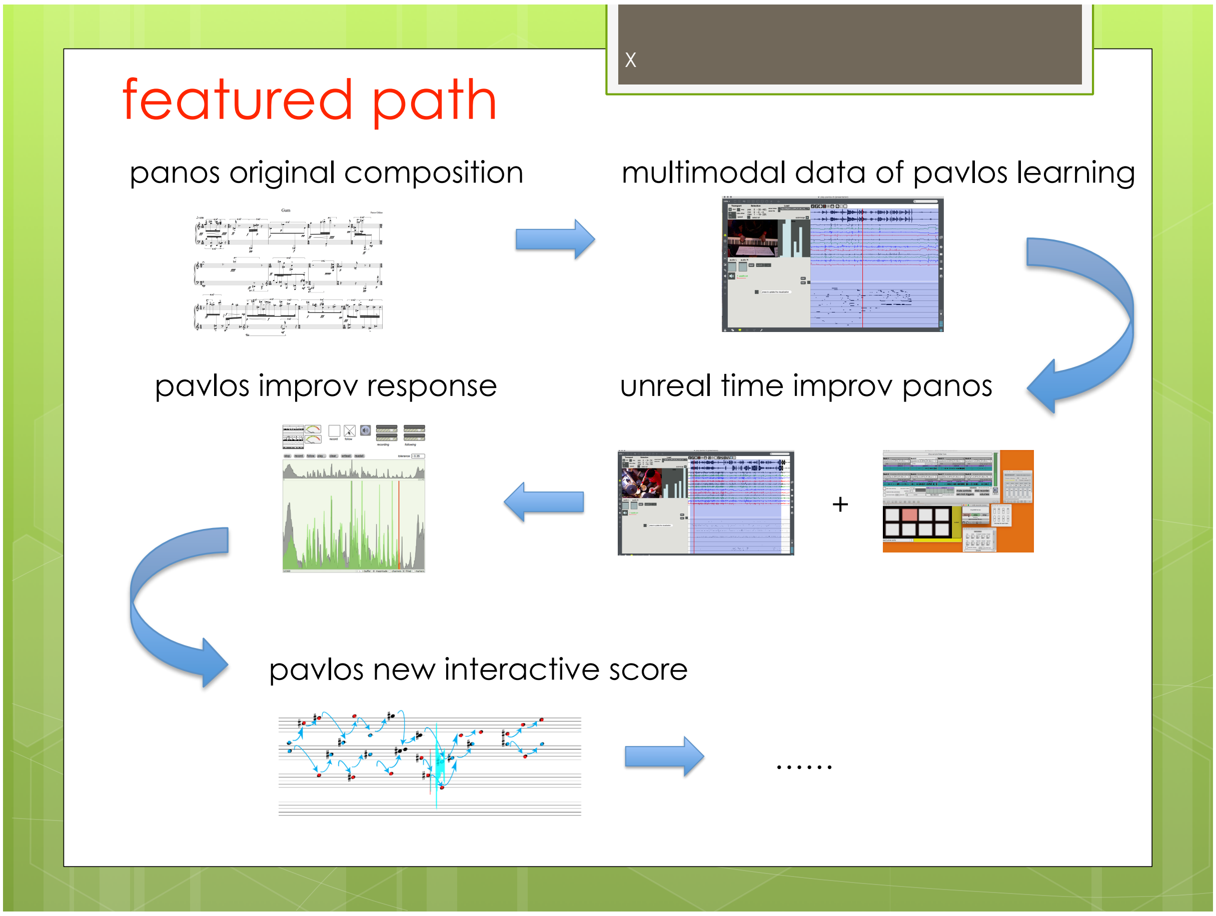

Figure 154: Schematic representation of the interaction between Panos Ghikas and Pavlos Antoniadis. The basis is Panos's original composition ("Gum" for piano solo). I recorded multimodal data during the learning process, which were subsequently fed into Panos's sampling system. Panos improvised with the samples of my learning process and I improvised a response to his performance, using the *motionfollower*. My performance generated a new notation, which subsequently started a new learning cycle.

In the following videos (all accessed 09.05.2018), you may watch some of the results of this process.

https://www.youtube.com/watch?v=-XGtl9brUEQ : Rehearsal at LabEx GREAM, Université de Strasbourg

https://www.youtube.com/watch?v=2ACtvNNPySw : Presentation at the *Music and / as Process* conference at Bath University, UK, June 2016

https://www.youtube.com/watch?v=kjYSRJyMRrM : Performance at Kontraklang Festival, Berlin, May 2017

Appendix 4 : List of Multimodal Recordings 2016-2018

Brian Ferneyhough: *Lemma-Icon-Epigram for piano solo*
Galina Ustvolskaya: *Sonata Nr. 6 for piano solo*
Ghikas Panos*: Gum, for piano solo*
Luigi Nono: *…sofferte onde serene… for piano and tape*
Mark Andre: *Contrapunctus for piano solo*
Nicolas Tzortzis: *Piano Concerto Nr. 1 for piano and orchestra*
Oliver Messiaen: *Mode de valeurs et d'intensités*
Protopopov, Sergej: *Sonata Nr. 2 for piano solo*
Wieland Hoban: *when the panting STARTS for piano solo*
Xenakis, Iannis: *Mists for piano solo*
Yuji Takahashi: *Chromamorphe II for piano solo*
Zimmermann, Walter: *Wüstenwanderung for piano solo*

Appendix 5 : List of Conferences and Publications 2008-2018

List of conferences & invited talks:

23.04.2018, Universität der Künste Berlin, Seminar für zeitgenössisches Klavier, invited talk: „Über *Wüstenwanderung* von Walter Zimmermann"

06. & 07.04.2018, Institut für Neue Musik und Musikerziehung, Akademie für Tonkunst Darmstadt, 72. Frühjahrstagung des INMM, invited talk and workshops with Frédéric Bevilacqua : „Musikalisierung des Körpers – Verkörperung der Musik: Interaktive Systeme für das Üben und Aufführen neuer Musik" ; „Workshop (nicht nur) für PianistInnen: Der Körper denkt. Klavierüben als körperliche Navigation durch Interaktive Systeme" ; „Campus Neue Musik für Jugendliche und Musikwerkstatt für Kinder" http://www.neue-musik.org/2017/06/01/tagung-2018/

27.03.2018, Université de Strasbourg, conference talk: « Les jeux subtiles de la poétique, des mathématiques et de la philosophie autour de la musique de Walter Zimmermann » : "Performance analysis of Walter Zimmerman's *Wüstenwanderung*" https://gream.unistra.fr/uploads/media/Programme_de_la_journee_d_etudes_Walter_Zimmermann_01.pdf

13.02.2018, Université de Strasbourg, Séminaire des jeunes Chercheurs, conference talk : « Navigation incarnée de l'écriture complexe pour piano: Réflexion sur l'interaction musicale de la perspective d'un interprète »

17.01.2018, Sonic Arts Research Centre, Queen's University Belfast, invited talk : "Interactive systems for the embodied navigation of complex piano notation" https://www.qub.ac.uk/schools/ael/FileStore/Filetoupload,789760,en.pdf

06.12.2017, Contemporary Music Lab, Aristotle University of Thessaloniki, invited talk: "Interactive systems for the embodied navigation of complex piano notation" http://cml.web.auth.gr/?p=504

02.09.2017, Musikstudio Ohrpheo, Berlin, invited talk: „Die digitale Revolution der Musik" https://pavlosantoniadis.wordpress.com/2017/12/27/02-09-panel-discussion-die-digitale-revolution-der-musik-musikstudio-ohrpheo-berlin/

24.05.2017, Laboratory for Research on Learning and Development, Université de Bourgogne, Dijon, invited talk: "Gesture cutting through textual complexity: A model and a tool for the embodied navigation of complex piano notation” https://www.youtube.com/watch?v=KmE3dRW04oA

17.03.2017, Université de Strasbourg, 5ème Journée des Jeunes chercheurs du GREAM: « L’analyse musicale au-delà de la partition », conference talk : « Le retour de la partition et les limites de la représentation dans le tournage performatif » https://gream.unistra.fr/activites/evenement/?tx_ttnews%5Btt_news%5D=14206&cHash=889db7f196443551ae85cf546bf3c3ac

15.12.2016, Kainan University, Taiwan, WOCMAT 2016 – IRCAM Forum Conference, invited talk and demo: “Gesture cutting through textual complexity: A model and a tool for the embodied navigation of complex piano notation” http://wocmat-ircam.strikingly.com/

13.11.2016, Shadok, Strasbourg, « Résonances électriques » , invited talk with Frédéric Bevilacqua : « Captation du geste instrumental et l’interaction » http://www.resonanceselectriques.eu/portfolio/captation-geste-instrumental-interaction/

29.10.2016, International College of Liberal Arts, Yamanashi Gakuin University, Kofu, Japan, “music + the brain symposium”, invited talk: “Gesture cutting through textual complexity: A model and a tool for the embodied navigation of complex piano notation” https://www.musicla.info/single-post/2016/10/17/2016-Music-and-the-Brain-Event-Schedule

22.09.2016, IRCAM, Paris, “New Notations Symposium”, invited talk: “Old notation, new interface: embodied navigation of complex piano notation with the GesTCom” http://www.sonicwriting.org/ircam.html

17.09.2016, Universität Mainz, XVI. Internationaler Kongress der GfM, conference talk : „Verkörperung des inneren Hörens in Mark Andres frühem Kavierwerk“ https://www.gfm2016.uni-mainz.de/files/2015/08/Details-Samstag-17.-September-2016-Saturday-17-september-2016.pdf

05. & 06.07.2016, Megaron, Thessaloniki, 3rd International Symposium on Movement & Computing, conference demo : "Simulation of learning Brian Ferneyhough's *Lemma-Icon-Epigram* for solo piano with the *GesTCom*" https://moco16.movementcomputing.org/index.php/2016-06-21-16-12-10/2016-02-08-11-49-49.html

02.07.2016, Bath Spa University, "music and/as process conference", conference talk and demo with Panos Ghikas: "Open Cycles: Embodied Navigation of Unreal-time Improv", https://musicandasprocess.org/2016/05/08/music-andas-process-conference/

09.06.2016, ExRotaprint, Berlin, Berliner Künstlerprogramm des DAAD, round table: "The ties that bond contemporary music and political action"

27-29.05.2016, Anglia Ruskin University, Cambridge, colloque international TENOR 2016, conference talk : "Processing of symbolic music notation via multimodal performance data: Brian Ferneyhough's *Lemma-Icon-Epigram* for solo piano, phase 1" http://tenor2016.tenor-conference.org/program.html

23-26.05.2016, Dias de Musica Electroacustica, Lisbon, Residency : "embodied navigation of complex piano notation"

04.05.2016 & 08.05.2016, Hong Kong University Museum & Hong Kong New Music Ensemble, Papay Gyro Nights 2016 Hong Kong, invited talk: "Embodiment and gesture capture as a performer-specific perspectival point to Iannis Xenakis' solo piano work" http://www.papaygyronights.papawestray.org/PGN2016_HK.html

01.04.2016, Institut für Neue Musik und Musikerziehung, Akademie für Tonkunst Darmstadt, 70. Frühjahrstagung des INMM, invited talk: „In Ketten Tanzen? Körperliche Navigation in Brian Ferneyhoughs Klavierkomposition Lemma-Icon-Epigram" http://www.neue-musik.org/2016/03/23/tagung-2016/

24.04.2016, Université de Strasbourg, Journée d'études GREAM, workshop organization: "Mener une étude expérimentale de l'interaction homme-machine en musique: concepts, outils et équipement" http://gream.unistra.fr/activites/evenement/?tx_ttnews[tt_news]=12485&cHash=8f65f5fd698c4cec3c4cb488c93bb65f

17.03.2016, Universidade Católica Portuguesa, Porto International conference on musical gesture as creative interface, communication: "Gesture cutting through textual complexity: A model and a tool for the embodied navigation of piano notation" http://artes.porto.ucp.pt/pt/porto-international-conference-music-gesture-as-creative-interface?msite=10

11.03.2016, Université de Strasbourg, 4ème Journée des Jeunes chercheurs du GREAM: « Instruments, instrumentalité, lutherie », conference talk : "Turning notation into an instrument: A model and a tool for the embodied navigation of piano notation" http://gream.unistra.fr/activites/evenement/?tx_ttnews%5Btt_news%5D=10228&cHash=775b21e5c65deb98f715fbea1bff6a6d

03.02.2016, Cité de la musique et de la danse Strasbourg, « semaine du piano / regards sur le piano contemporaine », conference talk and round table: "Embodied navigation of complex notation via *GesTCom*"

25.09.2015, Université de Strasbourg, Colloque franco-allemand, « Créer, écouter, ressentir, s'identifier: le dialogue musical franco-allemand aujourd'hui », conference talk: « À PROPOS DE TERRITOIRES DE L'OUBLI DE TRISTAN MURAIL» https://gream.unistra.fr/evenements/colloques/colloque-creer-ecouter-ressentir-sidentifier-le-dialogue-musical-franco-allemand-aujourdhui/

29.05.2015, Sorbonne & Ircam, Paris, colloque TENOR 2015, conference talk with Eric Maestri : "Notation as Instrument: From Representation to Enaction" http://tenor2015.tenor-conference.org/

13.03.2015, Université de Strasbourg, 3ème Journée des jeunes Chercheurs du GREAM « Entre subjectivité et objectivité, la recherche musicologique aujourd'hui », conference talk : “Embodied Navigation of Complex Notation via *GesTCom*: Representing how Subjective Interpretation transforms the Score-Object” https://gream.unistra.fr/evenements/journees-detudes/3eme-journee-des-jeunes-chercheurs-du-gream-entre-subjectivite-et-objectivite-la-recherche-musicologique-aujourdhui/

13.02.2015, Université de Strasbourg, Journée des études GREAM « Quand l’enregistrement change la musique », conference talk : « Captation du geste comme complément des enregistrements sonores. Recherche et implications esthétiques et ontologiques »,https://gream.unistra.fr/uploads/media/Programme_de_la_Journee_d_etudes_Quand_l_enregistrement_change_la_musique_02.pdf

04.12.2014, Staatliches Institut für Musikforschung, Berlin, 9th Conference of Interdisciplinary Musicology CIM 14, communication : “Gesture cutting through textual complexity: Towards a tool for online gestural analysis and control of complex piano notation processing” http://www.sim.spk-berlin.de/cim14_919.html

30.06.2014, New Interfaces for Musical Expressions conference, Goldsmiths University, London, Keyboard Salon Workshop: Connecting instrument designers and artistic practitioners. Demo avec Frédéric Bevilacqua & Dominique Fober: “Gesture cutting through textual complexity: Towards a tool for online gestural analysis and control of complex piano notation processing”

16.05.2014, École des hautes études en sciences sociales, Paris, séminaire « Le geste musicale »: “Gestural Navigation of Complex Piano Notation”, invited talk with Frédéric Bevilacqua

31.03.2014, IRCAM, Paris, Séminaires Recherche & Création : “Gesture Cutting through Textual Complexity” , invited talk with Frédéric Bevilacqua https://medias.ircam.fr/x2b55e6

08.03.2014, Aristotle University of Thessaloniki, Contemporary Music Lab, invited talk: “Corporeal Navigation of Complex Notation: Embodied and Extended cognition as a model for discourses and tools for complex piano music after 1950”

27.01.2014, IRCAM, Paris, Séminaires MaMux , conference talk: “Corporeal Navigation of Complex Notation: Embodied and Extended cognition as a model for discourses and tools for complex piano music after 1950” https://medias.ircam.fr/xa05de8

11.02.2013, Orpheus Research Centre in Music, Gent, research fellowship interview :
“Corporeal Navigation of Complex Notation: Embodied and Extended cognition
as a model for discourses and tools for complex piano music after 1950”

18. & 19.10.2013, Goldsmiths University, London, Notation in Contemporary Music: Composition, Performance, Improvisation, conference talk with Dimitris
Exarchos : “Notation and Temporality in Ferneyhough and Xenakis”

15.11.2012, Trinity College, Dublin, invited talk: “Performance-Practice for Complex Piano Music: From the sequence understanding-technique-interpretation to the notion of corporeal navigation”

13.11.2012, Goldsmiths University, London, invited talk: “Performance-Practice for Complex Piano Music: From the sequence understanding-technique-interpretation to the notion of corporeal navigation”

11.11.2012, Goldsmiths University, London, conference talk: The Interactive Keyboard Symposium: “The silent piano: Amalgamation of textual complexity, new interfaces and live-electronics in Nicolas Tzortzis’ *Incompatible(s) V*”

03.03.2012, Auditorium Institut Français d’Athènes, invited talk: “Complex piano music today: From interpretation to corporeal navigation”

11.01.2012, Hochschule für Musik C.M. von Weber Dresden, invited talk: „Von der Reihe Verständnis-Technik-Interpretation zu körperlicher Navigation“

18.10.2012, Tagung Musiker 3.0- Beruf mit Zukunft, HfM Dresden. Poster presentation:
“Klavier-Zentauren und –Navigatoren: Über die Aktualisierung der Ausbildung und das Schicksal des Klavierabends”

07-09.09.2012, University of Kent, Material Meanings Conference, conference talk : “Corps, que me veux-tu? Embodiment and Visuality in Post-1950 music”

01-03.04.2011, Goldsmiths University, London, I. Xenakis International Conference, conference talk: “Physicality as a performer-specific perspectival point to I. Xenakis' piano work. Case-study *Mists*”

01-05.07.2010, Aristotle University, Thessaloniki, conference talk Beyond the Centres: Musical avant-gardes since 1950, communication : “Learning Complex piano music: Environmentalist Applications”

02-06.07.2008, 4th Conference on Interdisciplinary Musicology: Musical Structure, Aristotle University, Thessaloniki, conference talk with Danae Stefanou : “Inter-structures: Rethinking continuity in post-1945 piano repertoire”.

List of publications:

1. Pavlos Antoniadis, Frédéric Bevilacqua, Dominique Fober, « Gesture cutting through textual complexity: Towards a tool for online gestural analysis and control of complex piano notation processing », Proceedings of the 9th Conference on Interdisciplinary Musicology – CIM14, p. 236-241, Berlin, Germany, 2014

2. Eric Maestri, Pavlos Antoniadis, « Notation as Instrument : From Representation to Enaction», Proceedings of the TENOR 2015, First International Conference on Technologies for Music Notation and Representation, p. 211-218, Paris, France, 2015

http://tenor2015.tenor-conference.org/TENOR2015-Proceedings.pdf

3. Pavlos Antoniadis, Frédéric Bevilacqua, «Processing of symbolic music notation via multimodal performance data: Brian Ferneyhough's Lemma-Icon-Epigram for solo piano, phase 1», Proceedings of the TENOR 2016 conference, p. 127-136, Anglia Ruskin University Cambridge, 2016 http://tenor2016.tenor-conference.org/TENOR2016-Proceedings.pdf

4. Pavlos Antoniadis, «Körperliche Navigation mittels interaktiver Systemen in Brian Ferneyhoughs Klavierkomposition *Lemma-Icon-Epigram*», Berichtsband der 70. Frühjahrstagung des INMM, Body sounds. Aspekte des Körperlichen in Neuer Musik, p. 218-235, Darmstadt, 2016

5. Pavlos Antoniadis, «Verkörperung des inneren Hörens in Mark Andres Klavierkomposition *Contapunctus*», Berichtsband der XVI. Internationaler Kongress der GfM, Mainz, 2016 http://schott-campus.com/inneres-hoeren-bei-mark-andre/

6. Pavlos Antoniadis «Corporeal Navigation: Embodied and Extended Cognition as a Model for Discourses and Tools for Complex Piano Music After 1945», in CeReNeM Journal, University of Huddersfield, Issue 4 (ed. P. Alvarez), March 2014 http://issuu.com/cerenem/docs/cerenem_journal_issue_4

7. Pavlos Antoniadis,«Physicality as a performer-specific perspectival point to Iannis Xenakis' piano work. Case-study *Mists*», Iannis Xenakis International Conference, conference proceedings, April 2011, Goldsmiths University, London https://www.gold.ac.uk/cmru/xenakis-international-symposium/programme/

8. Pavlos Antoniadis, «Learning Complex Piano Music: Environmentalist Applications», Beyond the Centres: Musical avant-gardes since 1950 conference proceedings, July 2010, Aristotle University of Thessaloniki http://btc.web.auth.gr/proceedings.html

9. Danae Stefanou, Pavlos Antoniadis, «Inter-structures: Rethinking continuity in post-1945 piano repertoire», JIMS Online Journal (Spring 2009) http://musicstudies.org/wp-content/uploads/2017/01/Stefanou_JIMS_0932105.pdf

10. Pavlos Antoniadis, «Körperliche Navigation: Verkörperte und erweiterte Kognition als Hintergrund der Interpretation komplexer Klaviermusik nach 1945», in: Jörn Peter Hiekel, Wolfgang Lessing (eds.) *Verkörperungen der Musik: Interdisziplinäre Betrachtungen*, p. 185-210, transcript-verlag: Bielefeld, 2014

11. Pavlos Antoniadis,«Corps, que me veux-tu? Embodiment and Visuality in Post-1950 music», in: Sarah Posman, Anne Reverseau, David Ayers, Sascha Bru, Benedikt Hjartarson (eds.) *The Aesthetics of Matter. Modernism, the Avant-Garde and Material Exchange*, vol.3, EAM (European Avant-Garde and Modernism Studies) book series, p. 319-334, Walter de Gruyter: Berlin & New York, 2013

12. Pavlos Antoniadis, Rezension zum: Stefan Drees, *Körper-Medien-Musik. Körperdiskurse in der Musik nach 1950*, 168 S., Abb, Wolke: Hofheim, 2011 in: *Positionen. Texte zur aktuellen Musik*, Heft 92, S. 50

Pavlos ANTONIADIS

EMBODIED NAVIGATION OF COMPLEX PIANO NOTATION: RETHINKING MUSICAL INTERACTION FROM A PERFORMER'S PERSPECTIVE

Abstract

This thesis proposes a performer-specific paradigm of embodied interaction with complex piano notation. This paradigm, which I term *embodied navigation,* extends and even confronts the traditional paradigm of textual interpretation. The latter assumes a linear and hierarchical process, whereby internalized understanding of the musical text is considered a prerequisite of instrumental technique towards personal interpretation. In lieu of that, I advocate for a dynamic, non-linear, embodied and external processing of music notation. At a second stage, the proposed paradigm serves as the basis for the development of methodologies and customized tools for a range of applications, including: performance analysis, embodied interactive learning, contemporary composition, free improvisation and piano pedagogy.

Piano, contemporary music, complexity, embodiment, embodied cognition, embodied navigation, interaction, notation, affordances, multilayered tablatures, *GesTCom*, interactive systems, gesture, movement, gesture capture, *motionfollower*, HCI, NIME, Xenakis, Ferneyhough, Tzortzis, Hoban, Andre.

Résumé en français

La thèse propose un paradigme d’interaction avec la notation musicale complexe pour piano selon une perspective « incarnée » et «située » de l’interprète. Ce paradigme, que je nomme *navigation incarnée*, s’oppose au paradigme traditionnel d’interprétation textuelle. Le paradigme traditionnel considère un processus de lecture linéaire et hiérarchique, selon lequel la compréhension et l’internalisation du texte musical sont les conditions préalables pour l’application de la technique instrumentale, permettant par la suite une interprétation personnelle. À la place de ce paradigme, je propose de traiter la notation musicale comme un élément dynamique, non linéaire, et à la fois incarné et externalisé. Dans une deuxième phase, le paradigme proposé devient la base du développement d’outils adaptés au projet de la navigation incarnée et de diverses applications, incluant l’analyse de la performance, l’apprentissage incarné et interactif, la composition musicale et l’improvisation.

Piano, musique contemporaine, complexité, incarnation (embodiment), cognition incarnée, navigation incarnée, interaction, notation, affordances, tablatures multidimensionnelles, *GesTCom*, systèmes interactifs, geste, mouvement, captation du geste, *motionfollower*, interaction homme machine, nouvelles lutheries, Xenakis, Ferneyhough, Tzortzis, Hoban, Andre.