Doctoral theses at NTNU, 2022:3

Mathieu Lacroix

Deus Ex Machina

Synchronization Strategies in Mixed Music

Doctoral thesis

NTNU
Norwegian University of Science and Technology
Thesis for the Degree of
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ISBN 978-82-326-5317-1 (printed ver.)
ISBN 978-82-326-5197-9 (electronic ver.)
ISSN 1503-8181 (printed ver.)
ISSN 2703-8084 (online ver.)

Doctoral theses at NTNU, 2022:3

Printed by NTNU Grafisk senter

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Abstract

Due to the live nature of mixed music, synchronization is a quintessential challenge. This thesis proposes to classify and discuss synchronization by introducing the concept of a synchronization strategy. This concept makes it possible to explore mixed music from both a poietic and aesthesic perspective, ranging from the compositional process to performance issues.

By comparing and contrasting pieces from the repertoire, this thesis attempts to develop a theoretical and graphical framework further to discuss and analyze mixed music. Discussions on synchronization strategies, performance techniques, synchronization hierarchies and deviation tolerance give a clearer understanding of issues surrounding the temporal relationship between musicians and electronics. The complex relationship between composition and synchronization is discussed by using the concept of affordances.

This thesis uses the paradigm of *recherche-création* to use art to further theoretical discussions. I worked as a RIM on several productions, which are described in the text to present in various perspectives issues of synchronization within the repertoire. Through this work, discussions of the effects of shifting synchronization strategies are broached. Three of my own compositions are also discussed further to show the links between synchronization and compositional processes.

The thesis attempts to combine elements from theory, RIM practice and composer practice to have a holistic view on synchronization and its complex relationship with the music. Analysis of repertoire pieces and pieces I have performed give a more balanced view of the field. Additionally, I attempt to discuss differences in repertoire between soloistic, chamber music and orchestral music and how each repertoire has its own challenges within synchronization, pragmatism, performability and composition.

Keywords: Mixed music, synchronization, compositional process, analysis, contemporary music, RIM

Acknowledgements

There are too many people to list in total for this endeveaour. I would like to thank all of the composers I have met on my trips and classes whether it was at IRCAM or Musiques et recherches or any other place. Many of these meetings have led to strong friendships. I'd also like to thank my early music teachers: Martin Laporte, Tommy McKinnon and Veronica Galicia. All three of you taught me the discipline and love of music needed to be able to accomplish this thesis. I wouldn't be here today without you. I would like to thank my colleagues at the music technology department at NTNU. Other important musicians and composers have been Espen Aalberg, Marianne B. Lie, Ellen Lindquist, Frank Ekeberg, Hilmar Thordarson, Gabriel Trottier, Tonje Elisabeth Berg, Trine Knutsen, Chaz Underriner, James O'Callaghan and many others. Thank you for the great conversations and discussions about contemporary music, performance and electronics. Trondheim Sinfonietta has also been an important actor and family for me throughout these years since joining in 2017. A huge thank you to my thesis advisors Andreas Bergsland, Trond Engum and Natasha Barrett. Thank you for listening to me groan and read through way too many revisions of the thesis. Thank you to my parents for letting me even get into music when they bought me (to their regret) a drumset and had to listen to it several hours every day. Last but not least, thank you to my beautiful wife Hilde, and our two furballs Maja and Gustav. I couldn't have done this without your support and understanding.

I would like to dedicate this thesis to Antony Cooper and Svein Håvard Fiskvik that both passed away in 2020. Antony, thanks for all the long talks about philosophy and music over the ten years we knew each other. I hope you found the peace you longed for. Svein Håvard, thank you for teaching me everything I can about logistics and rigging. You made long days at Olavshallen fun, and your humour was always contagious.

"There are two means of refuge from the miseries of life: cats and music." -Albert Schweitzer (Apocryphal)

Notes

Any translation from either French or Scandinavian languages to English is my own unless otherwise indicated throughout this thesis. The original text will generally also be quoted in a footnote.

Composition name (year) refers to a specific composition and its score. Time as measured when referring to a sound file or recording, is written as [mm.ss]. When referring to a score, measures (or page numbers if the measures are not numbered) will be given.

Some of the scores referred to are not necessarily for sale and must be loaned from the publisher, or sometimes directly from the composer. This is not mentioned in the text or bibliography.

When referring to notes and pitches, I will use the Scientific Pitch Notation (SPN) C0 to C8 where A4 refers to A440.

Foreign words written in italics such as *écriture* refer to that word's meaning in its original language when a translation into English does not seem suitable.

Introduction

Ce qui préoccupe l'artiste lorsqu'il imagine son tableau, lorsqu'il fait une esquisse, lorsqu'il se demande si son œuvre a atteint son point d'achèvement, c'est quelque chose de beaucoup plus délicat à traduire par des mots. Peut-être se demande-t-il tout simplement si "cela va comme ça". Et c'est seulement quand nous aurons bien compris la signification de cette question si simple et si vague en apparence que nous commencerons à saisir de quoi il s'agit vraiment.

- Ernest Gombrich, quoted in (Dusapin & McKinley, 2017, p. 71).

0.1 Scopes & Themes

Mixing acoustic and electronic sounds sources is interesting because it supports a wide range of compositional sensibilities in music. I first encountered mixed music as an undergraduate student by listening to composers like Arne Nordheim and Kaija Saariaho. Their use of electronics within a concert music idiom fascinated me. The democratization and availability of technology, which was prohibitively expensive, undoubtedly plays a role in the emerging popularity of mixed music. Information about this music and its composers is also more available today than twenty years ago.

The title of this thesis is “Deus Ex Machina”—god in the machine. However, theatre lovers will quickly point out that the expression’s meaning is quite different: it is a plot device that Cuddon (2012, p. 217) defines as “any unanticipated intervener who resolves a difficult situation.” The link to electroacoustic and mixed music is that many musicians and composers still perceive electronic processes as magical black boxes. Although this is slight hyperbole, it is an issue within the field despite the increasing normalization of technological literacy. Seeing electronics as a divine intervention that fixes everything is an attitude that has serious aesthetic and performative consequences.

Initially, the plan of this thesis was to focus on the links between electronic processes and the compositional process. However, it became apparent that the theme of synchronization often cropped up without it being explicitly discussed. There are some articles on the subject, but few go in-depth. Nevertheless, it has profound influences on the compositional and performative aspects of mixed music pieces. Much of the literature still problematizes the debate between real-time (working with sounds created here and now) and deferred time (creating a set sound narrative in a studio). This debate has focused primarily on the aesthetic rather than technical aspects of both paradigms.

This thesis's primary goals are:

- To explore the relationship between compositional procedures and synchronization strategies within mixed music. (Chapters II, IV, V and IX)
- To establish a vocabulary to discuss synchronization within mixed music. (Chapters I, II, III & VI)

This goal involves several sub-aims such as:

- To investigate performance aspects of synchronization strategies. (Chapters VII & VIII)
- To analyze and understand the various technologies and strategies that allow composers and performers to use electronics in mixed music. (Chapters II, IV, V, VIII & IX)
- To further develop a theoretical and graphic framework that lets us discuss and analyze mixed music. (Chapters II, III, V & VI)

It is essential to state that this thesis is from a composer's viewpoint, which involves a particular kind of bias. Performative aspects will be mentioned throughout, but these are not my primary field of experience. My background is mainly in music technology and composition, as well as a stagehand and sound technician for both studio and live work in many genres. I have also played drums for many years and recently began playing Chapman stick and bass.

The remainder of the introductory section will establish several of the essential terms for the field of study. Afterwards, a discussion will clarify the difficulties of studying mixed music and academic difficulties on an artistic subject. The thesis is further separated into two sections based on our main analytical paradigms: *poiesis* and *aesthesis*. These terms come from semiotics, popularized by the work of Nattiez (1987). These analytical concepts have been used in much of the literature, such as Roy's (2003) analysis of electroacoustic music. Poiesis is the production of the piece and its building blocks. Aesthesis is related to the perception of the work (Zattra, 2003).[1] Effectively, electroacoustic analysis and literature have been mainly interested in aesthesis.

[1] This thesis is not as interested about the neutral level as synchronization strategies are inherently connected to both poiesis and aesthesis.

Chapter I attempts to clarify temporality issues within contemporary music composition. Chapter II delves into synchronization strategies. Chapter III explores the literature on the compositional process and presents a new model for composing mixed music. Chapter IV brings together synchronization strategies and the compositional process by looking at the two's affordances (a term we will define in Chapter IV). Chapter V is a comparative study on several influential pieces. Chapter VI is a holistic study of Tutschku's *Zellen-Linien* (2007), which shows how the previous chapters' concepts can be used in analysis. Chapter VII discusses the performance and perception of mixed music. Chapter VIII is a comparative study on the RIM's (defined in 0.3) performance for several compositions that I have played. Chapter IX looks at synchronization strategies in three of my compositions. My personal compositional process allows me to reflect on synchronization strategies differently than in the theoretical analysis of Chapters IV and V.

0.2 Definitions & Basic Terms

The term mixed music comes from the French *musique mixte* meaning music that blends various mediums. In French, the use of *mixicité* makes more sense as it is similar to cohabitation, but it loses its meaning in English. Additionally, as Teruggi (2016) remarks, this definition would cover most of today's popular music. Most Billboard Top 100 productions every year feature a mix of acoustic and synthetic sound sources.

Michaud & Bonardi (2018) point out that the English term is singular, while the French term is often plural. Which media are mixed in this specific piece? Are there only two? Perhaps more? The various possibilities of cross-media works give radically different results but also change the audience's expectations. Would a traditional acoustic concert with a video projection count as mixed music? The situation is even more confusing when one adds the term live electronics, which has also gotten various connotations, especially between the United States and Europe. For example, Holmes (2016) uses the term much more freely than many of his European counterparts.

Although perhaps not as important as in academic circles, these terms are often too broad to use on search engines, which can be a problem for initiating new people to the field. It could be a better long-term strategy for recruitment for mixed music if more people could randomly fall on a website with recordings, for example.

For the entirety of this thesis, the term mixed music will refer to music in which some sound sources are acoustic and others electroacoustic, and that the through-composed tradition of the classical music concert stands at its heart (Tiffon, 2005). The Western cultural norm of the classical concert plays a central role in this definition. Therefore, it should be mentioned that the term electroacoustic chamber (or orchestral) music is a term that this author finds much more precise than mixed music. However, because this terminology is still not used broadly in English literature, the term mixed music will be used. It is also essential to understand that this is not a genre but a category to use Emmerson & Landy's (2016) terminology since it is based on a performance situation and aspects of technology and artistic approach.

Essentially, one could describe mixed music as a blend of contemporary art music with its post-second world war currents and electroacoustic music, which started with Schaeffer's codification of *musique concrète* and *écoute réduite* in 1948 (Gayou, 2007). Contemporary music means the many styles that have come out of the post-second world war generation, as described in Griffiths (2011) and Ross (2009). However, unlike Rutherford-Johnson (2017), I argue the term contemporary music should not include noise music artists such as Merzbow as they have more affinity towards popular music. To be considered mixed music, the music's tonal and technical language should reflect those of contemporary music. This demarcation also excludes musicians such as Nils Frahm and Ólafur Arnalds, whose music is also closer to popular music forms. Likewise, mixed music is not improvised music that blends electronic and acoustic instruments such as much free improvisation, which overlaps with contemporary music in terms of sonority. I argue that the concepts of notation and *écriture*[2] are central to the genre. The thesis will focus on the compositional trends and philosophies that have governed the concert music world to this day.

Electroacoustic music is harder to define. Landy (2006) establishes the term sound-based music to lessen the confusion of terms like electroacoustic. Furthermore, Emmerson & Landy (2016) mention that this is a bottom-up type of music because the composer builds up his or her material from scratch through the use of recordings (influence of *musique concrète* among others), electronic means (influence of *elektronische musik*), or of acoustic sound sources processed but presented in a fixed medium. If pitches are present, it is assumed that pitch (and pitch organization) plays a secondary role to timbre and texture and all of their extensions.

[2] The term *écriture* will be used throughout this thesis, which means writing. However, the French meaning of the word has more richness than its English counterpart as it includes ideas of style, context, technique and aesthetics.

0.3 Difficulties of Mixed Music

Mixed music is somewhat difficult to analyze in writing. Firstly, its combination of both note-based and sound-based music requires a broad skill base to analyze. Traditional musicology has often ignored the study of sound (Cook, 1987; Crispin, 2014). In a music category in which the combination of sound-based and note-based is the *raison d'être*, this becomes a grave issue. Many analyses in the field tend to focus on only a few aspects of a composition as the task of writing a holistic analysis is daunting.

Secondly, on the practical side, mastering note-based and sound-based composition is not easy. To this day, many composers, especially within the French ecosystem (which includes the RIM as a figure, see Zattra, 2016), use a RIM that will take care of the electronics. For many composers, this luxury is not a possibility. The word RIM stands for *Réalisateur en informatique musicale*. Although the term "computer music designer" in English exists, it does not cover the same functions, and it is not as ubiquitous as within the French tradition. In English, terminology such as computer music assistant and computer sound designer are used interchangeably. Although each term has slight differences, I will be using the term RIM for clarity and conciseness. Acosta (2016) points out that the RIM does not exist in most of the world. Issues of authorship related to the RIM's role have also become an important discussion point (Faia, 2014; Zattra, 2018, among others).

Thirdly, a vital aspect of mixed music's definition is the formal convention of the classical recital. When listening to a recording, the listener can lose this important context. It is not necessarily possible to notice what is live/acoustic and not, especially with similar sound sources. Except if the listener knows about the implementation of electronics, confusion may ensue. Because of the practices of recording technology, the division between what is live, electronic, or overdubbed are rather complex—for example, there might be up to several hundreds of edits between takes (King, 2017). Gould (1966) reflected on this issue and how it affected him as a performer and the artistic result once edited. If the electronics are edited in the same way, or perhaps redone afterwards, is it live? Analyzing and working exclusively with recordings of mixed music is inherently closer to the analysis of electroacoustic music. Couprie (2016, p. 170) remarks: "A stereophonic sound file alone cannot define the work." The work is more than just the recording. It is the score, the electronics, as well as the performance. Mixed music analysis should include both poiesis and aesthesis. The recording might not be an accurate representation of the piece (intentionally or not). Mixed music cannot effectively be analyzed or discussed without emphasis on concert practice. Once on a recording, there is no *mixicité* anymore; everything has become electroacoustic through editing and mixing, the work is now a fixed object.

Fourthly, multichannel pieces are often available only in stereo or binaural, which are problematic in translating the multichannel concert experience to a listener's home. Some record labels are releasing music in formats such as 5.1 or Atmos. Although it helps have a multichannel file, it will still most probably not represent the set-up in the concert hall. Additionally, it will be difficult to perceive the liveness and agency between electronics and the hall's acoustics.

Fifthly, what should one analyze? The score, which has been the main point of musicological analysis, is also fraught with problems. Manoury (1998) points at how notation lacks information. A C4 is principally just notated as a C4. Dynamics and a playing technique might be notated, but these three parameters are insufficient to describe the note that will be heard fully in terms of timbre, reverberation, amplitude, etc. The notation of electroacoustics within a traditional score often leaves the reader wondering how the music would sound. Couprie (2016) emphasizes that the score often only includes the information needed for the performer.

Sixthly, if one cannot wholly trust a recording or the score, what about the electronics? These can often give an understanding of the piece that would be difficult to get from other sources. It can be better to learn and understand a piece by testing the electronics instead of relying only on second-hand documentation. However, electronic components to mixed music works are rarely available publicly or commercially. System obsolescence is also an immense problem, and scholarly articles have been pointing at this issue for many years (Battier, 2004; Bonardi, 2013; Zattra, 2004; 2007).

These six issues show the difficulty in discussing and working within mixed music in academia. This thesis will not propose a solution for all of these difficulties, but they should be acknowledged as critical gatekeeping problems that can hinder a researcher's path. The methodology of this thesis is profoundly influenced by these issues and tries to take them into account.

Prelude I: Methodological Paradigms

Research in the humanities has had several seismic shifts in the last few decades, such as emergence of digital humanities, science and technology studies, and artistic research. These fields have made institutions question their methodology, modes of inquiry, and validity. This section aims not to go through all the scientific paradigms; it presents several epistemological issues when researching mixed music and the arts. Firstly, we will explore some of the issues facing the arts in academia. Although research in the arts might appear simple, it has deep-rooted problems and conflicts with academia. Recently, there have been countless debates about the arts in academia, both in Norway and abroad. For example, in Norway, artistic work and practice were officially recognized as being academic work.[3] The far-reaching consequences of this change are still not clear and will not be for several years. Secondly, several practice-based paradigms will be presented and compared. Thirdly, we will look at several traditions and paradigms within musicological, performance and composition studies. Fourthly, several methodological examples in mixed music will be presented. Finally, we will establish the methodology used in this thesis.

I.I Art in Academia in Norway

Artistic practice in academia is not a novelty. Art has often been included through the study of art history, the aesthetics, musicology, and other related fields. For example, in the United States, it has been possible to get a doctorate (Ph.D, not DMA) in composition since 1937 (Cook, 2015). This section will compare several relevant frameworks/paradigms for artistic research to lay the groundwork for this thesis's methodology.

Within the Norwegian context (and several European countries), doctoral studies are separated into arts-based and academic. The former requires to hand in mainly artistic products with a reflection, while the latter requires a thesis.[4] Leavy (2017) argues that this constructed dichotomy is closer to a continuum with art and science on their respective sides. Professor Bjørn Rasmussen at the Norwegian University of Science and Technology (NTNU) used this concept as the basis of seminars to familiarize graduate students with various frameworks and their challenges (Rasmussen, 2018). A division between theory and practice is at the heart of the debate. With this as the case, is it possible to gain knowledge through practice alone?

Borgdorff (2006) separates the arts into three groups: research on the arts, research for the arts and research in the arts. These possibilities require completely different research designs and often encounter different ways of knowing (Heron & Reason, 1997).

[3] It is far beyond the scope of this thesis to go into the ramifications of this decision. In practice, there is still a rather large schism between the two, despite the artistic Ph.D program now being officially recognized as a Ph.D. See Norwegian Government (2018).

[4] These forms to show results are still being debated..

Research on the arts is the traditional paradigm of studying art as an object. Examples include art history and musicology. These fields often have more to do with traditional practices in the arts by studying the object of study from a distance. Therefore, the researcher is not necessarily a practitioner or member of the group of study. Several scholars mention the irony of how music has been mainly studied from an artifact (the score) instead of through the senses (Cook, 1987; Crispin, 2014). Schenker famously proclaimed that a work of music exists without being interpreted (Stévance & Lacasse, 2013). However, this idea assumes that interpretation is not an essential part of art.

Research for the arts "can be described as applied research in the narrow sense" (Borgdorff, 2006, p. 6). These studies look at specific aspects of artistic activity, such as specific materials or techniques. In the case of music, this would include most performance studies. An example in music composition could be a portfolio of compositions utilizing spectral techniques or methodology.

The final possibility is research in the arts, which Borgdorff compares to Schön's idea of reflective action (Borgdorff, 2006). In this framework, there is little separation between the subject and object. This approach is radically different from research on the arts in which the researcher might not have any stakes within the artistic community they are studying. "It is not formal knowledge that is the subject matter of artistic research, but thinking in, through and with art" (Borgdorff, 2006, p. 1). Doing and reflecting on what one is doing becomes a critical aspect of the research (Arlander, 2010).

In both research for and in the arts, the idea of excellence seems to be of importance (as the final result is based on artistic practice), but this has been debated. Arlander (2010) specifies that full artistic production is often too complicated and challenging for research purposes. Leavy (2017) declares that we should not be asking the results of such research to be great art but on what it has brought to the research question(s). Rasmussen (2010) argues that the basis of "good art" should perhaps be less about refinement and more about social engagement and interaction. The costs (both time-wise and economic) must be considered when working or evaluating the arts in academia. Borgdorff (2012) further explains that to do successful research (by creating art), one must be considered excellent by one's community of artistic peers.

Several aspects of an art form can only be understood by working on a full production. This is because of the ephemeral nature of artistic practice. For example, only creating a piece that is "good enough" for academic research will affect the overall quality of the results. However, is it framed as "difficult" within an academic context to give the time, logistic, artistic and economic support to create a complete artistic work or body of work. Additionally, documenting these productions can be problematic. For example, how does one submit a multichannel work to a committee that might not have access to a room with multichannel playback? If spatialization was the central object of study, the committee could not scrutinize it thoroughly.

The research design needs to help the doctoral candidate achieve their goals (Gray, 1996). In Bjørn Rasmussen's (2018) class, it also became apparent that many of the graduate students wanted to use the arts, but their projects did not depend on their professionality/expertise within their respective art fields. Their community of peers would be exclusively composed of researchers within an academic field and external to the artistic field. Therefore, one could argue that their research was not part of artistic research. Understanding this field is undoubtedly demanding since few seminars and classes address the issues, the result being that some understanding only rests with artistic practitioners themselves.

The literature on arts-based research, such as Borgdorff, often seems to be arguing against a monolithic view of science and academia, which is a constructed and unnuanced view that almost serves as a scapegoat. For example, Borgdorff (2012) mentions more nuanced forms of academic research such as Mode 2 (Hess, 1997; Nowotny et al., 2003), yet he continues to describe science as unilaterally agreed-upon methods. Additionally, he compares Mode 2 to artistic research:

> *Mode 2 research is characterized (sic) by being carried out in contexts of application; it is predominantly interdisciplinary or transdisciplinary; it has no epistemological core and is methodologically pluralistic; and the direction and quality of the research is not determined by disciplinary peers alone* (Borgdorff, 2012, p. 68).

If anything, this shows that artists and academics are similar in their argumentation for more cross-disciplinary work that questions the traditional research paradigms. This monolithic view of science seems reductionistic, and at worse, is forcing us into a disciplinary ghetto, as it were, instead of opening up debates and discussions across academia. A larger debate across disciplines could also help change the situation regarding funding and discuss more significant issues such as how academic work of all kinds can be judged and reviewed.

I.II Paradigms and Traditions in Music & Contemporary Mixed Music Research

This section compares and contrasts some of the various traditions within mixed music and contemporary composition in academia. Disciplines like music technology are between traditional fields, mixing elements of performance, composition, engineering, and musicology. Cook (1987; 2001) discusses mainly performance and musicology, for example. Performance studies have become an increasingly vital voice within academia through art-based research (as described in Crispin, 2014) and in academic research such as Davidson & Good (2002). It is also essential to remember that performance, musicology and composition form an ecosystem between each other.

Composition studies have often been separated from performance studies for logistical and historical reasons. This separation is sometimes pragmatic, and sometimes the result of an insular culture. However, there is a long tradition of self-reflection and academic-philosophic writings in the field of composition. Borgdorff mentions how art has always embedded tacit knowledge and self-reflection.

> *Research in the arts will remain naive unless it acknowledges and confronts this embeddedness and situatedness in history, in culture (society, economy, everyday life), as well as in the discourse on art* (2012, p. 65).

The writings of many composers throughout the 20th century address precisely these issues. Schönberg's (2010; 2016) writings are one of the early examples. The embeddedness and situatedness in history and culture are also vital components of the Darmstadt composers' writings (Boulez, 1963; 2005; Griffiths, 2011; Iddon, 2013; Stockhausen, 2017, among others). Later generations have also written extensively the cultural context of their art ranging from Dufourt (2007; 2014a; 2014b), Feldman (Friedman, 2000), Ferneyhough (1995), Luther Adams (2004; 2009), Xenakis (1992), and many others. Donin (2013b) draws self-analysis as one of the most important aspects of 20th-century music. As Romitelli said: it is his reflection on the language of *écriture* as fundamental to his practice that makes him modern (Cohen-Levinas, 2005).

Research's importance to contemporary and mixed music history was is evidenced by the number of research institutions within and outside academia. The most famous example is perhaps Boulez's IRCAM (*Institut de Recherche et Coordination Acoustique/Musique*). At the heart of this institution lies the idea of collaboration between scientists and artists as one of the great paradigms of art (Cont & Gerszo, 2010; Jameux, 1991). This utopian vision remains a model to follow, even with its problems (see Born, 1995 for a detailed account of

IRCAM in the 1980s). Research conducted around these compositions is inherently related to the artistic process, such as Blondeau (2017). His research was on the relatively new programming language Antescofo (see Cont, 2008). The research was about developing the language in a meaningful way so it could be disseminated and understood by composers who are without institutional support. The research included writing music and exploring aesthetic possibilities granted by this new writing and synchronization tool. Faia's (2014) thesis is almost based solely on his experiences as a RIM during his time at IRCAM, CIRM, and as a freelancer. Similarly, Green (2013) fuses traditional academic discourses from humanities and practice-led artistic research as an essential method to analyze and discuss music technology from a broader perspective.

This section is meant as an introduction contemporary research methods rather than an exhaustive list. This type of research is neither new nor radical. It builds on a long tradition that has been especially visible in France because of Boulez's polemics and his foundation of IRCAM in the 1970s. Inspired by these research projects and methodological paradigms, I will now define the methodology used in this thesis.

I.III Methodological Approach for this Thesis (and *Recherche-création*)

This thesis is within the Norwegian context of arts in academia, which has been rapidly changing. This project was approved as practice-based, making it a hybrid between the academic and practice-based schools of thought. The issues covered in previous sections would have been highly detrimental to studying mixed music if the study had been purely theoretical. However, by being a practitioner and using tacit knowledge, I can more effectively achieve my academic goals. In essence, I would not be able to assess how to correctly analyze pieces without being a practitioner. As Didi-Huberman (2018) asserts, it is impossible to study fireflies' light if they are dead. My experience affirms Gray's assertion that "critical practice should generate theory, and theory should inform practice" (1996, p. 8).

In *recherche-création*, making art alone is not considered research; neither is a reflection. As Stévance & Lacasse (2013) assert, research must base itself on a valid scientific frame. This frame exists for mixed music through previous research, as discussed earlier. Further, Stévance & Lacasse make four crucial points (p. 17):

1. Musical creation in and of itself is not scientific research
2. A musical concert is not a scientific publication
3. *Recherche-création* is not a contemplation of the composer themselves
4. *Recherche-création* is the project, not the individual

Similar to Borgdorff (2006; 2012), Stévance & Lacasse (2013) argue that a project needs to develop further discussion in the specialized field. It is not research unless critical analysis and debate are done within the specific field. One has to actively contribute to the body of research in the field. Therefore, it cannot just be an artistic reflection. *The recherche-création* paradigm asserts that artistic creations should be used to push and test theory forward. This paradigm is especially relevant in fields and with questions in which traditional academic work might not be enough.

The use of art is in service to the academic work. The art is not necessarily subordinate to the academic work, as it is a vital part of the process, but it is not the research in and of itself. The art should be somehow influenced or take inspiration from the current debates within the specific discipline. Specifically, Stévance & Lacasse (2013) explain that in *recherche-création*, the artistic creation must lead to a larger debate and discussion. This opening up of artistic practice to discussion and theory is in direct contradiction with the previously discussed method of artistic research, in which the art itself is considered to be academic research. In artistic research, art does not necessarily need to open up to a larger debate within the field, while it is a critical aspect of *recherche-création*.

Furthermore, Stévance & Lacasse (2013, p. 84) describe that the scientific method and practice should be "inherently inseparable".[5] In essence, the research should answer all the standards of general academic research with the issues of professional practice. Paquin & Noury (2018) point to a difference in dissemination. In artistic research, the art itself is disseminated through performance. In *recherche-création*, publishing articles and other scholarly activities are just as important as artistic presentations. Boutet (2018) develops the role of the single artist within *recherche-création*, explaining that since each artist will approach problems differently, this is useful to a more generalized research and debate. In essence, the artistic production can be used to compare and contrast with the existing corpus and literature to further the debates in a field.

Throughout this thesis, artistic endeavours were used to experiment and interact with the literature. Because synchronization is so inherently related to the process of playing and composing music, artistic creation must be part of the process of understanding synchronization. My artistic practice was sometimes able to confirm or deny aspects that were described theoretically in the literature. Writing and working through this thesis, I have

[5] *(…) intrinsèques et indissociables (…)*

"situated myself theoretically while doing a critical or analytical reflection around the problems that are inherent in the artistic production. The artistic production has sometimes served as a pretext to reflection, or a laboratory in which constitutes as a reflection" (Stévance & Lacasse, 2013, p. 133).[6]

Additionally, due to the idiosyncrasies of my own artistic practice both as a RIM and composer, several aspects that theory alone could not explore are developed more due to first-hand experience. The theoretical frame of artistic practice is used in this thesis to further the debates and discussions around synchronization within mixed music. Artistic works themselves can stand on their own within my field, but the point of this research is not the art, it is to contribute to the scholarly conversation on synchronization strategies and mixed music analysis.

This push-and-pull between art and theory is relevant to the field of mixed music because so much is based on the ephemerality of the concert. Therefore, the text is separated into two main sections: theory and practice. These sections are titled poiesis and aesthesis. It is possible to read both of these sections simultaneously or to criss-cross because artistic production and theoretical discussion are intrinsically linked. It is essentially impossible to gather enough information on synchronization without working as a RIM and/or composer. The ephemeral nature of creation and the dissemination of the work (in the form of the concert) make artistic production necessary to discuss synchronization.

I believe that this combination of *recherche-création*, the traditions of contemporary music musicology, and my self-analysis as a composer and RIM can lead to a fresh take on mixed music by concentrating on synchronization strategies. The compositions and artistic endeavours discussed are not included purely on artistic merit. These works showcase expertise that clarifies the theoretical discussion at hand. It is also important for scholars now not use the dialectic of science as some Darmstadt composers have in the past. For example, Boulez would use science and scientific debate to further his ambitious artistic claims without genuinely engaging with the material (Nicolas, 2010).

To summarize, I believe *recherche-création* has the right balance between academic and artistic research to enlighten the field of mixed music on the topic of synchronization strategies. The academic side of the research synthesizes the information available and

[6] *[…] il faut pouvoir se situer, se positionner théoriquement (…) [faire] une réflexion critique ou analytique autour des problématiques soulevées par la production de l'artiste. Plus encore, la réalisation artistique peut parfois servir de prétexte à la réflexion ou, mieux, de laboratoire a l'intérieur duquel se constitue peu à peu une réflexion.*

scrutinizes relevant paradigms and artistic works. Artistic practice permits a testing out of theories discussed in the literature. Through my own artistic practice, I have also addressed combinations of synchronization strategies that are outside the literature as it currently exists.

Prelude II: A Short History & Review of Mixed Music

A complete and detailed history of mixed music has not yet been written. Cabanzo (not yet published) is currently writing a history/analysis of real-time mixed music between 1990 and 2016. McCaffery (1978) argues that linear history is impossible for his field of sound poetry. Mixed music was never a movement either. It is a complicated network between electroacoustic and contemporary music, which has sometimes had an outbreak in various areas both geographically and aesthetically. The act of placing artworks beside each other and discussing their chronological order and importance affects our view of history and aesthetics, as Didi-Huberman asserts in the history of visual art (Alphant & Bouhénic, 2015). Hence, this prelude does not attempt to write a complete history of mixed music. Instead, it focuses on a few historical, cultural and technological aspects essential to its development. These should help the reader to understand the background of the field, which has influenced its aesthetic and technological limitations.

Throughout the history presented here it is important to remember our earlier established definition of mixed music. The classical music recital is at the heart of our definition, which influences the aesthetics of the history. Contemporary classical music and its aesthetics are essential to understand the music and theories discussed later on. Emmerson (2018a) discusses how much of the terminology we take for granted has changed over the years and still changes from territory to territory.

For example, the term live electronics is problematic in our context. The term often highlights playing on electronic instruments, often with improvisation (Holmes, 2016; Emmerson, 2018a). The line between live electronics and mixed music is, in fact, quite fuzzy. Holmes' (2016) examples are almost explicitly within a North American improvisational aspect. These complicated issues of terminology and aesthetics help refine what the thesis will be exploring. A duo between an electronic and acoustic instrument is not mixed music or included in our history unless it specifically relates to the classical recital and the aesthetics of post-World War Two contemporary music.

The term electronics refers to any and all possibilities of non-acoustic sound sources, whether it is analogue or digital. I use this term out of simplicity but also to separate it from the live performers. Although electronics vary significantly between sources, aesthetics and programming, the main importance and difference for mixed music is how it is not a live classical music performer.

II.I Precursors

The idea of mixing media is not new to our times. In the late 19th century and early 20th century, the arrival of recording technology was considered shocking. For the first time in history, it was possible to hear music without playing it or listening to someone else. Although the invention of mechanical instruments such as the pianola had given similar possibilities, it was not until the phonograph (and especially the gramophone) that one could genuinely listen to music without actively participating (Katz, 2004). Music was now encapsulated within a medium. Katz (2004) argues that this created what he terms phonographic effects: portability, invisibility, repeatability, temporality, reception and manipulation. All of these are essential components of electroacoustic music and, by extension, mixed music.

This invention started to inspire composers and artists. Respighi used a recording of a nightingale in *Pini di Roma* (1924), which, according to Ross (2009), is the first use of media within classical music. There are some disagreements between academics on which piece is the first to mix media. Cont (2012) considers Cage's *Imaginary Landscape No. 1* (1939) to have this honour. Although Cage's piece is by far more influential than Respighi's, there is no doubt that the latter is correctly the first piece in history to have blended media.

The rise of radio theatre plays (*radiospiel*) is also a significant aspect that influenced Pierre Schaeffer's aesthetics and practice (Gayou, 2007). Dack (1994) asserts that radio theatre was essential to the development of electroacoustic music. It showed the possibility of new music originating from the innovative use of technology instead of earlier musical forms. Mixed music is slightly different in this sense. It clings to the creative use of technology, but it is likewise attached to contemporary music's more traditional *écriture*.

Sound-based poetry also appeared in the early 20th century, which shows some of the sonic implications of using technology, but mostly about organizing sound into a form. Tutschku (1999) singles out Guillaume Apollinaire's trailblazing work from 1912, in which he wanted to expand on the possibilities of the human voice.

Before the National Socialists' rise to power, Paul Hindemith and Ernst Toch also experimented with the possibilities of manipulating gramophone discs to create a type of proto-electroacoustic music, as can be heard on recently found tapes. Their concert demonstrates that some of these ideas were starting to spread globally, especially in Europe. Additionally, records show that the American composer John Cage was present (Katz, 2004).

The use of records in Cage's oeuvre last from 1939 to 1952, ending with *Imaginary Landscape No. 5* (1952). Cage's music profoundly influenced what would become live electronics in America (Piekerut, 2011). Although many of these Cage-influenced composers did not work within mixed music, their will to push the boundaries of music and work across various media permeate mixed music to this day. However, their philosophy of transcending and breaking down the classical repertoire barriers makes their music challenging to align with other mixed music aspects, especially among the Fluxus-inspired composers.

Another important figure is Edgar Varèse. His importance to the development of electroacoustic music is well documented (Holmes, 2016). His piece *Déserts* (1954) is one of the significant early works of mixed music. The most important aspect is how Varèse explored breaking down the note/pitch paradigm before it became common. Pieces like *Ionisation* (1929-31) break down the limits of what was considered music at the time, without breaking the classical music concert tradition (Holmes, 2016). Varèse's art was controversial, and many of his ideas would be at the forefront of high modernism.

II.II The 50's Zeitgeist of Science & Research

The post-World War Two generation of composers is when mixed music truly starts. There are several vital elements of this generation and period which must be discussed. Firstly, the technological evolutions of the Second World War are significant for artistic development in many ways. For example, one cannot overstate magnetic tape's importance to electroacoustic music (Holmes, 2016). This German wartime technology became an essential part of music's development.

Secondly, the political climate of the time played a large part in how much money society invested in the arts. Groth (2014) shows how political will, rapid changes to society, and modernization played an essential role in establishing the EMS studio in Stockholm. In many countries, this led to significant investments in national broadcasting corporations that were willing to go along with aesthetic experiments that were far from conventional. Griffiths (2011) asserts that the evolution of the post-war avant-garde would not have been possible without these significant investments. John Chowning explains that Bell Labs started hiring more musicians, with some of them not having that much relevant education.[7] These possibilities gave musicians and artists unique and extensive opportunities. The climate lasted several decades, with the state assuming an almost paternal role in educating the masses about the arts. In Norway, composers like Arne Nordheim were given much time on the newly developed television medium to discuss electroacoustic music and composition (Nordal, 2018).

Thirdly, Groth (2014) terms the cultural climate of the 1950s as a "science position," likening the development of music (and the arts) to scientific research. This attitude was important on regarding technology and art, which often have become fused, such as in the establishment of IRCAM in the 1970s (Machover, 1984). In the polemics of the time, science's power and imagery were actively used to justify aesthetics. This argumentative style was part of the polemics of the Darmstadt generation (Iddon, 2013). Many philosophers present at the Darmstadt gatherings introduced a pseudo-scientific approach that influence music and polemics to this day.

This generation of composers and artists lived through the destruction and reconstruction of Europe, then the arms race of the Cold War. Technological development was of vital importance and was often actively discussed throughout society. In Eastern Europe, it was part of the new doctrine of socialist realism after Stalin's death in 1956 (Crowley, 2019). It is not surprising that this could influence contemporary music at the time. Several studios, such as the GRM and the Cologne studio, emerge during this period. Both of these institutions were aesthetically influential (Griffiths, 2011; Holmes, 2016). After only a few short years, studios started opening worldwide, such as EMS (Elektronmusik Studion), RAI (Radiotelevisione italiana or Radio Audizioni Italiane until 1954), NHK *(*Nippon Hōsō Kyōkai) and PRES (Polish Radio Experimental Studio). *Musique concrète* and *elektronische musik* are often presented as two rival factions (Holmes, 2016; Groth, 2014 among others). However, Gayou (2007) and Tiffon (1994) both point out that there are only a few years before figures such as Stockhausen started blending both aesthetics in pieces like *Gesang der Jünglinge* (1956).[8]

All of these studios were experimenting with techniques in which they could use technology in their music. It seems natural that several of them would try to combine these new ideas with acoustic instruments. For example, in 1955 at Darmstadt, Stockhausen

[7] Private conversation on November 6th, 2019.
[8] *Gesang der Jünglige* (1956) is *not* a mixed music work. It is a radiophonic work. It is historically significant in which sound sources Stockhausen uses to compose.

mentioned how combining electronics with acoustic instruments might address the impasse that serialism was experiencing at the time (Groth, 2014). Schaeffer himself had also commented on this possibility in 1948, mentioning how combining both sound worlds is challenging (Iddon, 2019).

By this point in time, several composers had tried to create mixed music with pieces such as Maderna's *Musica su due dimensioni* (1952), Schaeffer & Henry's *Orphée 5*1 (1951) and Varèse's *Déserts* (1954). Schaeffer and Henry's piece was a scenic work, which is the case for many of the early GRM mixed pieces (Tiffon, 1994). The work also has a relatively different aesthetic than typical *musique concrète*. However, it does not fall into the standard tropes of mixed music as there is a fully acousmatic version. Maderna's and Varèse's pieces embrace many of the trends and challenges present in mixed music to this day. In both of these pieces, the acoustic instruments and tape parts are heard separately to avoid synchronization issues due to technological limitations. Maderna viewed this approach as a sort of artistic and interpretive fresh start (Vidolin, 2009). His piece is also one of the earliest examples of a composer working closely with a researcher or RIM (Groth, 2014). Varèse's work took a long time from composition to fruition. The acoustic composition was finished in 1950, but the tape was only completed by 1953 (Tiffon, 1994). Varèse meticulously planned how to make the tape intervene in the piece between the acoustic sections. Maestri (2016) has analyzed both of these works in detail.

Tiffon (1994) considers the pieces before *Kontakte* (1959) as the first age of mixed music. The period is characterized by a more experimental approach and concludes with *Kontakte* (1959) as one of the first reference pieces within an up-and-coming repertoire. As technology advanced and more studios were available for composers to work in, more composers tried their hand at mixed music. Interest in live electronics also pushed composers towards these possibilities, such as Stockhausen with works like *Mixtur* (1964), *Mikrophonie* (1964), and *Mantra* (1970) (Boutard & Gustavino, 2012). Tiffon (1994) describes 1960-1973 to be the second age, and he describes its main characteristic being that tape is conceived not as a new musical medium in itself, but as a medium among many others at the service of an artistic idea.

Hardware boxes and computer synthesis software with real-time capabilities appeared towards the end of the 1970s. Examples include SYTER at GRM, the 4A, 4B and 4X at IRCAM, the SSP in the Netherlands, the Systems Concepts Digital Synthesizer (known as the Samson Box) at Stanford and the FLY5 and FLY10 at CRM (Holmes, 2016; Teruggi, 2016). This type of hardware standardized some processing possibilities and featured a relatively more accessible interface, despite still being challenging to use and prohibitively expensive. The hardware is often difficult to replicate, and each had its own quirks. Puckette cannot fathom how certain parts of the 4X managed calculations, for example (Clarke, Dufeu & Manning, 2020). Among these machines, the 4X is probably the most important, with Akkermann (2016) listing the following compositions as being breakthroughs with the device: Boulez' *Répons* (1981-85), Manoury's *Neptune* (1991), Nunes' *Lichtung* (1988-1991), and Stockhausen's *Kathinkas Gesang* (1985) among many others. Several machines such as the 4X and SYTER were hybrid machines combining analogue and digital solutions. A GUI was often controllable and operated hardware processing units (Teruggi, 2016). Essentially, this started the way many composers work today—one has several modules and, throughout the composition, virtual potentiometers vary how much of the various effects are used.

This hardware opened the door to real-time processing possibilities, which became an aesthetic and ideological battleground for many years. It also helped establish a standard repertoire of live processing techniques which can be heard in many pieces. It is primarily from these pieces that trends and clichés were established. Tiffon (1994) defines the period from 1974 and afterwards as the third age of mixed music with the main characteristic that pieces now often had live processing as an important aesthetic aspect.

Manoury's *Jupiter* (1987), which featured an early version of Max to be used as a score follower, became an essential example of real-time technology. The technology was rapidly moving forward, making the workflow of composers and technicians smoother. Max's graphic user interface was a breakthrough for letting composers work more actively with electronics (Clarke, Dufeu, & Manning 2020). Because of its dependence on technology, mixed music has often been related to research. Institutions such as IRCAM solidified this position, especially with its increasing dominance in the 1980s.

II.III Closing Words

After the arrival of hardware such as the 4X, the next revolution was the use of digital technology. Computer based synthesis started already in the 1950s and 1960s with the ILLIAC and later with the development of Music N software. The price of digital technology because much cheaper from the 1980s to the 1990s, which democratized and globalized much of the field. The cost of data storage per MegaByte went from $10 USD in 1990 to $0.015 USD within ten years (Holmes, 2016).

I argue that this change is the start of the fourth age of mixed music, in which composers are less dependent on institutions, and that work can be done on personal computers. The arrival of digital audio workstations (DAWs) such as Pro Tools in the 1990s combined with cheaper storage led to people worldwide being able to create music (Bennett, 2018; Brooker & Sharrock, 2016; Holmes, 2016, among others). In the following years, increasing access to the internet allowed interconnection of a global community to discuss issues related to music genres and software. Rudi (2019) marks 2000 as the start of a new generation of composers because of how globalized the world had become and especially because composers were now, more than ever, influenced by multiple genres of music.

Music technology programs increasingly proliferate all over the world. The advent of easily streamable content led to mixed music being spread to areas where it has never been heard in concert. The irony of this democratization is that it has still not broken the white euro-centric hegemony over art music. Most of the literature is still from these research centers with their gatekeeping, but the tides are turning with articles written from non-major centers and underrepresented groups. For example, South American and Asian academics and composers have been participating more (Farra, 2018; Landy, 2018, among many others). Mixed music has often been influenced by the dominant compositional paradigms and philosophies from acoustic and electroacoustic music. Therefore, styles such as serialism, noise, spectralism, *musique concrète* and many others can co-exist within the same repertoire or even the same artistic work.

In lieu of an exhaustive history, this section has explored the networks that rose in many countries that were often connected to institutions such as GRM, IRCAM, EMS, Cologne Studio, and PRES. The aesthetics of the Darmstadt generation profoundly influenced the emergence of this type of music. In recent years, the discussions surrounding electronics have also been widened to include a vast diaspora of musics, such as those explored in Emmerson (2000; 2007), Green (2013), Magnusson (2019) and Waters (2007).

Part I – Poiesis

Chapter I: A Quick Discussion of Time

> *Music is purely an art of time, and the musician - with or without a composer - builds and regulates the experience of the speed of time passing. Time becomes matter in music; therefore composing is exploring time as matter in all its forms: regular, irregular. Composing is capturing time and giving it a form.*
>
> -Kaija Saariaho, quoted in (Howell et al., 2011, p. 81).

1.1 Introduction

Before we can explore synchronization strategies, an essential element must be discussed: time. It is perhaps the single most crucial element within music and an a priori element of life and perception. Time and music are inherently linked since music is sound (or lack thereof) in time. A composition is organizing sounds through time, as Varèse said (Holmes, 2016). Rofe (2014) remarks that the word composition's roots come from putting together or ordering sounds.

Time has primordial importance within mixed music—music using both acoustic and electronic elements—for several reasons. Firstly, synchronization of the acoustic and electronic elements presents many challenges that are inherently related to time. Secondly, contemporary music has several types of time. If the acoustic and electronic elements utilize different temporal paradigms, how does one address the issue of time for both analysis and integration? Although authors such as Alperson (1980) would argue that time (outside of music) and time in music are the same concepts, separating the two definitions is an asset regarding issues of synchronization, as we will discuss in section 1.4.

Music analysis has been traditionally primarily interested in the score (Cook, 1987), which is, according to Rofe (2014), a rather Newtonian or scientific way of viewing composition that ignores many aspects of the work. Kramer (1988) argues that analysis has emphasized the influence of pitch and rhythm rather than time. Because mixed music utilizes both the traditional Western musical notation as well as elements that are often not represented using the same system of notation, it is necessary in performance practice to adopt a more relative view of time than in solely acoustic music. Time is not one thing; it is in flux, changeable and manipulatable by the composer and performers.

This chapter tackles the issue of time and its relevance to mixed music. The chapter

- Establishes a basic definition of time and its various types

- Reviews the concepts of time by composers and theorists such as Boulez, Kramer and Roads
- Looks at the differences between musical/score-based time, performance time and perceptual time
- Introduces perception concepts from psychoacoustics such as fission and fusion

1.2 Time: A Basic Definition

Within the context of mixed music, we must explain the two time types that will be used further throughout this thesis. The first is *musical time*. Musical time is a flexible, relative organization of sonic events using notation. The notation generally consists of the pitches to be played and in which order and rhythm. Tempo and time signatures give us the temporal information that musicians need to synchronize musical events. However, rhythms written in musical notation are not necessarily meant to be precisely calculated. For example, such as if one has a 4/4 time signature at 100 bpm, it does not always mean that each 8th note has to be precisely 200 ms. Score events are written in musical time, meaning that they are always in a relative relationship to each other.

Just like dynamics, tempo has become an essential aspect of interpretation—a Beethoven piano sonata played by Paul Lewis is different from the same sonata played by András Schiff in multiple musical parameters including dynamics, tempo, articulation, etc. The interpretation of tempi in scores is a subject of debate, as shown in Howat (2009). The elasticity of time even has its own musical term, rubato. The performance practice of musical time has also changed throughout history. If one listens to early recordings, the amount of rubato can shock a modern listener, sounding almost as if the performer's hands are not in sync (Day, 2000).

The second type of time is *absolute* (or chronometric) *time*. Using absolute time in music became popular after World War Two in works such as Cage's *Number Pieces* (1987-1992) and mixed works like *Epitaffio* (1963) by Nordheim. In the latter, the composer at several parts in the score will write an exact length in chronometric time that a specific figure should be played. These composers instituted a radical shift in the conception of time in music, as for centuries composition was limited to musical time. It is also of interest to note that some composers such as Penderecki in his *Second String Quartet* (1968) wrote gestures that include an indication for absolute time.

Absolute time is also relevant in the discussion of programming and the use of electronics. Because computers are deterministic machines, one must generally write events in milliseconds instead of musical time. This use of absolute time has often profoundly influenced composers and performers, as we will see later in chapters IV, VII and VIII.

1.3 Score Time

Boulez was one of the first composers to write about abstract time in his book "*Penser la musique aujourd'hui"* (1963). This book was a landmark for the post-war generation and continues to be relevant due to its deep analysis of composition and performance. Although Boulez mainly discusses score time in this book, several of his temporal categories are helpful when thinking about performance and perception. Boulez defines three types of time: amorphous time, pulsated time, and striated time.[9]

1.3.1 Amorphous time (temps lisse)

Boulez (1963) described *amorphous time* as how the ear could lose its point of reference in time, focusing on the perception of time as being of primary importance. One of the central aspects of Boulez's concept of amorphous time is that its use eradicates the feeling of pulse. Therefore, the note values only relate to each other in time by proportions (Boulez, 2005). Amorphous time is not counted by an absolute measure, in contrast to the idea of absolute time. He argued that by writing absolute time, the musicians would count, which brought them to regular striated time with sixty beats per minute. He summarized amorphous time as the "time [we occupy] without counting it" (Boulez, 1963, p. 107).[10] Manoury (2017a) gives the examples of Louis Couperin's *Préludes sans mesure* (1660) in Figure 1 and Franz Liszt's *Sonata in B Minor* (1854) in Figure 2 as amorphous time in which the notes are out of the temporality of the piece. Much contemporary music, such as Berio's *Sequenza* (1958-2002) is in amorphous time.

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[9] The translations to English used for these concepts are by the translators Bradshaw, S. & Bennett, R. R. whom translated Boulez (1963) to English. These translations have also been used by other authors such as Goldman (2011). The synonym "smooth time" has also been used for amorphous time.
[10] *(...) dans le temps lisse, on occupe le temps sans le compter (...)*

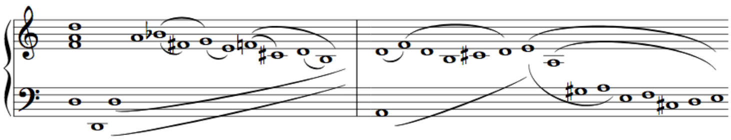

Figure 1. Amorphous time in the first prelude from *Préludes sans mesure* (Couperin, 1660).

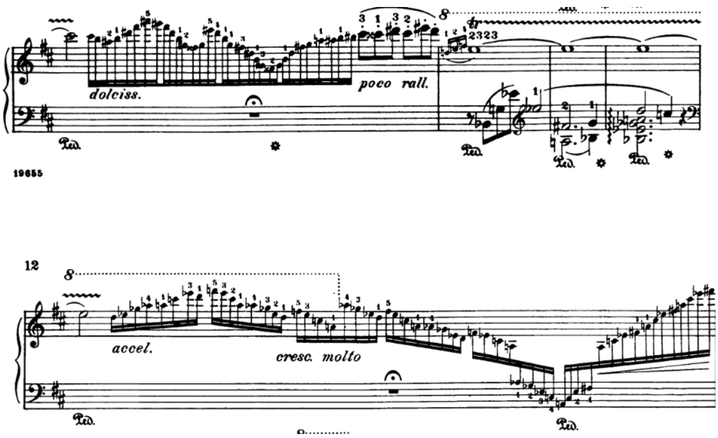

Figure 2. Amorphous time in *Sonata in B Minor* (Liszt, 1854).

Proper amorphous time is when the control of time is not in the performer's hands. Effectively, the music and its events are outside musical time and do not refer directly to absolute time. Examples can be found in compositions like *Éclat* (1965) by Boulez in Figure 3. The conductor effectively controls the length of time and the rhythms will not fall properly in place such as in striated time. Each entry is cued. The timing is amorphous and floats.

Decarsin (2001) also notes that certain forms of notation that may look liked striated time are amorphous in execution. He refers to the idea of sheets of sound as well as Stockhausen's time fields. A clear example is Ligeti's micropolyphony, such as his *Second String Quartet* (1968) in Figure 4. Examples of graphical notations such as the previously mentioned *Second String Quartet* by Penderecki (1968) could also fall into this category. The notation features no time signature and often does not include any precise note values. Still, measures and other elements keep the musicians together, showing them how their collective sound should be evolving in time.

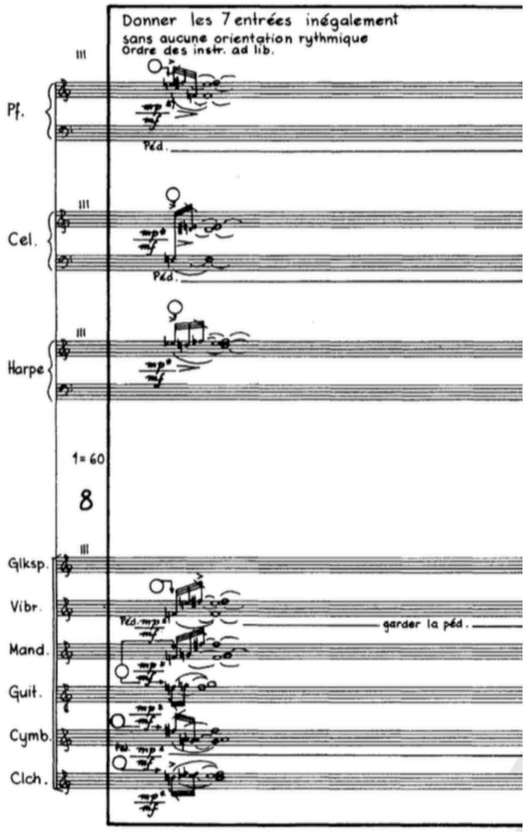

Figure 3. Amorphous time in Boulez's *Éclat* (1965).

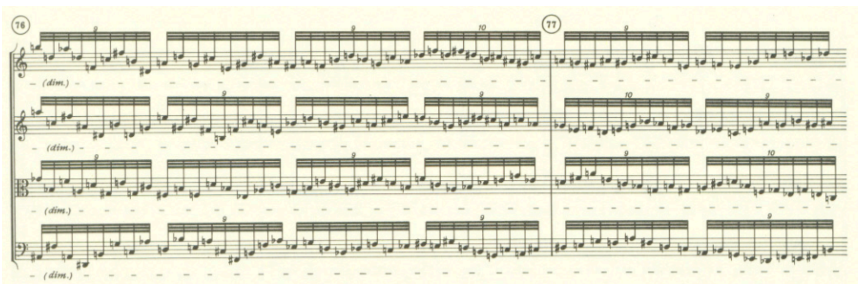

Figure 4. Ligeti's *Second String Quartet* (1968) as amorphous time.

One of the most important aspects of amorphous time for mixed music is its flexibility. Since the musical values are not exact but relative, this will influence the possible strategies for integrating electronics into performance. For example, if the relationship between the electronics and musicians is amorphous, the exactitude of the integration (in milliseconds) is less significant and has more deviation tolerance as will be explored in Chapter II.

1.3.2 Pulsed time (temps pulsé)

Pulsed time is more straightforward than amorphous time. It is marked regularly or irregularly either by the smallest unit or a multiple of the simple unit (Boulez, 1963). This is a vital distinction from only naming the time signature and its pulse as it invites the possibility of pulsated time being different from the measure's pulse—syncopation. Pulsed time can be found in music for several hundred years and was often used by composers. For example, Beethoven and Haydn wrote sections in one apparent time signature while using the time-feel of another to fool the ear and surprise the audience (Rosen, 1998).

1.3.3 Striated time (temps strié)

Goldman (2011) describes *striated time* as a "succession of accents that create sharp, audible discontinuities" (p. 12). He gives an example from the B section of Boulez's *Dérive 1* (1984) shown in Figure 5, which uses a quarter note pulse to trigger grace-note tuplet groups. Boulez (1963) defined striated time as when space/time is demarcated in a determinate systematic fashion, whether regular or irregular. Therefore, it is easy to perceive the pulse, tempo and direction of the music.

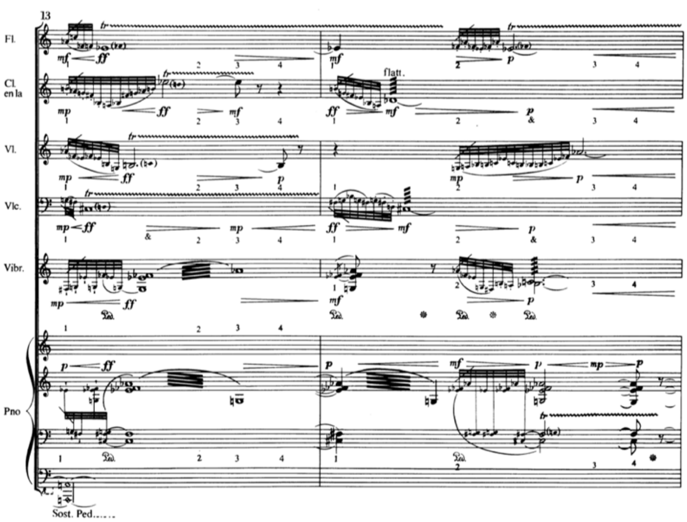

Figure 5. Striated time in *Dérive 1 (1984)* by Boulez.

Boulez summarized striated time as “We count time to occupy it” (1963, p. 107).[11] He understood that in extreme examples such as the previously mentioned compositions by Ligeti, time could be perceived to be striated when, in reality, it is amorphous. Similarly, a regularly pulsed striated time could be thought of as amorphous.

1.4 Performance Time

One might think that the musical time in a score is the same as performance time. However, there are some dissimilarities. These differences are often on the level of what is possible to perform and how it will sound, which relates it more firmly to perceptual time. Ferneyhough’s music is an extreme example of this where the score time is radically dissimilar from the performance time, which is also unlike perception time (Fitch, 2014). Critiques from composers Grisey and Manoury realign Boulez’ ideas with that of performance.

Grisey strongly disagreed with Boulez’s view, stating: “The notion of smooth (unmeasured) and striated (measured) time described by Pierre Boulez (1968, 1971) is merely the invention of a conductor bereft of any phenomenological awareness.” (Grisey, 1987, p. 240). In his view, time can only be separated into two systems. The first one is time as related to a pulse, a meter or anything that gives a periodic reference point. The second is durations, which, in his opinion, occur as soon as there is no reference to a pulse. In this second point, he includes Messiaen and the Second Viennese School (and assumingly, many of the post-war generation).

Manoury (2017) revises Boulez’ categories as well. He argues that striated and pulsed time is of the same nature. He argues that pulsed time is regularly striated time. He adds that it is possible to have different temporal layers simultaneously, such as amorphous and striated time.

In both of these critiques lies the idea that a musician will not differentiate between pulsed and striated time. For the musician learning a piece of music, they will count the pulse to have a reference point to play the music, inherently changing the concepts of time Boulez analyses in notated music.

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[11] *(...) dans le temps strié, on compte le temps pour l’occuper.*

1.5 Perceptual Time

Another aspect of time is how it functions for the listener. Perception is an essential aspect of electroacoustic music, which helps bind the worlds of notated and electronic music. We will first look at another note-based theory before moving on to perception in the context of electroacoustic music.

1.5.1 Kramer's Concept of Time

Kramer (1988) thought of time mainly from the perspective of the listener. His first category is *linear music*, which he defined as goal-oriented music. Baillet (2001) preferred to call this the arrow of time, which is based on the listener's expectations, such as in tonal music. Schenkerian analysis (as explained in Cook, 1987) is based on the arrow of time as the whole system's idea is that a piece will formally go from the tonic to the dominant, and then back to resolve dissonance. The implication of something that must happen (such as resolving a dominant seventh) is the clearest example of this linearity. Baillet (2001) and Kramer (1988) demonstrate how musical events are linear because they are dependent on previous events.

Non-linearity, on the other hand, is based on the lack of development from earlier events (Kramer, 1988). Baillet (2001) describes Debussy as being the beginning of non-linearity in the 20th century. However, he notes how Gregorian chant was non-linear and that it was one of the inspirations for the Second Viennese School. He asserts that the temporal non-linearity of serialism explains how the twelve-tone row's order does not influence our perception of time. The row will probably be reversed and transformed throughout the composition. Therefore, the row is inherently non-linear as a musical device. Another aspect that contributes to the non-linearity of serial music is how the use of the row is not inherently based on earlier elements in the piece. As Baillet points out, using the row (or any permutation) does not imply any specific temporality or musical logic. The analysis of particular works of music has been problematic because of this non-linearity. Pieces such as Webern's *Op. 20* (1927), *21* (1928), *22* (1930) and *31* (1940-43) are examples where the prime row is not necessarily the first element heard in the composition (Bailey, 1991). Although this is perceptually insignificant, it is often considered an important element in the analysis of Webern's music.

The temporal non-linearity of serial music is the subject of some critique. The pianist Jérôme Ducros (2012) based his rejection of twelve-tone music on its non-linearity, which he explained as the listener not perceiving a wrong note in a musical flux. He compared twelve-tone music to Mozart, where a single wrong note will be clear as it does not fit in the harmonic profile of a sentence. Many others quickly criticized Ducros' assertion, such as Dusapin (2013) and Manoury (2013a).

Kramer's (1988) last function of time is *vertical time*, which he compares to stasis. This function is non-linear, but it is also the complete absence of the arrow of time. Both scholars use minimalist composers as examples. However, Baillet (2001) points out how Reich's compositional oeuvre does not fit this definition as there is a clear arrow of time. He also criticizes Kramer's lack of inclusion of some of the spectral composers. Some spectral pieces do have a clear sense of the arrow of time – meaning a forward drift. However, they still revel in the sound of stasis as they build their music vertically. "They have learned that the absence of implication, motion, hierarchy, and contrast need not be nihilistic. They have learned to enter a piece and revel in its sounds." (Kramer, 1988, p. 54). One can understand Baillet's point that sheets of sound or musical stasis does not necessarily mean a lack of direction in the piece's temporality. Therefore, predictability in the progression of a work is not necessarily in direct correlation with the arrow of time.

1.5.2 Time in Electroacoustic Music

Although electroacoustic music is often lauded as a schism from classical music's limits, it cannot escape temporality, which has been crucial for discourse within music. Much of the theoretical work in the composition and analysis of electroacoustic music is devoted to perception and time. A piece such as *Riverrun* (1986) by Barry Truax is a study in perceptual changes of texture throughout time, often with subtle differences between perspectives (Clarke et al., 2015; Clarke, Dufeu & Manning, 2020).

Roads (2004) explains that time is both an absolute, contextual and cultural concept that varies. Unlike Boulez and Kramer, his systematization of time goes beyond the scales of what we usually consider in music ranging from infinite to infinitesimal. Within most musical contexts in this thesis, we will mainly be concentrated on the movement of sonic objects at the macro- and micro-level. The former is defined as "The time scale of overall musical architecture or form, measured in minutes or hours, or in extreme cases, days." (p. 3). The latter is in the chronological time of milliseconds.

Roads' view is slightly more nuanced than the previous views and considers both acoustic and electronic sound sources, and their cultural meaning. Additionally, because he focuses on electronic sounds, he has a broad interest in the morphology of sounds, shapes and textures. There is no doubt that Roads is highly informed by Schaeffer's (1966) and Smalley's (1994; 1996; 1997) typologies, both of which are based on the perception of sound.

Roads' systemization of time can be combined with Boulez's concepts. In essence, Boulez discusses mostly musical time and Roads' ideas reflect possibilities inside and outside of music. A theoretical perspective of time that includes both Roads and Boulez gives us chronometric, cultural, perceptual and musical time, which lets us address all of the elements relevant to mixed music.

This hybridization of systems permits us to discuss different layers of time and electronics simultaneously, clearly, and concisely. Parametric thought in composition is nothing new, such as in Boulez's serialist music, but discussing these various layers of time separately is novel and useful. This theoretical separation is vital in various electronic effects that work in the time domain, which are an important compositional tool. For example, sampling is a digital signal process where a musician might record live content and then replay those samples using time-stretching and auxiliary spectral delays. In this example, we have several time scales. The musician might be playing in striated time, but the stretched samples could be in amorphous time controlled in the mesoscale while the spectral delay is on the microscale.

1.5.3 Psychoacoustics

Perception plays a substantial role in Roads' (2001) time scales. When composers started abandoning the dominance of pitch, perception became an important compositional and analytical tool. Gestalt psychology and analysis of music has been an exciting field for several decades. For this thesis, we are not interested in all of psychoacoustics, but how one can compose and think of synchronization. For example, Marco Stroppa was influenced by the fusion and fission theory of McAdams (Tiffon & Sprenger, 2011a).

There are two elements from psychoacoustics that are most useful to us: sound source identification and timbre. Both of these are concerned with time, frequency, and how to separate sound sources. Donnadieu (2007) states that timbre, sound source identification, and audio stream segregation are inherently related. Considering that within the history of mixed music, blending both sound worlds into one has been seen as a goal, it seems natural that this aspect must lie within our conceptual groundwork.

General gestalt principles have a heavy influence on the field of psychoacoustics. Deutsch (1982) explains that the principles of proximity, similarity, good continuation and common fate help to create a common gestalt. For example, McAdams (1982) explains that to identify sounds as a single source, or to use perceptual fusion, three elements seem to be the most important: the harmonicity of the sounds, coordinated modulation of spectral components, and the relative familiarity of the spectral envelope. Fission, on the hand, is possible through three elements which he defines as:

- Tone onset asynchrony
- Asynchrony of onset of coordinated modulation for different source spectra, and
- The temporal correlation among the modulations belonging to separate sources.
  Another area that will eventually need to be addressed is the frequency proximity of spectral components between separate sources. (McAdams, 1982, p. 291)

McAdams & Bregman (1979) reveal that the attack and decay ramps of instruments are among our primary cues to differentiate them within an orchestra. London (2004) adds that we have around a two-second limit to connect successive events. This limit influences how musicians synchronize themselves when it is a fast or slow tempo. Fusion, fission, and separating sound events are closely related to each other.

Most of the literature describes relatively simple, tonal music and/or purely synthetic electronic sounds as their musical basis. Emmerson (2018) criticized these scholars as their research often lacks some of the contextual importance of musical cues. McAdams (2019) adresses these problems by discussing specific musical examples and comparing their orchestration, timbral differentiation and sound source identification.

Perception and how we experience musical compositions plays a large role in analysis and composition. McAdams gives many examples throughout his work of specific orchestrations, such as the two-part crab canon in J. S. Bach's *Das Musikalische Opfer* (1747). Unless one is analyzing the piece, the audience would not hear the crab canon, yet it is one of the most salient and oft-mentioned elements of the composition. Some musicians learning the piece would probably realize the ingenious device Bach uses from the similarity of gestures, but this cannot be taken as a given.

Semiological and semantics in music have played a large role in aesthesic analysis of electroacoustic music. Molino (1991), Nattiez (1990), Roy (2003), and Thoresen (2009; 2010) are critical scholars in this field. In Roy's and Thoresen's typologies, parsing, timbral organization, fusion, and fission become essential concepts for a holistic analysis. Although I will not be using semiology in my analyses, these scholars have influenced musical analysis and, by extension, composition.

1.6 Conclusion

Kramer and Boulez discuss many of the same concepts using different terminology. The former bases his perception of time from the listener's perspective, while the latter looks at it from the composer's perspective. This dichotomy is relatively close to the various methods and concepts of analysis and discussions of mixed music. Some are mainly based on an aesthetic or more Schaefferian analysis (based on the listener), against a more compositional and constructivist approach (in the sense of Battier, 2003). I do not view these two conceptions of time as opposites, but as useful tools to discuss time within a compositional or listener-based model, whichever suits the situation at hand. This terminology and philosophy will be used throughout the rest of this thesis as a theoretical backbone for discussing time.

A composer can choose to ignore timbre, harmony, rhythm, and harmony, they can never ignore time, which is why it is such a fundamental aspect of all music. The conception of time within post-World War Two music has been an important compositional parameter. Composers such as John Cage, Elliott Carter (Bernard & Carter, 1990; Wierzbicki, 2011), Morton Feldman, Györgi Ligeti, Karlheinz Stockhausen, Gérard Grisey (Castanet & Fineberg, 2000) and many others have challenged the notions of time within composition. As Delaere (2009) notes, having no exact synchronization between events also became an element of contemporary composition in Stockhausen's *Zeitmasse* (1955-56) and Lutoslawski's *Jeux vénétiens* (1961).

The influence between Western and Eastern thinking around time has also brought many new ideas of how time may influence composition into the field (Harrison, 2007). States of being instead of temporal movement are an essential aspect of much contemporary music ranging from purely acoustic with Messiaen's music to the purely electronic with Monty Adkins. In between there somewhere lies all of the inherent possibilities, problems, dichotomies and difficulties of mixed music and time.

Chapter II: Synchronization Strategies

Music attempts to suspend or abolish time by accomplishing it. Achieving this takes thought, work, time. A journey can be prepared at length: the schedule of the journey itself has little to do with the schedule of the preparation. The composer plans a kind of journey susceptible of capturing the listener's attention: the time of composing is not that of performing or listening.

- Jean-Claude Risset (1999, p. 37)

2.1 Introduction

Synchronization has often been the central issue in using technology in mixed music. When writing acoustic music, the details of notation influence how musicians will interpret and synchronize the musical material. The orchestra's evolution happened simultaneously with the evolution of notation and the role of the conductor. Before discussing the musical and philosophical reasons for utilizing electronic and computer-based technologies in musical performance, we must establish how they are related to performance itself.

This chapter looks at the synchronization strategies of acoustic and electronic sound sources. Although this might sound like a relatively benign issue, it actually has a considerable influence on all roles in the musical process. For the composer, it may be an intrinsic part of how the piece is composed. For the performers and sound engineer, synchronization can be the difference between a pleasurable concert and an agonizing one. There is a potential correlation between synchronization and the audience's perception of the acoustic and electronic as a coherent whole. In a mixed music concert, it can sometimes be challenging to have more surrogacy (Smalley, 1997) or liveness (Croft, 2007) because the physical gesture of the performers often binds the sound experience, even if the audience understands that a violin does not sound that way.

The concept of synchronization is an important issue in the literature of mixed music, especially from the 1980s and onwards. However, it is often only mentioned in passing. This chapter will focus solely on synchronization from the composer's perspective. The performer's perspective will be analyzed in Chapter VII. This chapter explores:

- The various roles in a mixed music performance in an actor-network system
- How synchronization has been defined historically as a battle between deferred and real-time processes
- The definition of synchronization strategies
- Establishing a corpus of synchronization strategies
- Establishing a corpus of synchronization performance techniques

- Establishing a graphical framework for the synchronization of multiple layers

2.2 Actors Involved in Synchronization

Before diving into the definition of synchronization, it is perhaps wise to look at the actors involved by using actor-network theory (Latour, 2005). One of this theory's advantages is that it encourages us to think of other non-human agencies[12] as an important aspect of social interactions (Zell, 2011). In our musical context, physical and non-physical agencies play essential roles, which we will look at shortly. The use of the actor-network theory will help clarify which actor (human or not) synchronizes others, which leads to a distinction between several concepts we will be discussing in the rest of this thesis.

Piekut (2014) points out that non-human agencies can influence human actors in various ways. Cage's Silence (1961) did not influence Fred Frith the same way it influenced minimalists like Reich and Glass, for example. Technological actors influence composers and musicians in various ways. This is an essential point as it severely restricts the concept of technological determinism, which most modern music scholars now reject.

The actors and their agencies are summarized in Figure 6. A short description of each of them will follow with details of their relationship to and affordances on the actor-network. The network can vary in other circumstances. For example, if the composer is alive or if there was no RIM, so on and so forth. This figure is a generalization of all actors involved in mixed music.

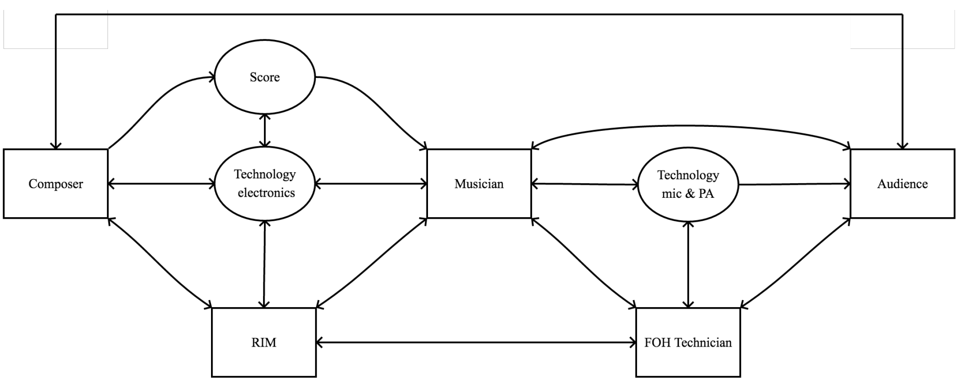

Figure 6. The actor network in mixed music.

[12] Agency here is with the meaning from social sciences, not music.

The figure will be analyzed from left to right. The composer plays a central role by creating a piece of music to be played. They may have a direct relationship with the musicians, but this usually is not the case, unless perhaps for the premiere or if the composer will be at the concert. It is vital to note the two-sided agency in the relationship between the composer and the audience. The composer does not write in a vacuum; they need the audience. Likewise, the audience will want to hear the works of the composer (and the performers).

The RIM (Chapter VIII explores this actor in depth) is not always present. There might also be two RIMs, one for when the piece was composed and another for the concert. The RIM will be especially important in the agency between the score, technology and musician.

The musician is the actor with the most agencies and connections in this network. The performer has a central role in how the composer can access the audience. The performer mainly works with a document (a score of some kind), discussed further in Chapter VII. Their role includes understanding the work's ontology, including appropriate performance practice the given genre and style. Performance practice and philosophy is a broad field, and although it is beyond the scope of this thesis, it is vital to remember its importance to both synchronization and mixed music as whole (Silverman, 2007). The audience is also vital for the musician, as they actively engage with them through performance.

The FOH (Front of house) engineer has a more direct role in connection with the musician, RIM and audience. Towards each of these, the engineer's role is to make sure the RIM and musician's musical goals are conveyed to the audience clearly and safely.

The audience typically has a passive role. However, it is important to be aware that the audience has an active role in some pieces. Some works include the use of sensors or even microphones in the audience. Additionally audience participation and reaction to the music directly affects the musicians on stage (Kawase, 2014).

The non-human agencies have two specific roles in this network. The first is the electronics of the piece, which are similar to the score. Electronics and RIMs also require a performance practice that is important to understand within stylistic boundaries, despite being rarely mentioned in the literature. For example, the musician might have to play individual sections at a specific volume, so the live processing achieves its proper sound and timbre. The roles of technology in performance are discussed further in Chapters IV, V and VIII.

Understanding the actor-network in mixed music allows us to better understand synchronization strategies. This network will be referenced in future discussions throughout this thesis.

2.3 Synchronization Strategy Definition

Before we can discuss synchronization strategies, we must first define the terminology. Echeveste (2015) is one of the few scholars focusing on synchronization. He writes about coordination strategies[13], which he defines as the musicians' complex temporal relationships. His approach is practical, as he is looking at the specifics of a score following program. I argue that synchronization is perhaps more abstract and should be approached in a software-agnostic manner. Based on the definition first elaborated in Lacroix (2018), a synchronization strategy is any strategy used to manage temporal relationships between electronic and acoustic sound sources. There are three elements in this definition: strategy, temporality and relationship.

Why the word strategy? At the start of this project, I thought the word method should be used; however, method insists on a single precise way to synchronize. Additionally, method has a slight connotation of right and wrong. Various approaches give various affordances and have a more complex relationship to the compositional process. The word strategy is adopted as it makes sense for both poiesis (how the composer has conceptualized it) and aesthesis (the practical sense of how it affects the musician's playing and final sounding result).

Chapter I explored temporality, which is important on many levels in mixed music. There is always a temporal relationship between the musicians and electronics, time is tightly connected to musical roles, and time affects how we perceive musical gestalt. The previously mentioned fusion or fission concept plays a central role in source bonding between acoustic and electronic sources (Smalley, 1997). Temporality influences how the audience perceives various musical roles in the mixed music actor network. Temporality in composition and synchronization will be developed further in Chapters IV and V.

A critical division should also be drawn between the composers that are detail-oriented regarding the synchronization of acoustic and electronic elements and composers for whom the issue is merely a pragmatic afterthought. This can be seen as a continuum as we will discuss in the next section.

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[13] *Stratégie de coordination*

These strategies must function in the context of contemporary music. Outside of specialist literature, one can often read about strategies for music with a clear bass, melody and simple rhythm. However, this is far from always being the case for much of contemporary music. An example is how Stroppa & Echeveste (2015) presented some of their findings after working with solo piano music with Antescofo. Their goal had been to recreate how different voices can lead or follow organically. Therefore, they had used mainly the music of Bach and Chopin. Although their findings were fascinating, the audience criticized them for being limited to standard period music, and that nonetheless, they had only looked at solo piano music. Additionally, they had separated the hands of the pianist, which is unnatural.

A synchronization strategy is any strategy used by the composer (and RIM) to shape the temporal relationship between musicians and electronics to achieve a compositional goal. Synchronization strategies and their use are a vital part of the composition itself. It is possible to change strategies within a single work, as we will explore in Chapters IV and VII. The performer has to navigate the synchronization strategies chosen by the composer. The context and musical goals of a composition are essential to decide which synchronization strategies might best fit it. The optimal synchronization might be looser or stricter depending on the piece's temporal relationships and desired perception. A composition might also have several musical goals for which different strategies are used in each section, as Chapter IX explores.

2.4 Relevant Analyses in the Literature

How do these synchronization strategies and performance techniques relate to the literature in the field of mixed music? Over the years, there have been many taxonomies, but none have addressed synchronization issues solely. Hagan (2016) divides compositions and compositional schools into a continuum between fixed and live. However, this system does not elaborate on the various synchronization strategies and their compositional affordances. Instead, it mainly discusses the placement of individual composers and compositions within the continuum.

Croft (2007) created a taxonomy (shown in Table 1) to explore the relationships between musicians and electronics. His taxonomy delves mainly into the musical function of the electronics, and little into how they interact with the musicians. However, he discusses conditions for a functional relationship between instruments and electronics. These conditions are close to problems Berweck (2012) and McNutt (2003), discussed further in Chapter VII.

Croft's writing is filtered through his aesthetics that liveness is not necessary within mixed music, contrarily to Hagan (2016), who sees it as an aesthetic goal. Much of Croft's taxonomy has the electronics in a lesser, more reactionary role or as a hybrid instrument. For example, the idea of the electronics leading a piece musically is not included. Synchronization is implicitly present in the possibility of electronic accompaniment and response, but it is never discussed in detail. The backdrop and environmental paradigms show how Croft believes in a looser type of synchronization as ideal.

Table 1. Paradigms resume, Croft (2007)

Paradigm	**Backdrop**	**Accompanimental (sic)**	**Responsorial**	**Environmental**	**Instrumental**
Description	Most remote relationship in which the electronics function as a background. Any points of contact between electronics and acoustic sources are not causal.	The electronics function as a more-or-less traditional accompaniment.	Antiphonal relationship between the electronics and acoustic sources.	The creation of an acoustic environment using electronics.	Creating a hybrid instrument. The use of the electronics is done in an almost analogous way to how the performer would normally play on the instrument.

Frengel (2010) also created a typology of the relationships between acoustic and electronic sound sources as shown in Table 2. His system is more detailed than Croft (2007) and Hagan (2016). His writing is aligned with recent ideals of electroacoustic music in the UK as expressed by Emmerson (1986) and Smalley (1994; 1996; 1997). An interesting component of Frengel's (2010) article is that he mentions many mixed music pieces' fail because they try to incorporate several discourses and typologies. He describes that each of these typologies requires different modes of listening (referring to Schaeffer, 1966). To me, this is not a deficiency, but rather a part of the beauty of mixed music. It challenges us to listen in different modes than solely acoustic or acousmatic music can. Mixed music creates new, hybrid modes of listening that open new compositional potentialities. Additionally, only holding oneself to specific function for electronics can be unnecessarily pedantic—it is normal for instrumental groups to have various functions throughout a piece in traditional acoustic writing. Why can't it be the same for the elements of mixed music?

The only reference to synchronization in Frengel's article is the behavioural and temporal axes. However, the idea of only being synchronized or not is too simplistic, as we have discussed already. Likewise, Frengel's behaviours are somewhat reductionistic and do not approach all of the musical possibilities and electronics' roles. Frengel's system is based on the general perception on either the live musician or the electronics being dominant. Although this is often the case, hybrid and more subtle relationships are also a possibility.

Table 2. Axes resume Frengel (2010) with my annotations (in italics).

Axis	Description	Subcategories
Segregational	This axis means how the electronics and acoustic sound source come together into either a single or several morphologies. Monomorphological means that the output, although composed of an acoustic and electronic sound, comes together as one morphology. *It is important to note that Frengel means to analyze this axis as pairs, meaning that it is possible to have a monomorphological and polymorphological relationships at the same time between different elements in a composition.*	Monomorphological / polymorphological
Proportional	A weighting of which part dominates the sound field between the electronics and acoustic performer. *Frengel remarks that the added visual element in a concert setting might put the balance closer to the instrumentalist.*	Live-dominant / non-live-dominant / balanced
Temporal	The temporal relationship between different sound sources. *Frengel writes how perceptually and temporally, an event can be perceived as synchronous in the former but not the latter.*	Synchronous / asynchronous
Timbral	This axis is about how close the electronics and acoustic sound sources are to each other timbrally (spectrally) on a spectrum.	Equivalent / similar / dissimilar
Behavioural	How much autonomy the two sources have, once again on a spectrum. A monomorphological sound is singular by default.	Independent / interdependent / singular
Functional	The role of the different musical components currently being played. It is inherently related to the behavioural axis; however, this axis is more interested in the musical function, not whether it is independent or singular. Traditional music roles are mixed with roles that come from electronic music as well.	Environment / dominant vs subordinate / coequal / causal / extension

Spatial	The spatial relationship between different components. He explores the different compositional possibilities of using space as a parameter between acoustic and electronic sound sources.	Actual source location / motion / implied source location / intrinsic spatial settings
Discursive	This axis is about whether the sound components have the same mode of discourse (aural or mimetic, taken from Emmerson, 1986).	Analogous / disparate
Pragmatic	This axis is about the implementation issues. It is about how the electronic sound sources are synchronized and implemented into the performance.	Variance / interactivity / sound production format / interface

Lalitte (2017) sees the relationship between electronics and instruments in three typologies: relation of communications, relations of identity, and complementarity relations. By communication, Lalitte means how the acoustic instruments and the electronics co-exist. Identity is how the listener perceives their co-existence. Complementarity means how the two worlds complete each other. All three of these topologies are tightly interrelated.

Table 3. Lalitte's typologies (2017)

Paradigm	Sub-Paradigm	Description	Example
Communication	**Inexistence**	A lack of a direct relationship between the electronics and acoustics.	Varèse – *Déserts* (1954)
	Coexistence	There is a parallel between both worlds, a certain amount of independence although they can come together sometimes.	Saariaho – *Six Japanese Gardens* (1994)
	Dialogue	A certain amount of exchange between the two worlds as if they are discussing an issue.	Stockhausen – *Kontakte* (1958-60)
	Confrontation	Contrasting and conflicting between the two worlds.	Reynolds – *Ariadne's Thread* (1994)
Identity	**Fusion**	Integration between both worlds, almost a dissolution. It is almost not possible to hear the differences. The electronics could be a mirror of what is played according to Lalitte.	Murail – *Désintégrations* (1982-83)
	Hybrid	The two create a new identity as one or by the passage of one to the other. Can also be done by morphing.	Stroppa – *Dialoghi* (1984)

	Double	The electronics are thought of as a reply to the acoustic source. This is the idea of the synthetic shadow.	Harvey – *Ricercare una melodica* (1984)
	Paragon	Unlike the idea of the double, here it is the instrumental sound that is modelled to come closer to the electronics.	Reich – *Different Trains* (1988)
Complementarity	**Aura**	An effect of coloration or sonic halo such as reverb.	Saariaho – *NoaNoa* (1992)
	Densification	A change of density or stratification done by the electronics.	Stockhausen – *Mantra* (1970)
	Extension	An extension of the acoustic instrument's sound either by amplification or effects like harmonization.	Stroppa – *Spirali* (1987-88)
	Interaction	This is only when there is a complete interdependence, influence on both sides between the acoustics and electronics.	Manoury – *Tensio* (2010)

Lalitte's analysis tries to establish straightforward ways of discussing the relationships between the note-based and sound-based elements. By nature, this is relatively abstract. As Lalitte (2017) states, it is also rare that a good piece of mixed music will remain in any one type of relationship throughout. Frengel (2010), Tiffon (1994; 2010) disagree with Lalitte (2017) on this point. However, these typologies fail to see the practical elements of how these relationships are bound together and how they are technologically/musically possible. Synchronization strategies form a bridge between these abstract typologies and practical aspects, illuminating how they afford the compositional process. Lalitte's topologies are geared towards source identification. There are many possibilities in the topologies between instrumental sounds and electronic sounds. However, the various musical roles of the musician and electronics are not discussed.

These typologies might hide certain biases. For example, Croft (2007) and Frengel (2010) discuss mainly sonic qualities and elements that fall closer to sound-based music. Their use of language can show a certain bias: using "mixed music" or "live electronics" for example when the latter might imply that liveness is better. Sallis et al. (2018) suggest that these two expressions are related to the cultural background rather than stylistic traits. Croft's (2007) ideas of electronics can be somewhat limited, ranging from the purely traditional (accompaniment) to elements closer to acousmatic music. Frengel (2010) mentions synchronization on the pragmatic and temporal axes. However, these ideas and their influence are not developed further. Croft (2007) includes aspects of interactivity and interface. He explains that the differences are purely technological between action-based and sound-based interfaces. He does not go into any details of the musical details of how this affecs a composition. Frengel (2010) mainly includes the idea of temporal synchronicity between both sound worlds.

Lalitte's (2017) clear separation with three topologies within a spectrum is visually the most straightforward system, yet remains informative. His view on mixed music is slightly more towards the note paradigm (Landy, 2007). However, he also shows a clear understanding of the affordances and relationships between acoustic and electronic sound sources by giving examples from musical pieces all over the spectrum. His focus on the relationship between sound sources makes his system pedagogically useful.

Earlier attempts to discuss and analyze electroacoustic music are also relevant. Frengel (2010) and Croft (2007) seem closer to much of the traditional literature on electroacoustic music because of their basis in perception. However, I use Lalitte's typology in Chapter VI to analyze Tutschku's *Zellen-Linien* (2007).

2.5 Synchronization in Literature

Synchronization is often mentioned by composers but has been rarely explored in a theoretical way. It is also rarely discussed within the analysis of mixed music compositional practices, as we will see in Chapter III.

Technological aspects adjacent to synchronization, such as MIDI pedals and tape, are often mentioned in the literature. Cont (2012), for example, discusses why he wanted to create the programming language Antescofo for score following. Often, scholars and researchers try to propagate their own strategies of synchronization. For composers such as Manoury, this is a form of polemics inspired by the post-World War Two composers like Boulez and Stockhausen. Even in the case of discussing modernizing electronics for pieces, synchronization is rarely at the forefront except for the difference between fixed media files and resynthesis (Coccioli & Bullock, 2005).

Many composers have touched on the subject. For example, Alvarez (1993) mentions the effect of using a click track on his composition *Papalotl* (1987). In Cohen-Levinas (1999), Murail admits to his piece *Allegories* (1990) having "synchronization problems" that are local (p. 26, discussed more in Chapter IV). Jodlowski (Jodlowski & Suescun, 2009) explains in an interview that he likes the various types of interactions and synchronizations between piano and electroacoustic devices in his piece *Série noire* (2006). For him, this provides the possibility tension within interaction, a dichotomic relationship between music and narrative, reality and fiction, and person and group. These choices form an integral part of his aesthetics and compositional choices.

Reynolds (McAdams, 2004) mentions having to "time up" computer parts and the instrumentalists for *Angel of Death* (1998-2001), yet he never mentions synchronization explicitly, and it seems as if the electronics are of second-order importance. Rather, the synchronization of electroacoustic music is not highly relevant to his compositional aesthetic. Because of his focus on composing notated music for human performers, Reynolds mostly uses technology to compliment his acoustic composition rather than as an actor with more agency in the mixed music actor network. These are just a few examples, we will reach more in-depth into how synchronization strategies shape the compositional process in Chapter IV, and we explore case studies in Chapter V.

Synchronization strategies are non-symmetrical and dynamic processes (Echeveste, 2015). They have a considerable influence on several compositional parameters and their relationship to the composition is complex and multi-layered. There is no one-to-one affordance that is easy to outline. Because of this complexity, understanding synchronization strategies is vital to gaining a better understanding of mixed music.

Cont (2012) and Risset (1999) mention heterogenous times within mixed music, meaning the presence of various temporalities simultaneously. Cont explains this heterogeneity as the dissimilarity between the time of playing and the time of media. Risset shows this as the difference between the time of performance and composition. Additionally, I think one should also think of the piece's musical time might be dissimilar from the performance time or even from the audience's time.

Historically, synchronization-related issues were discussed as the division between real-time and deferred time. This split was technological and ideological. Risset (1999, p. 4) explains that he is against real-time for five specific reasons. Firstly, he argues that digital systems have limited complexity. This has changed drastically with the increased processing power of computers in the last twenty years. Secondly, at the time real-time synthesis systems provided less flexibility than analog systems. This is a relevant aspect for this thesis, as the possible number of variables varies to a certain extent between synchronization strategies. How many variable changes in real-time can be truly perceived by the audience and performers? For example, shifting a thousand variables might have little perceivable musical meaning. Thirdly, Risset criticizes real-time practitioners as not being good enough with offline synthesis, hence their need for real-time novelty. Fourthly, he explains that real-time systems are often short-lived. This has become an important issue in the field, although outside this thesis's breadth. Lastly, Risset argues that music for tape is not "dead" as many in real-time music claimed at the time. Tape is performed, which is in line with other composers' thoughts, such as Annette Vande Gorne (2018). For Risset (1999), the schism is ideological. In this sense, he is the polar opposite of Manoury who sees real-time electronics as essential.

Stroppa (1999) explained that this debate mainly hid the compositional problems behind the technology. He mentions Stockhausen's *Kontakte* (1958-60) as an example. Although the piece was technologically limited with tape from start to end, its actual performance and musicality are not negatively affected by this limitation because of how Stockhausen devised the piece. As Cont (2012) asserts, synchronization is an interpretation and composition issue. It affects all aspects of composition and performance and reflects the presence of heterogeneous time and time scales. Additionally, Stroppa (1999) mentions further that thinking only the possibility of rubato or slightly different tempi as the essence of classical music is an insult to musicians' competence. Performance and interpretation are much more in the subtle nuances of a player's technique.

2.6 The Three Synchronization Strategies

By working as a scholar, composer, and RIM, I have tried to think of synchronization strategies both abstractly and practically. To theorize and discuss these strategies, it is vital to define and categorize them. This section categorizes synchronization strategies into three main groups or archetypes: fixed media, cues, and following. These three strategies contain many possibilities within them, and may be used in various combinations.

These strategies are not mentioned as archetypes throughout the literature, but rather as technological methods. Fixed media is present in the historical literature and in the articles debating liveness and deferred versus real-time processing. Cues are mentioned in the literature on performance and regarding porting already-existing pieces to recent software and hardware. Following is mentioned in articles on real-time and score following. Aspects of these strategies are taken from the literature and my experience in the field. Chapters IV, V and VIII will explore the use of these strategies in specific examples and contexts.

Some readers might wonder about the lack of live processing as a strategy. Live processing is one of the possibilities of using electronics, but it is not a strategy that helps control a temporal relationship between musicians and electronics. First, live processing is not a strategy but instead part of a performance technique (described later in section 2.7.3). Secondly, the literature often considers the use of live processing as something that transforms the performer's instrument rather than as a synchronization technique. It becomes a hybrid, augmented or hyper instrument (Bevilacqua et al., 2006; Essl & O'Modhrain, 2006; Kimura, 2008). Much of the literature on the relationship between instruments and electronics is focused on augmented instruments. Thirdly, live processing might have no temporal variation at all—it also exist as a timbral unison.

For each synchronization strategy, I will discuss deviation tolerance—how much the strategy tolerates rhythmical/temporal deviation between the electronics and the performers. Deviation tolerance is dependent on musical context. Figure 7 shows how the strategies lay on an axis in which the left side is strictly together, and the right side represents a looser synchronization. Circles represent strategies, while squares represent performance techniques. The Y-axis represents whether this deviation tolerance is mostly set by a performer (RIM or musician) or composer. The distinction can be subtle, but in the case of a tape part in which the composer has a strict and precise narrative, the performer does not influence the deviation tolerance as much as in following, where most of the narrative is directly based on the musician. A tape with a set series of events in time is much more strict than one in which the tape mainly serves as a backdrop. The primary observation here is that performer-driven strategies and performance technique tend to allow for a looser deviation tolerance.

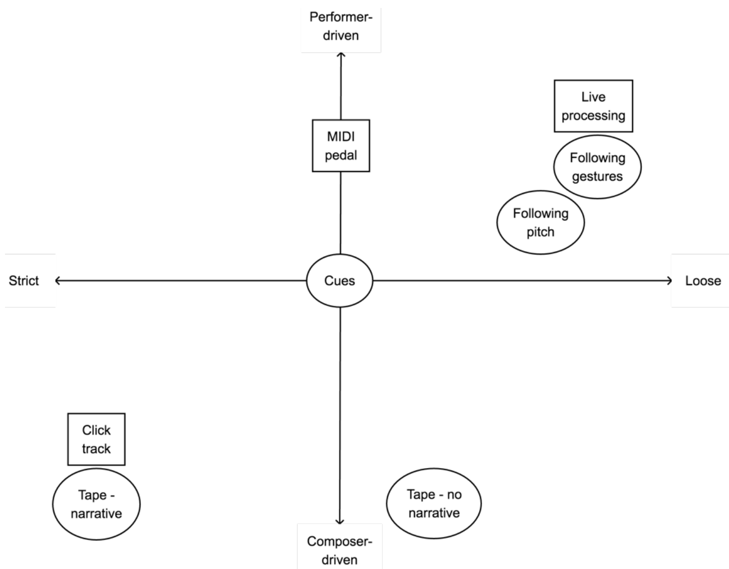

Figure 7. Deviation tolerance in synchronization strategies and performance techniques.

2.6.1 Fixed Media

The arrival of tape on the post-World War Two market had a considerable influence on compositional practices, which can be reflected in the various approaches of figures such as Schaeffer (Gayou, 207) and Stockhausen (2017). Though tape has become the quintessential medium of fixed media, it is far from being the only medium. Before the tape, gramophone disks could be used for some of the same ideas

Historically, fixed media was not a synchronization strategy, because it was the only option, an obstacle to be overcome. Therefore, one can argue that before the use of early samplers or ADAT units with fixed points, fixed media was not a synchronization strategy. With this historical context as a given, fixed media should be included within this corpus of strategies. In pieces like *Kraanerg* (1969) by Xenakis, fixed media is used to the musicians and dancers. However, the organization of the piece is still mainly around cues to trigger the fixed media on tape (Harley, 2015).

Throughout the thesis, fixed media will be used to mean any form of media that is fixed, ie. pre-recorded in any way, shape or form. This can also include other media types than sound, such as video, which is becoming a commonly used media such as in Michaud's "N I E N T E …" (2018). Each technology has both upsides and downsides. However, technological advancement has made many of these challenges of early computer processors more manageable. For example, in the 1990s, it was of paramount importance to think of how many files one could play simultaneously in a piece because of the read/write speed of hard drives (Faia, 2014). Except for extreme cases such as corpus-based compositions (see Echeveste, 2015), this is probably not an issue for most laptops today, partly because of the prevalence of faster hard drives and solid-state drives as well as their low prices.

How is fixed media a synchronization strategy? The use of fixed media will generally set a linear temporal narrative for the musicians. However, the presence of fixed media is not always a synchronization strategy. It can only be a strategy when the fixed media has a minimum length to create a narrative for the musician, however short it may be. Therefore, in pieces where granular synthesis (based on samples) or corpus-based techniques are used, fixed media is not necessarily used as a strategy for synchronization. The use of longer audio files in fixed media tends to dictate the flow of the musician. This is the case where the media is a single file (or tape) for the whole piece, such as was common in the 1960s such as in Nordheim's *Epitaffio* (1963), or in more modern pieces where shorter sound files are played, such as Saariaho's *NoaNoa* (1992). This set of fixed events, for good and bad, determines when musicians should play. There are exceptions to this dictation of time flow by fixed media. An example is the use of SuperVP to use vocoder techniques to shift the timing of fixed media to stay in tempo with a musician by also using a score follower (Trapani & Echeveste, 2014).

Some composers create a looser tape part, such as in the works of Ivo Malec, that still have a sense of synchronicity inherent in how the work is composed and played (Dudas, 2015). Many composers before the 1980s came up with novel ways or creating synchronization points between the fixed media and musicians. These points are what Stroppa (1999) has termed pivot points. We will look at how these temporalities and compositional strategies come together in Chapters IV and V. Essentially, one could view fixed media as a strategy that may be rhythmically strict or loose depending on the compositional context and usage of pivot points. The musician may have more temporal freedom between the established pivot points. In other words, the deviation tolerance of fixed media varies considerably, despite its reputation of tyranny in the literature (McNutt, 2003).

The use of fixed media has often invoked compositional paradigms and principles from acousmatic music. Moore (2016), Smalley (1997), and Vande Gorne (2018) are some of the many authors that have gone in-depth into the creative possibilities and paradigms of electroacoustic music. In practice, fixed media can widen the gestural possibilities of composition, and perhaps a open a more developed sense of spectromorphology. The spatialization traditions ranging from diffusion (Harrison, 1998) and multichannel work (Barrett, 2002) are also relevant. Conceptually, a composer of fixed media works may feel that one is working in some of the same ways as acousmatic music regardless of style or genre, which some might want to avoid. However, many composers may prefer to work with the studio as a compositional tool instead of more traditional programming languages such as Csound. The use of a DAW in the context of composition has perhaps a lower learning curve than several of the common programming languages and also offer the possibility of using commercially-made tools and plugins with relative ease.

There are some disadvantages to fixed media. Firstly, it is fixed, by nature. If it is artistically essential for the composer and/or performer that a work be constructed or changed in the moment, then fixed media is perhaps not suitable. However, when files are shorter, making some temporal changes in concert may create an illusion of liveness. This can also be purely pragmatic—for example, a RIM extending a sound by a few seconds or changing fade-ins and fade-outs to suit a performance in real time. Secondly, most composers do not have the same listening conditions when working in a studio as in the performance space. Although several practitioners have come up with solutions of varying success such as Tremblay &

McLaughlin (2009), these solutions are not necessarily suitable for every situation. Thirdly, it is often harder to quickly adjust the files' parameters that need to be changed due to the acoustics or deficiencies in the hall. Fourthly, fixed media is in chronometric time, which is an external time to what the musician usually is playing, which can create issues of synchronization. From a compositional point of view, this is one of the more challenging aspects of using fixed media. How long should each sections be? How will the performer know when a new section starts? Should I have audible pivot points? Composers throughout time have found solutions to these questions in their own aesthetic, and technical capabilities.

Composition Examples:
Jodlowski – *60 Loops* (2006) – Chapters IV & VIII
Schubert – *Hello* (2014) – Chapters IV & VIII
Smalley – *Piano Nets* (1990) – Chapter IV

2.6.2 Cues

A cue is "a signal (such as a word, phrase, or bit of stage business) to a performer to begin a specific speech or action" (Merriam-Webster, N.D.). In mixed music, this means a trigger (audible or not) for the electronics to begin a specific action. This synchronization strategy is also called the scene system, reminiscent of scenes on digital mixers to switch between cues, sending auxiliary channels to various effects, so on and so forth. A cue can change which effects an instrumental sound is sent to, trigger a new sound file, change the lights on the stage or anything else. Compositionally, cues may be easy to imagine or hear in the mind's eye. When writing the score, it is easier to write that at the start of m. 42, event 13 begins. Cues can also be set within a musical time instead of being purely chronometric.

How is a cue a synchronization strategy? Effectively, each cue can be seen as a pivot point between the electronics and the musician. What happens between each cue might not be perfectly synchronized. In this sense, the deviation tolerance of cues is higher than fixed media. Once again, the deviation tolerance is highly dependent on the musical context, but also on what the cues are themselves. For example, triggering fixed media files might have less deviation tolerance than changing the type of live processing used. The point is that cues offer a linear, structural point of contact between the musician and the electronics.

As mentioned above, a cue can be anything in practice, ranging from fixed media files or digital signal processing to a non-audible process. It is most common to see a MIDI pedal used by the performer to trigger cues of fixed media and live processing. Cues can be an important compositional parameter which is not necessarily heard by the audience or musician.

There is often an additional person shadowing the musician to make sure all cues are correctly triggered. Most commonly, this will be the composer themselves or a RIM. The point is to ensure the proper order of cues, and any other discrepancies without negatively affecting the musical interpretation. There are many reasons for having a back-up plan during the performance, often based on the performer's impossibility to fix any problems from the stage. This aspect of performance will be explored more in Chapter VII.

The cue strategy's main advantage is to make a musician feel included in the control of the electronics directly. As a performer, it makes the relationship between what one hears and what one does more straightforward. It is also a simple way to synchronize the start of a process, although synchronizing the process beyond simple triggering poses certain difficulties. Additionally, the clarity and preciseness of cues make them easy for composers to conceptualize and create. In conclusion, cues allow the electronics and/or the musician to take the lead musically and dynamically change this throughout a piece.

Composition Examples:
Harvey – *String Quartet No. 4* (2003) – Chapter V
Murail – *Winter Fragments* (2000) – Chapter IV
Tutschku – *Still Air 1* (2013) – Chapter V

2.6.3 Following

Although score following might be ubiquitous, there are many other types of following which are not pitch- or notation-based. Therefore, this strategy is called only "following" instead of score following. In essence, following is using any variable from a musician's performance to synchronize with the electronics.

Historically, following has been thought of as only score following. In the 1980s, Berry Vercoe and Roger Dannenberg independently worked on methods for score following (Puckette & Lippe, 1992). Puckette's work with Manoury, starting with *Jupiter* (1987) and *Pluton* (1988-89), showed more advanced compositional and technical possibilities. An example is how he already codified score following as the separate actions of recognition and following (Manoury, 1998). The former is the chronological recognition of what the performer is playing. The latter is the “detection of events that we do not know in advance” (Manoury, 1998, p. 76).[14]

Early uses of score following relied mainly on recognition. Puckette explains that for *Pluton* (1988-89), Manoury had to compose with a linearity that was not in the original conception of the work in order for the recognition to work properly (Clarke, Dufeu & Manning, 2020). In the late 1980s, score following was often entirely based on MIDI, and the technology could only follow relatively simple aspects of the performer’s musical flow with three notes at a time (Manoury, 1998). This type of recognition and following can feel static for the performer and has little flexibility. Cont (2012) believes that the exciting aspect of score following is how human it can be. Musicians might be a bit late, but they will not stop playing but instead try to catch up. Score following attempts to reproduce this aspect of human performance.

Although many of the well-known compositions in the repertoire use pitch tracking, other following possibilities have become popular in recent years. Gesture tracking has become more promising and prominent in music and other art forms such as dance, for example, Palacio & Romero's *Piano & Dancer* (2016). Gesture tracking means that the computer must recognize the movements of a performer. Many have used sensors on string bows to receive meaningful data as well (Bevilacqua et al., 2012; Nichols, 2002; Wilmers, N.D., among others). Although there have been several projects for bow sensors, there is still no commercially available solution. It is not always possible to attach sensors to bows as it offsets their balance point, which is crucial for string players. As McNutt (2003) notes, one of the problems for many performers has been how much time and technology are needed to learn their instruments, making them uncomfortable with changes to the physicality of the instrument. Additionally, the amount of allotted rehearsal time is then mainly used on the piece's technological aspects instead of interpretational aspects, to the detriment of the performance.

Several projects have recently tested gesture recognition for the conductor for more ensemble-based music (Bacot & Féron, 2016; Thordarson, 2019, among others). The justification for using the conductor has often been their traditional role as a gatekeeper and the foremost interpreter in ensemble music. Therefore, giving this person the control of the electronics is seen as an extension of their musical role. In my experience, many conductors seem even less comfortable controlling electronics than musicians. One can also question

[14] *(…) la detection d’évènements qu’on ne connait pas d’avance.*

whether they can afford the time to work with electronics and understand them, although it is slowly changing (Moore, 2020). In Thordarson's (2019) project, the conductor would often turn down the electronics. However, the conductor's monitoring position may have led her to misjudge the electronics' amplitude.[15] The differences between instrumentalists' and conductors' gesture recognition emphasize the challenges between soloistic and ensemble writing. Additionally, gesture following has also been done through the use of video, such as in Nordin's *Sculpting Air* (2015).

Audio descriptors have recently become more popular through their wide use in improvisation and corpus-based compositions, among others. Their use can be as simple as the amplitude controlling the length of a reverb, such as in Saariaho's *NoaNoa* (1992)[16] to more complex possibilities mentioned by Malt (2017). Baschet and her RIMs changed a composition's strategy following from gesture to the use of audio descriptors for her composition *BogenLied* (2005) (Baschet, 2019; Lemouton, 2009). This newer version of the piece, created in collaboration with Lemouton, makes several aspects of the work easier. The first one is that there are now fewer cables involved and no sensors. Secondly, the piece is now more portable—making it easier to send the electronics to be played anywhere. More information about this composition as well as *StreicherKreis* (2007-08) will be given in Chapter IV.

In all of these examples, recognition is a primary aspect of following because it affords triggering events or complex mapping relationships with a single sound. The examples given are non-exhaustive but give a clue as to the various possibilities and prove that following is technology-agnostic. One could consider the physical activity of having a RIM follow where a musician is and change specific parameters to be following as well. In many of the SWR compositions, such as Nono's *A Pierre: Dell'azzurro silenzio, inquietum* (1985), the electronics were done manually (Boutard, 2019).

Following allows a level of both flexibility and precision that is difficult to match. Many of the uses of following afford radically different compositional possibilities based on logic and processes. It can also let musicians interpret the music more flexible forms of performance practice unhindered by technology's robotic, absolute time. The deviation

[15] Furthermore, the musicians are often not in a favourable monitoring position either. Monitoring in mixed music has been an underrepresented problem. This aspect was already explored in Lacroix (2016).
[16] It is interesting to note that although this is mentioned in several sources such as Lorieux (N.D.) it does not work in all the official MaxMSP patch versions that are official (private conversation, Conforti, June, 2019 at IRCAM, Paris, France). This lack of clearness between the piece's documentation and performance shows some of the major dilemmas when one is to reprogram these pieces.

tolerance of following is often quite high, as everything is based on the musician's behaviour. However, in most pieces, the composer will probably have created several processes, which can restrict the musician's actions and/or take the lead musically.

The most significant disadvantage of following is that it may be volatile and unstable. In gesture following, many of the solutions are prohibitively expensive and sensitive to outside factors such as the amount of light on stage. Depending on the technology used, environmental issues outside of the musicians' or technicians' control can make the performance challenging. Using following in an interesting manner often requires significant time for programming. It is more difficult to establish such a system than using the strategies of fixed media or cues. Additionally, following can alienate some performers and make them feel that the electronics are an impenetrable black box because of the complexity of the technology required to create effective following. There is often a larger gap between the score (or musical thought) and the execution, making it difficult to conceptualize and be confident it will function. This gives following a steeper learning curve than the two other strategies.

Composition Examples:
Blondeau – *Namenlosen* (2017) – Chapter IV
Manoury – *Tensio* (2010) – Chapter V
Nordin – *Sculting Air* (2015) – Chapter IV

2.7 Performance Techniques

These synchronization strategies may seem somewhat abstract since their use and conceptualization lie closer to the composer than any other actor. Performance techniques are used to connect these strategies to the performer and generally solidify the temporal relationships between the performer and electronics. These may be physical, such as a MIDI pedal or microphone, but may also be audible such as a click track.

The practical use of performance techniques and how they are interlinked with synchronization strategies will be developed further with specific examples in Chapters IV and V. This section will establish what the main performance techniques how they function in practice.

2.7.1 Click track

The click track is a well-known tool. Its periodic sound at a given tempo give the musician the needed beats and accents to stay in time. Studio musicians in popular music learn quickly to play around the metronome perfectly. However, click tracks have a relatively bad reputation within contemporary music. Many musicians have criticized how stiff they can feel (Kimura, 2003; McNutt, 2003, among others). The general hypothesis is that musicians within classical music are not used to playing with a metronome in performance, and therefore when faced with the challenge, they must concentrate more on the metronome than their listening. This can lead to a stiffer feeling, and at worst, to intonation problems. McNutt (2003) explains that classical musicians have spent years learning how to project their tone in many types of rooms in performance instead of listening to a click track. An example of this is given in Chapter VIII: musicians were practicing Jodlowski's *60 Loops* (2006) and it was quite a different result for them to play with and without a click track. The use of the click track affected their intonation.

An alternative to the click track is for a composer to write chronometric time—the number of seconds for a gesture. Historically this was quite common within the use of graphical scores and more recently in performance art and the music related to it. Works by Jennifer Walshe, for example, often use chronometric information instead of a traditional score. In general, one can extend the definition of the click track for performance technique as any time that is external to the musicians or conductor whether it be musical (as a traditional click) or a chronometric specification in the score.

Click tracks have several advantages. Ding (2006) asserts that they are beneficial to maintain tempo within improvisation. Alvarez (1993) considers the effects of a click track positively and negatively on his music, depending on its temporal needs. The main advantage of a click track is that it gives a "perfect" temporal synchronization between the musician and the electronics. João Pedro Oliveira swears by this method. It allows him temporal freedom to use fixed media in a way more reminiscent of acousmatic music without worrying about deviation tolerance (Oliveira, 2019).

Click tracks are sometimes used to synchronize with sound files that include a reference pitch, especially in microtonal music. The lack of sufficient rehearsals can also aggravate reference pitch problems, and therefore the use of a click track with reference files is a pragmatic solution (Bell, 2016). The tensions between what is aesthetically necessary for a piece of music and the musician's technical needs is an exciting aspect of mixed music.

Click tracks are often the first technique used by up-and-coming composers to combine electronic and acoustic sound sources. It is mainly associated with the strategy of fixed media historically, but it can also be used with cues. It is often antithetical to the following strategy, which desires a looser temporality. The click track and chronometric time are considered a technique and not a strategy because the click track does not inherently synchronize acoustic and electronic elements. Rather, it must be used in conjunction with a strategy.

Composition Examples:
Jodlowski – *60 Loops* (2006) – Chapter VIII
Romitelli – *An Index of Metals* (2003) – Chapter VIII
Schubert – *Star Me Kitten* (2015) – Chapter VIII

2.7.2 MIDI pedal

The MIDI pedal is ubiquitous in mixed music performance. It also gives a sense of control to the musicians, which can be positive or negative depending on their previous experiences. It offers a relatively secure method of triggering cues. If the musician happens to miss a cue, a RIM can trigger it instead. The main advantage of this technique is how secure, safe and easy it is to implement. The required technology is lo-fi, cheap, and physically robust. Additionally, pressing a pedal is a comparably easy technique for musicians to practice at home to learn the physical coordination needed.

However, there are difficulties associated with this technique. The physical aspect of pressing a pedal can be problematic. Although it is possible to shift the pedal's polarity—meaning that there is only a trigger when one releases the pedal—pressing it can be uncomfortable. The amount of discomfort is personal but also varies from instrument to instrument. A piano player is used to pressing pedals; however, a violinist or clarinettist might not be used to the physical gesture. It might not seem like much, but asking a woodwind player to press a pedal while standing up can be quite daunting. If the composer has not taken care of where the pedal markings are, it can become an even more daunting task, especially in challenging music.

Another issue is the lack of haptic feedback (Berweck, 2012). The musician might be uncertain if they triggered the event. There are ways to circumvent this, such as giving a graphical interface to the musician which shows event numbers. However, this also creates an additional element that takes up valuable milliseconds of the musician's attention. It might not be an issue for someone comfortable playing mixed music, but since most musicians are not, it can be a severe issue. This will be explored further in Chapter VII.

All in all, the MIDI pedal technique is flexible. It is often used for both fixed media and cues. It also has the advantage of giving a bit more control to the musician, which could be positive for specific pieces and somewhat restrictive for others.

Composition Examples:
Lacroix – *Quasar* (2020) – Chapter IX
Murail – *Winter Fragments* (2000) – Chapter IV
Tzortzis – *Incompatible(s) IV* (2010) – Chapter VIII

2.7.3 Performance Tracking & Live Sound Processing

The idea of a microphone as a performance synchronization technique might seem odd at first, but it has its place for several reasons. Firstly, live processing is one of the most common musical elements in mixed music. Secondly, it is relevant for synchronization strategies that use the microphone as a sensor to follow pitch or other audio parameters. One has to distinguish whether the microphone is used solely for information or if it is also used for amplification, which influences the aesthetics as well.

McNutt (2003) declares that amplification can be uncomfortable as it highlights sounds that classical musicians have spent years trying to hide or minimize. However, many pieces use amplification precisely to capture and amplify these sounds. Microphones can drastically alter the instrument's use. They can also be used for live processing, in which case, one might not hear these artifacts from the musician's playing. Since McNutt's publication, more musicians are becoming comfortable with amplification. For many, it is becoming a part of their sound and aesthetic. It has become more common for musicians to own a microphone (often a clip-on DPA4099). The rise of composer-performers with electronics as an important aesthetic has also become more common. Examples include Émilie Girard-Charest, Bára Gisledóttir, and Decoder Ensemble. We will come back to amplification in Chapter VIII.

Thordarson (2019) discusses how the ensemble musicians and the conductor were terrified of feedback during rehearsals. The musicians felt a lack of control over the sonic environment, which became an issue. However, a good sound technician that understands microphone bleeding, positive feedback, classical music instrumentation can fix these issues during soundcheck and rehearsals. It is also possible to have some form of processing that minimalizes the possibility of feedback, such as using a frequency shifter. In a smaller concert hall, only sending out processed sounds (and not reinforcing the acoustic instruments) can minimize the risk of feedback. However, this is more difficult to do in larger concert venues where the instruments need amplification for appropriate audibility.

Microphones are useful for the detection of audio descriptors and other following-related parameters. Baschet & Lemouton (2019) managed to eliminate the need for expensive and delicate sensors by using audio descriptors, as will be explained in Chapter IV. One should understand this is time-consuming work even with several RIMs. Therefore, it is difficult or unrealistic for many composers because of the lack of time and resources.

In general, microphones are mostly associated with the strategy of following and/or for amplification. Because of the prevalence of live processing, this technique is one of the mainstays of mixed music.

Composition Examples:
Baschet – *BogenLied* (2005) – Chapter IV
Manoury – *Tensio* (2010) – Chapter V
Tutschku – *Zellen-Linien* (2007) – Chapter VI

2.8 Layers of Synchronization Strategies

Although the strategies of section 2.3 were presented as separate, the lines between these are often blurry. It is possible to combine all three strategies into a single piece simultaneously. A single strategy will often have a more critical role, but other strategies will still be present. An example is how triggering (through a MIDI pedal) might be the main strategy, but each trigger plays several shorter fixed media files. These events triggered by the pedal can also change the presets of live processing modules. In this case, the cue strategy is the most crucial. To help clarify these complex issues, I have made a graphical system that will be used throughout the rest of the thesis. Different layers or hierarchies of strategies and performance techniques can be illustrated graphically.

In Figure 8, circles represents people (usually a musician, conductor or RIM), triangles represent physical devices (such as a MIDI pedal or microphone), and squares represent any digital (or non-physical) process. Each colour represents a synchronization strategy. Blue is anything that can be related to following, red is anything relating to cues, and green is anything related to fixed media. Black is processes or actors that are not inherently part of a strategy. The most critical synchronization strategy will always be those closest to the diagrams' top. The arrows also show where a sound signal or information (in the case of audio descriptors) go, and how they are used.

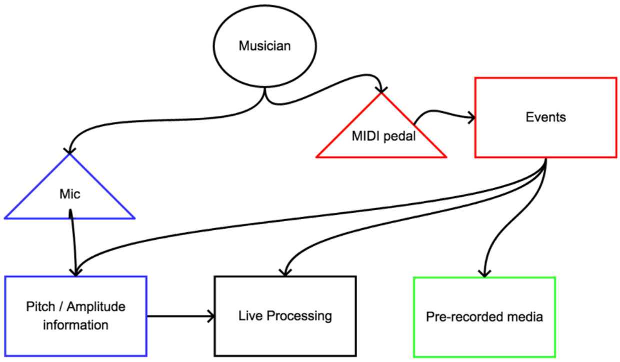

Figure 8. Synchronization strategies and performance techniques in NoaNoa (1992).

Figure 8 is a relatively simple example with all three synchronization strategies are present. In this case, cues are the primary synchronization strategy, which controls everything else within the piece with the help of a MIDI pedal. With the pedal, the musician controls when the 63 events shown in the score are triggered. The events change processing parameters such as reverb and harmonizers. The events also trigger fixed media files (which in this case are not a synchronization strategy since the samples are quite short). A microphone is used to amplify the signal, and the flutist's amplitude is supposed to modulate the amount of reverb.

This piece is typical in its use of synchronization strategies. Many of the pieces that have come from IRCAM use similar strategies and hierarchies. Mikhail Malt, a teacher within the IRCAM Department of Pedagogy, explained that the use of the MIDI pedal is often the easiest to implement technologically. It is easier for composers to understand while affording many compositional possibilities.[17] The use of a pedal may also reassure musicians that are not used to playing with electronics that they still have control.

In Manoury's *Tensio* (2010), following is the highest layer as it controls most other processes, as shown in Figure 9. His Antescofo score is cueing directly many events, but the following is the highest layer as it has more temporal influence on the music. Although

[17] Personal communication with Mikhail Malt while at Manifeste in June 2019, Paris, France.

following is the highest layer, many similar compositions also have the possibility of cueing to be used if the highest layer fails. This piece is analyzed and discussed further in Chapter V.

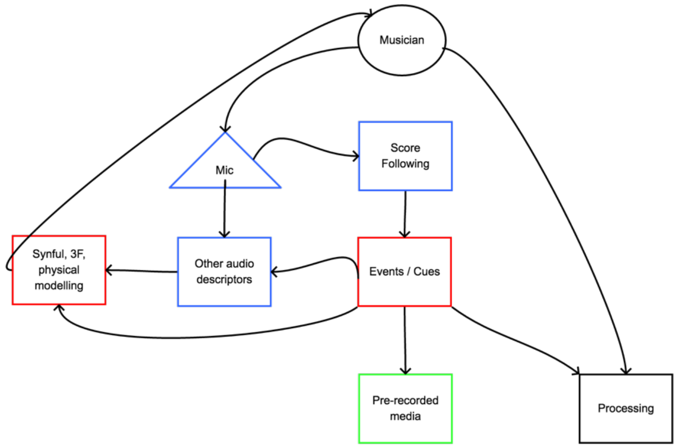

Figure 9. Synchronization strategies and performance techniques in Tensio (2010).

2.9 Conclusion

Synchronization strategies are a concept to analyze mixed music from a musicological angle and as a compositional tool. Throughout the rest of this thesis, this terminology will be used as the main framework to discuss the difference between the score, performer and electronics. There are three main strategies: fixed media, cues and following. These can all be combined in various combinations, although one will generally be of more importance. The hierarchy within one piece is what we refer to as synchronization layers. Synchronization performance techniques further specify how to connect electronics with musicians temporally of pieces using tools such as click tracks, MIDI pedals and microphones.

I have compared the concept of the synchronization strategy to some of the existing literature on mixed music. Although many authors touch on similar subject matter, few directly discusses the effects and affordances of synchronization strategies. These strategies are useful for furthering mixed music discussion as they allow us to discuss issues of aesthetics and poiesis. In the next chapter, we will look a bit at the compositional process before looking at composition and *écriture* in connection with synchronization strategies.

Chapter III: The Compositional Process

We are musicians and our model is sound, not literature; sound, not mathematics; sound, not theatre, or the plastic arts, or quantum physics, or geology, astrology, or acupuncture!

-Gérard Grisey, quoted in (Gilmore, 2009, p. 17).

3.1 Introduction

The compositional process is sometimes seen as mystical. Popular culture presents composers as Romantic geniuses that composed in a vacuum. Historical and musicological studies debunk this view but still put older European composers on pedestals. The compositional process is challenging to study, as it is a personal experience that often leaves few traces. The last few decades have seen more articles written by composers and musicologists on the subject (Harvey, 2008 among others). Exploring the compositional process is essential in the context of this thesis because synchronization and composition are implicitly connected. Relevant theoretical conceptualization about the compositional process is needed to understand how synchronization has affordances on compositions. Understanding both aesthesis and poiesis in composition is critical for discussing synchronization strategies and their link to the compositional process.

Additionally, a difference from traditional working methods should be emphasized. Until relatively recently, with the advent of mock-ups and sound libraries, it was impossible to hear a work-in-progress unless a composer played it himself or had it played by others. Conceptually, art music is a pen and paper type of music, meaning that the music does not "exist" before it is played. Therefore, in acoustic composition the conception generally comes before the result. This changed with the advent of *musique concrète* and sound-based music. The (relatively) immediate auditory feedback when working on electroacoustic music makes the compositional process inherently different. This chapter will:

- Contrast and compare studies on the compositional process
- Look at examples of the compositional process
- Establish a diagram of the compositional process that suits mixed music

3.2 Research on the compositional process

Research on the compositional process has been relatively slow to appear. Especially after the Second World War, composers wrote more about their processes, but these writings were generally more personal. Dusapin had the following to say:

> *How might one bear witness to musical creation as it took place? Can we indeed convey a composition-in-progress? I do not believe so. Composing has taught me that the invention of sounds is a phenomenon one cannot distil into an exposé. …Describing the procedure through which a work of music evolves cannot capture the essence of the creative act as it occurs. It is only a description* (quoted in Donin, 2013, p. 29).

However, I would argue that Dusapin's books attempt to do this, although in a non-linear manner (Dusapin & McKinley, 2017; Dusapin, 2012). Huber explained his compositional process and reflected on its meaning as well (Mahnkopf, 2010). However, several studies have tried to present the compositional process in a standardized linear manner. There have also been cases of scholars tightly following composers on a project such as Leroux's *Voi(rex)* (2002). Leroux kept track of his compositional decisions to re-use them in another composition *Apocalypsis* (2005-6), to examine how similar the compositions would turn out (Donin & Theureau, 2005). Reynold's *The Angel of Death's* (1998-2001) compositional process was documented and analyzed by McAdams (2004). Additionally, Reynolds (2004a; 2004b) has elaborated on his process, as will see later.

There are many arguments why composition cannot be considered straightforward or linear in any sense. Delalande (2007) criticizes the often-cited example of electroacoustic composition, which is presented as a linear process from recording to transformation and then mixing. Delalande created a model named the "Teruggi Strategy" (after the composer Daniel Teruggi), as shown in Figure 10. Additionally, he uses the concept of decision-making as a cornerstone. The composers he interviewed create electroacoustic music, which leads to some differences in strategies and views. Delalande (1993) explains that compositional strategies can influence style within electroacoustic music.

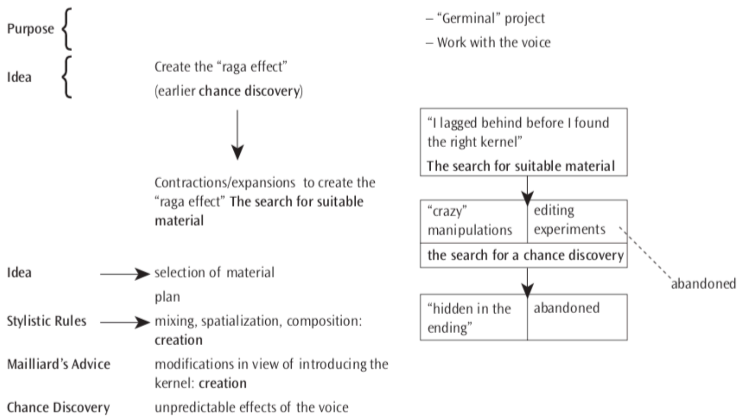

Figure 10. The Teruggi Strategy according to Delalande (2007, p. 16).

Roels (2016) notes that Delalande's theories are mainly deduced from electroacoustic composition and might not transfer to acoustic composition. Roels looks at eight composers, and none of them tend to do much sketching or rewriting, which seems uncommon in historical accounts and my own experience. The composers Roels has chosen to study also tend to write outside of contemporary art music. He asked the composers to draw their process. All of them showed a linear process. They also put writing and rewriting as a single process happening simultaneously.

Donin (2018) wrote an overview of research in the field and points out the irony that musicology rarely focuses on the compositional act. His research shows that stylistic differences within contemporary composition do not play a significant role in known composers' processes. The compositional process has "determined qualities such as the coherence or novelty of an opus" (Donin, 2013, p. 27). Donin (2018) separates the creative process into two main tendencies. The first is synoptic planning, which means that "the composer defines the piece of music through several global conceptions that demand a characteristic evolution of the compositional material" (p. 13).[18] The composer would then compose a time axis with different compositional parameters that would change over time. The second is heuristic primacy, which means that the work's main characteristics are discovered and generated as the piece is being composed.[19] Often both will be found in local operations. Additionally, Donin asserts that many composers come to a form of learning in

[18] *Planification synoptique.*
[19] *Primat à l'idéation heuristique.*

their compositional process. They learn to master a particular process and use it. Composition becomes a "problem" in which the composer finds a solution to "fix".

Furthermore, Donin (2013b) explains that a composer's self-analysis is a valid method to discuss the compositional process. Hervé presents note-taking as a tool to generate and generalize theory. Donin’s view on Hervé is closer to the *recherche-création* paradigm as described in the introduction of this thesis. A schematic for the compositional process by Jean-Luc Hervé (1999) is of note, which I have reproduced and translated in Figure 11 (reproduced from Donin, 2013, p. 1646). Although Hervé's view is relatively linear, it shows that several composition elements happen simultaneously. His graphic also shows that the "writing" is a relatively small part of the process, while the conceptualization and building of units, form, vision are the bulk of the work.

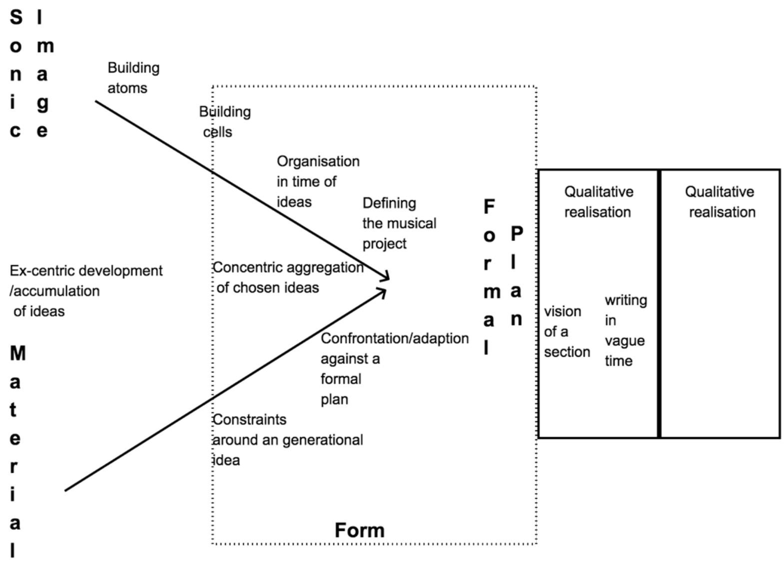

Figure 11. Hervé's (1999) graphical representation of the compositional process.

Brown & Dillon (2013) define five modes of compositional engagement: attending, evaluating, directing, exploring and embodying, as summarized in Table 4. A composer often seamlessly shifts between them. The most interesting aspect here is how the process is shown as non-linear. Additionally, attending is especially relevant for mixed music as we have elements that we can hear and others we have to imagine, forcing us to utilize several types of attending simultaneously.

Table 4. Brown & Dillon (2013) 's five modes of compositional engagement.

Mode	Definition (Brown & Dillon, 2013, p. 82-83)
Attending	Listening to the work (perhaps even in the Schaefferian sense) either through performance, recording or with imagination.
Evaluating	Looking at one's work critically. It could be reviewing a complete section or concentrating on the strings' orchestration in the whole work.
Directing	Manipulating different musical materials and parameters to form them as one wishes. This could be through an automated process in computer-assisted composition as well.
Exploring	Unlike directing, this is manipulating different parameters and materials without a clear goal. It is done to clarify a particular conception of the work, usually (although I would argue not always) within defined boundaries.
Embodying	Similar to how a musician will improvise on her/his instrument. One falls back on patterns, concepts, theories and ideas one is familiar with.

These authors and models are trying to explore the various views one can have of the compositional process. Delalande (2007) is focused on acousmatic music. Roels (2016) is more general but seems improbable in contemporary music. Donin's (2018) repertoire is within contemporary music, which makes it relevant. Brown & Dillon (2013) is also too general for our uses. Most of these systems rely on linearity within the compositional process, which is problematic. Donin shows that the task's non-linearity and complexity can be better understood by looking at a composer's process. Within my own experience, I rarely experience a linear compositional process—I constantly move between various modes and rarely work on a piece from start to finish. I tend to work on various sections simultaneously, constantly moving between macro and micro views.

3.3 Reaching the compositional process through analysis

Trying to reach the compositional process by deduction, such as mentioned in Donin (2018) is not new. Nattiez (1990) and Molino (1991) are essential sources for the concept of the neutral level in semiotics, which has played a prominent role in the analysis of electroacoustic music through scholars such as Roy (2003). The idea that an analysis of aesthesic and poietic elements of composition can help us understand its creation has become accepted in the field (Zattra, 2004). Often, this assumption is an analytical necessity, as information from the composer or RIMs might be lost to time or unavailable. This section looks at examples of these analyses to show how analysis can be a valid research method for studying the compositional process.

In 2007, a special edition of Computer Music Journal was dedicated to John Chowning, with an in-depth look at *Stria* (1977). A large part of the issue was dedicated to re-creating the piece from scratch (flaws included) to get an insight into his creative process (Chowning, 2007; Meneghini, 2007; Zattra, 2007). Reconstruction and understanding the technological tools available to Chowning were of primary importance for these scholars to assess his compositional process.

Another example has been the analytical work on Stroppa's *Traiettoria…Deviata* (1984). Tiffon & Sprenger-Ohana's (2011a) analysis starts by exploring the composer's background to explain how his compositional process functioned at the time. They then extrapolate from Stroppa's top-down work method that his musical (i.e. acoustic) goals often trump his programming, despite his goal of combining these two worlds entirely. An example is his use of speakers to excite the piano's acoustic resonances.

Stroppa's ideas on musical information organisms influenced his composition of the second movement called *Dialoghi* (1984), in which he wanted to augment the resonances of the piano as a compositional gesture (Stroppa, 1989). According to Tiffon and Sprenger-Ohana (2011b), it was around this time that he became aware of the psychological studies on fusion and fission by McAdams (1989) that would then underpin Stroppa's musical philosophy. This example shows a composer getting an idea, sketching it and then refining it through theory. In Chapter IV, we will explore how this influenced his use of synchronization strategies.

Castanet & Fineberg's (2000) analysis of Grisey's music sheds light on many of his spectral techniques. Exarchos (2018) is an example of a specific analysis of *Le noir de l'étoile* (1989-90), which sheds light on Grisey's concepts of time. His view of time can influence our perception and his compositional ideas on the modulation of time. Because of the genesis and documentation of the spectral style, Féron (2011) identifies a historical progression in how Grisey's use of spectra changed with time, essentially in the evolution of his compositional process in the 1970s. Tristan Murail has also been interviewed, discussing, for example, how he tends to move between electronics and his written music (Cohen-Levinas, 1999). It is also well documented that Murail's compositional process radically changed during *L'esprit des dunes* (1994) because of his use of PatchWork (Hirs, 2009a). He is also well known for basing acoustic compositions on electronic principles such as *Mémoire erosion* (1976) based on a tape loop.

The most relevant example of writing about Murail is Hirs's (2009b) analysis of *Le lac* (2001), which is relevant as it discusses analysis from a perception-based (aesthesic) perspective and a construction standpoint (poiesis). *Le lac* (2001) and *Winter Fragments* (2000) exhibit clear structures and processes. The former's first section of the piece shows how Murail repeats a sequence of objects from mm. 1-66 with permutations and variations. After two similar repetitions, he changes the structure and permutation, making more significant changes. Because of this process, the listener may discern how the heterogenous elements are related. Understanding the structure and the use of musical objects makes it much easier to grasp Murail's composition process and how they are an inherent part of his *écriture*. We will explore his compositions again in Chapter IV.

Nicolas' (2010) model of Boulezian of musical intellect in Figure 12 is an interesting way to analyze a composer's process and ideas. One can view this model as a form of hermeneutics, meaning the interpretative method and science defined by Feder (2011) as:

> *In other words, we seek to understand the work in terms of the conditions of its creation, its original being, and its original effect, before the conditions were forgotten and before the work was altered and its effect weakened in the historical course of transmission, performance, arrangement, and reception. Out of the unhistorical understanding comes a historical understanding that is not coolly distant from the aesthetic message but in the closest possible relationship to it. Granted, this aesthetic understanding can be only approached, not completely realized, and must necessarily always proceed from a contemporary perspective* (p. 88).

The point is that Boulez's understanding of musical intellect requires an understanding of influences, even if these are historically incorrect.

This is relevant in our context because a composer's view of the sciences can influence the compositional process and use of synchronization strategies. Especially within the post-World War Two polemics, scientific argumentation was typical, although rarely backed by facts. Sciences could mean the use of concepts from acoustics for compositional purposes. The philosophy, understanding, and aesthetics of a composer inevitably influence their view of composing music. For example, one can argue that Reynolds is not as interested in a perfect blend of electronics and acoustic sound sources; therefore, synchronization strategies might be a lesser problem or priority. Hermeneutics and a more constructivist approach are already established practices within this field. Battier (2003) asserts that understanding the available equipment's possibilities in making an electroacoustic piece is vital to understanding its composition and analysis. Boulez himself would sometimes remark that the composer does not necessarily know best, and he often aligned his thought with that of the gestalt psychologists who view the whole as more important than the parts (Nattiez, 2010). Theory, critique, and aesthetics hold a significant influence on looking at a specific piece's compositional process and understanding it.

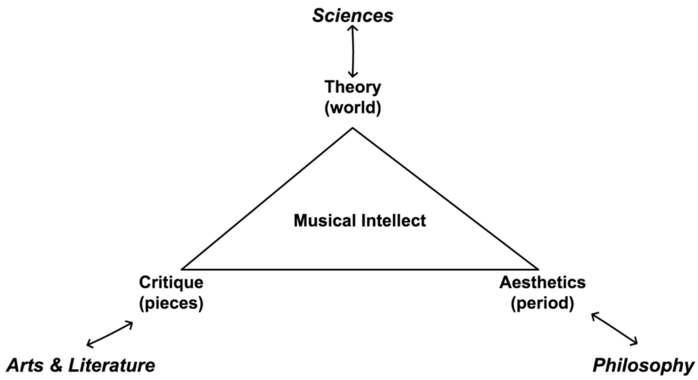

Figure 12. A translation of Nicolas' (2010) Boulezian musical intellect.

I argue that analysis has been of central importance for understanding contemporary composition and the compositional process since the Second World War. For example, the courses at Darmstadt were often the central place to get an education on the more cutting-edge compositional techniques, which often spread to the analysis of works (Griffiths, 2011; Iddon, 2013). Theorists and analysts, like Leibowitz, played a significant role in the dissemination of the modernist style (Jameux, 1991).

On a more personal note, this has been an important stepping stone for me as well. Having studied for both my undergraduate and graduate degrees with rather conservative composers, I had to analyze the pieces that interested me in contemporary music to grasp how they were composed and how these composers worked. This experience seems to be shared by many other composers I have met through workshops and seminars. For many of us, the combination of analysis, theoretical articles, and self-analysis articles from composers have been of utmost importance to understand their compositional process and style.

3.4 The Compositional Process in Mixed Music

How can we try to include all of the previously mentioned research to discuss the mixed music compositional process? It is often more challenging to analyze music and the compositional process when one does not have detailed notation or information for every aspect of the piece.

The model I propose (shown in Figure 13) is a synthesis of the previously mentioned models that have been filtered through understanding other's compositional processes. This model gives us a practical framework in which to discuss synchronization strategies and their role within the composition process. There is often much intermixture between all of these steps, such as evaluating/attending one's work. The main difference of the mixed music process compared to acoustic composition is that evaluation goes across several modes. Many composers use technological tools such as mock-ups for evaluation. If one is working on an electroacoustic work, one can listen directly to a render of one's work with relative ease. Although many issues arise, such as not having the same sound system as the venue, grasping the final sound created in performance is perhaps not quite as dependant on the imagination as the acoustic composer. However, within mixed music one must deal with the difficulties of both acoustic and electronic sound worlds, making evaluation rather tricky. As Jonathan Harvey wrote:

> *It was not an easy process, because the CDs that were being played into the computer had little or nothing to do with the sounds that would be played into the computer in the concert. So one had to imagine how such treatment would affect often (sic) quite different sounds, which I was going to compose in the coming months* (in Harvey, 2004, p. 44).

Harvey's quote relates directly to Hervé's (1999) graphical sketch of composition and Donin's (2018) compositional tendencies.

While working on various aspects of the material and sonic image, one mainly works with synoptic planning. However, this is not the case if the material is mainly sound-based, as it is then probably closer to heuristic primacy. One must write the piece either without listening to the electronics or without hearing the acoustic instruments. Even when often shifting modes between working on the score and the electronics, the compositional process often requires extra imagination and a developed inner ear. When formalizing the composition, the individual pieces are not there, but we work with the gestalt. Formalization and concretization, therefore, often feedback into each other in an infinite loop. The model proposes a view that includes how composers must shift between the various tendencies and modes discussed in the previous section.

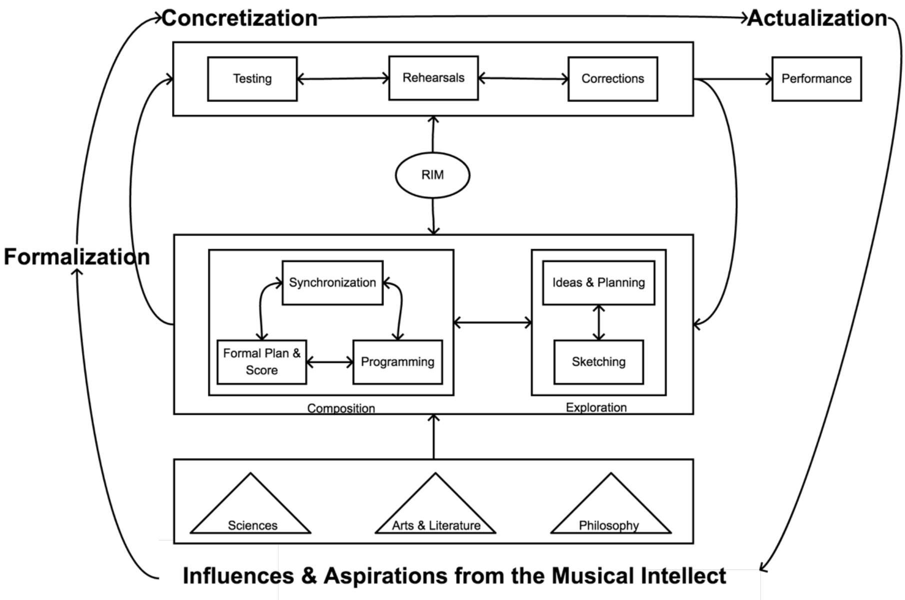

Figure 13. The mixed music compositional process diagram.

Hervé's model is mainly in the formalization section. Donin's synoptic planning is an in-between state between formalization and concretization, while his heuristic primacy is in the concretization part. Brown & Dillon's and Delalande's concepts are included in the exploration part of formalization. My model breaks down the linearity present in many of the previously mentioned models. Instead, it is represented with the possibility of working on several aspects of the composition simultaneously, often unconsciously.

Additionally, the Boulezian concept of musical intellect is included to illustrate how important it is to discuss synchronization strategies within the compositional process. The sciences (and technology) inherently influence the synchronization strategies used, but I also argue that the composer's aesthetics and philosophy can profoundly influence synchronization choices. Synchronization strategies are between the formal plan and programming, forming a tripartite working step. Although I include it in the formalization, some composers might feel it is more within the concretization, especially if one has a RIM. However, I believe that even non-electronics-savvy composers will have some ideas on synchronization, and therefore it fits more within formalization. This will be discussed further with examples in the following three chapters.

The goal of this system is to further discuss where synchronization strategies come into play in mixed music composition. A formal conceptualization of the compositional process explicitly made for mixed music may give us insights into composers' minds and discuss aspects of conception and aesthetics. The model lets us begin to discuss how we need to shift our way of thinking, working and perception while writing mixed music.

There are two weaknesses within this model: The first is that intention and result are often far from each other, as we will see throughout the thesis. One could also have imagined using the effect in a specific way while doing synoptic planning to create a macroform, but it does not work as intended when listening to it. There is no doubt that there is more crisscrossing in the middle of different modes and work types, but for the model's legibility, I have limited the number of feedback-like loops.

The second is the RIM. The role was included because of its historical and institutional importance. However, the practice seems to be disappearing, or perhaps, the literature is finally starting to present a more balanced outlook. As Acosta (2016) suggests, most composers are not working with institutional support and, therefore, probably do not have access to a RIM. Nevertheless, most of the literature focuses on the institutional pieces. It is possible that the younger generation of digital native composers feels more at home by having control from the conception of the piece to the final programming and sound engineering.

3.5 Possibilities and Innovation in the Use of DSP

Sound effects and digital signal processing are a vital part of the aesthetics of mixed music. These effects have a considerable affordance on the compositional process and on how we can analyze a piece. The reason for including a discussion on sound effects and processing within the compositional process section is to show how connected the two are. There is already a large body of literature that focuses on the electronics' specific use within the compositional act.

Saariaho often uses harmonizers in her pieces, such as *Lichtbogen* (1986).[20] It is possible to create these harmonizers within the FFT domain, which would objectively make them more reliable and "better" sounding. However, her use of the harmonizers is not specifically to harmonize but to create glissandi. This explains why they are programmed within the time domain instead of the frequency domain. They are not meant as a traditional harmonizer but as an effect to extend instrumental gestures within time. In this case, there is

[20] Initially, this was hardware harmonizers, although it is now customary to use a MaxMSP patch. Jean-Baptiste Barrière maintains Saariaho's Max/MSP patches.

also a question of history. At the time, FFT-domain harmonizers were not available, so it was not necessarily meant for the harmonizers to create this glissando effect specifically. It is more likely that Saariaho came upon when experimenting with available hardware as she was writing the piece.

Baudry & Bonardi (2015) researched how a single effect has many uses. Frequency shifters shift the frequency of an incoming sound by a specific number of hertz contrarily to a harmonizer, which transposes by semi-tones. The frequency shifter is outside of our tuning system and works directly on the frequency content, effectively distorting the resulting harmonic spectrum. In their research, they looked at a corpus of well-known compositions such as *Répons* (1981-85), *Neptune* (1991), *Jupiter* (1987). They found that the same composer would often use the same effect in various ways. Bonardi & Baudry (2015) show the various implementations of the frequency shifters, which can also explain some of these discrepancies depending on which RIM created them. They also take into consideration the differences between the time and frequency domain implementations. They have not been able to investigate why each RIM chose a specific implementation. However, Bonardi & Baudry argue that RIMs might not be consciously aware of the aesthetic variations.

In *Jupiter* (1987), Manoury has a frequency shifter sound like a tremolo effect. In *Neptune* (1991), the frequency shifter is used more as a timbre and harmonic modification. In *Anthèmes 2* (1997), Boulez uses it as a rhythmic motif by using an implementation with delay lines and feedback (Bonardi & Baudry, 2015). These are three radically different uses from the composers of the same institution using similar implementations.

It can be challenging to separate intention and result regarding DSP. Reverb can be used to change the timbre of a sound and make it longer and thicker. A chorus effect can be used to thicken up a sound or make an instrument sound detuned. When one looks at Max/MSP patches, effects might seem confusing in how they are constructed due to unconventional digital signal processing methods. The idiosyncratic use of effects (by accident or design) is vital in recreating, analyzing, and porting mixed music pieces.

The use of various types of electronic processing can be essential as a formal aspect of the composition. Therefore, the exploration of this effect and finding its characteristics is important. A specific type of processing can happen in the electronics but also within the musical language used. For example, filtering sounds like an effect and filtering harmonies in the score for acoustic instruments.

3.6 RIMs & Authorship

The RIM has been absent from the discourse in a traditional history of mixed music. Many articles laud composers for their work without asking critical questions about the authorship of pieces or their ideas. Born (1995) shows the systemic subordination of the RIMs at IRCAM in the 1980s, and there is no reason to believe this was not widespread at other institutions. Recently, scholars increasingly acknowledged these RIMs. Carl Faia (2014) worked as a RIM at IRCAM during the 1990s. The culture was still similar to the 1980s but slowly changing towards a better understanding and appreciation of the RIM. Zattra (2006; 2016, among others) has also been writing about these issues.

This section will explore authorship. Tired of being asked about this issue, Miller Puckette (2017) once answered, "Perhaps I was the one using Manoury to develop Max." This section is not meant to sow doubt in composers' abilities but to shed some light on the role of the RIM's role in composition, which influences the synchronization strategies used in a piece. Jameux (1991) mentions how Gerzso should be considered a co-author of Boulez for his piece *Répons* (1981-85). Boulez would ping pong ideas between himself and Gerzso before committing anything to paper. This piece is also the first piece to be composed for the 4X machine. Boulez may have required Gerzso's knowledge to understand the machine's sonic possibilities (Akkermann, 2016).

Another example with Boulez and Gerzso is the piece *Dialogue de l'ombre double* (1985). Akkermann (2016) claims the first version of the piece was written in 1976 without electronics. The final version (with electronics) is from 1985 and features state-of-the-art electronic possibilities of IRCAM.[21] Although Boulez had already explored spatialization elements, especially acoustically, it is difficult to believe that he came about the ideas in *Dialogue* on his own. Boulez's early fascination and distrust of electroacoustic music are also well recorded (Gayou, 2007).

In his thesis, Faia (2014) explains how many composers would have no idea how to work with electronics:

> *It is possible to divide the composers into two general groups concerning their relationship to technology. The first group would be those who were more or less incapable of creating on their own anything with technology (in whatever form), much like Phillippe Leroux. The second group of composers were capable of creating for themselves works with technology. They were invited to IRCAM to work with me because they wanted to use some*

[21] It might be relevant to mention that Boulez notoriously changed his pieces after their premiere. He was a meticulous composer that had no qualms about revisiting works.

> *experimental technology being developed at IRCAM or the work itself was so complex that having a collaborator would be necessary, much like the work I did with James Wood or later with Alejandro Viñao. My experience since then confirms this general grouping of composers. I mention this because it does bear on the collaborative relationship I would have with the composer. Everything from explaining or presenting a technique or topic in relation to the work, or accepting a role as "programmer only," or advising on feasibility, or tutoring composers are just some examples of how the collaboration might develop according to the experience and willingness of the composer* (Faia, 2014, p. 53).

He explains further that most of the institution's RIMs had a specialty, which led to their sound. In his case, this is related to the use of Diphone, which one can hear in Harvey's works during this period. In later years Harvey often worked with Gilbert Nouno. Much like Faia, Nouno made Max/MSP patches for the composer, explained settings and their effects. Afterwards, the composer would head home and experiment with the patches while writing the piece (Harvey, 2008; Zattra, 2018).

Manoury corroborates Faia's view (Clarke, Dufeu & Manning, 2020). It was positive because the RIMs' styles and aesthetics allowed Manoury to learn new ideas. However, there are also downsides to the heavy influence of RIMs on composers. In many IRCAM patches, one can recognize finished modules found in well-known pieces of their repertoire, which shows a rather service-oriented workflow that often lacks dedication to programming for individual works.

How much of the product we hear in the final piece is the composer's intention? As mentioned earlier, many of the IRCAM RIMs had their own sound. Who then is responsible, for example, for the typical Manoury sound of the late 1980s and early 1990s? Without a doubt, the musical language is from Manoury (2013; Kaltenecker & Bahier, 2010), but he has sometimes presented the ideas surrounding *Tensio* (2010) and its technology as his own, even though it is clear that Demoucron and Cont have significantly contributed. Considering Manoury's admissions of not keeping up with programming since the 1990s, it seems improbable that he programmed or thought of those concepts alone (Manoury, 2012). He openly admits that the RIMs he has collaborated with have had a considerable influence on his work and thought processes (Clarke, Dufeu & Manning, 2020).

These examples reinforce an important point when analyzing much of the mixed music repertoire: the works are often (and perhaps nearly always) a collaboration. In the compositional process, this can have significant repercussions as the process then involves several people, becoming more logistically complex. In much of the literature cited, the composer had to work on the score in between the programming and testing sessions. This structure, which is imposed by institutional support, drastically changes the compositional process's flavour. One could consider that RIMs impose a more linear compositional process because of economic/logistical issues—an attempt to streamline the creative process in favor of institutional efficiency. It is essential to remember that the use of RIMs is especially relevant to composers that do not have the technical know-how to create electronics. Their existence has been traditionally rarely mentioned in the literature. However, there is little doubt that RIMs have had and continue to have an important influence on composers' aesthetics.

3.7 Conclusion

The compositional process is difficult to summarize because of its all-encompassing nature. Although it is a complex field that is challenging to navigate, we have gone through several compositional process models from both the acoustic and acousmatic music worlds. We have addressed several theories regarding of the compositional process. Recent constructivist views that analyze works in light of the composer's available equipment have become standard in the literature. With this in mind, I then presented my model of the compositional process. This model presents a perhaps more balanced view of the compositional process as practiced within mixed music.

Additionally, my model attempts to illustrate the non-linearity and complexity of the compositional task. When discussing synchronization strategies in the following chapters, this framework may help understand how various strategies can influence a multitude of aspects of a piece and its compositional process. Afterwards, the discrepancies between intention and perception of the use of effects were discussed. Various implementations of the same effect may have vastly different musical consequences. Finally, we explored issues of authorship with the use of RIMs as more recent literature uncovers how large their influence has been historically.

Chapter IV: Synchronization Within the Compositional Process

> *In the ecology of human culture, unsolved problems play a role that is even more essential than that of solutions. Although the solutions found give a field its legitimacy, it is the problems that give it life.*
>
> -Miller Puckette (2004, p. 1)

4.1 Introduction

The previous three chapters established frameworks to discuss synchronization strategies, such as synchronization layers, performance techniques, and a new compositional process diagram. This chapter will compare and contrast various aspects of synchronization strategies in mixed music. The main goal of this thesis is to establish a link between compositional procedures and synchronization strategies. We will use the hierarchical layers graphic framework, and compositional framework from the previous chapters to establish this link. This chapter will focus more on general outlines and trends, while Chapter V will focus on specific case studies. Pieces from the solo, chamber, ensemble and orchestral repertoire will be used to illustrate challenges inherent to each genre. As a method, this chapter compares and contrasts composition examples, and the discussion will be centred around the following topics:

- Synchronization affordances on composition within three repertoires
- Technology and *écriture*
- The musical role of electronics & synchronization
- Electronics and time
- Pragmatism and performance from the composer's point of view
- Interactivity
- Mapping

The term affordance will be used to describe the influence of synchronization on electronics. An affordance is defined by McGrenere and Ho (2000, p. 1) in the following ways:

- *An affordance exists relative to the action capabilities of a particular actor.*
- *The existence of an affordance is independent of the actor's ability to perceive it.*
- *An affordance does not change as the needs and goals of the actor change.*

McGrenere and Ho are furthering and refining the definitions first set and popularized by Gibson (1979) and Norman (1988). The concept of affordance shows how synchronization strategies influence many aspects of both the compositional process and the mixed music actor network. Regarding this, I argue that each synchronization strategy and performance technique may influence the compositional process. Some synchronization strategies may influence the differences between the formalization and concretization stages of the process. For example, in following and other more performer-sensitive ideas, a large part of the rehearsals might be to set the levels and thresholds in the programming properly.

I find the concept of affordance suitable to synchronization strategies because it includes aspects of capability and perception. A composer's (or RIM's) comfort in specific programming environments or technology, in general, will always influence the compositional possibilities from various synchronization strategies whether or not they are aware of it. The terminology of affordance is relevant to human-computer interaction (HCI), which is relevant to the compositional process of mixed music. Therefore, the theoretical jump between fields seems reasonable and not too large. The main difference between my use the common HCI terminology is that I see affordances affecting each other in mixed music. That is, in mixed music, the actor has affordances towards a synchronization strategy, but the strategy also has affordances towards the actor. Both of these have affordances towards the compositional process. Despite environments also having affordances, I will rarely mention these to attempt to be more technology agnostic. An illustration can be seen in Figure 14.

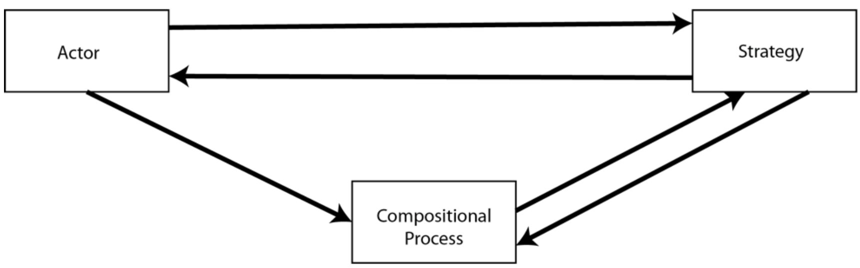

Figure 14. Graphical illustration of affordances in mixed music.

4.2 Synchronization Strategies & Composition

This thesis's central premise is that synchronization strategies and composition have a complex relationship and must be examined together. Both of these have affordances towards each other and all elements of mixed music composition. Using the framework laid in the first three chapters, we will first look at three repertoires in various historical periods to lay a foundation for the complex relationship between synchronization strategies and composition.

Because synchronization strategies afford various compositional possibilities, aesthetics are paramount in the discussion of synchronization. Therefore, it is crucial within the following chapters that the electronics' musical role is discussed. Stroppa's use of synchronization is often inherent to his compositional thought (Stroppa, 1999). According to Stroppa, the ends justify the means—any strategy can be valid as long as it suits the composer's musical needs at hand. How smooth the relationship between electronics and performers is can be an aesthetic choice. For composer Stefan Prins, the disjointedness between acoustic and electronic is a part of post-modern aesthetics as it represents our contemporary life (Ciciliani, 2017; Draus, 2019).[22]

4.2.1 How Technology Affords Écriture

An important aspect to explore is the affordances of technology on composition in general. Before looking at specific examples, let us look at some of the attitudes about technology in mixed music. Boulez described two ways to work with technology: following and obeying technology as a sort of improvisation, or the use of technical processes to suit the musical structures/organizations of the composer (Duchez, 1991). Roads, on the other hand, says: "To select a composing tool is to already begin to define an aesthetic philosophy" (Sani, 2004, p. 193). Today, we tend to not see technology as deterministic. Papers such as Green (2013), Magnusson (2009; 2019) and Waters (2007) describe the relationship as being closer to an ecosystem, with a feedback loop between the user and technology. Sometimes, composers will also willfully use technology in a non-intended manner, which opens up other possibilities or artifacts.

Historical examples include many pieces using the 4X machine (and its followers), starting with Boulez' *Répons* (1981-85) (Akkermann, 2016). Puckette's initial creation of Max was also instrumental in helping composers use the machine (Lippe, 1996). In Manoury's *Jupiter* (1987), sections have various DSP effects, which were limited as various DSP effects had to be loaded in the 4X (May, 2006). Puckette explains that Manoury wanted an open form in *Pluton* (1988-89), but it was not possible because of the technological limitations of score following at the time (Clarke, Dufeu & Manning, 2020). His music from this period is a perfect example of affordances between synchronization strategies and

[22] The term post-modern is used in its broader aesthetic/cultural meaning, not purely musical.

compositional processes. A more detailed discussion of Manoury's aesthetics and other works is in Chapter V.

Risset's *Duet for One Pianist* (1989)[23] is an effective counterpoint to Manoury's use and affordances from technology. Both pieces used pianos with MIDI capabilities, which gave them enhanced possibilities through the Max interface. The electronic processes in the works receive the musician's performance data then send information out to be played automatically on the MIDI piano. Manoury uses Markov chains (Manoury, 2015), while Risset varies between various processes in each section, such as mirroring the pianist's gesture in the second section (Risset & Duyne, 1996). Risset's composition is perhaps closer to acoustic composition using computer-assisted composition technology in real-time as the piece is still a solo piano piece at heart, while Manoury uses the same technology to expand his compositional possibilities further. However, both composers are effectively within Croft's (2007) accompaniment and responsorial paradigms.

Various technologies are no longer available, making several pieces unplayable, which is one of the biggest problems within the historical repertoire (Bonardi, 2013). Manoury, among others, has expressed his fears about using commercial technology that might not be available after a few years (Manoury, 2012). Using commercial technology that is highly specialized has its risks. Format changes can also have a considerable influence, such as the change between tape (or ADAT tape) and using a sampler on an HDD, making it easier for composers to synchronize smaller fixed media files with performers. Better, faster and more reliable storage allowed a performer to trigger sound files by pressing a keyboard while sitting in the ensemble, such as in pieces by Murail explored in section 4.2.3.4.

4.2.2 The Role of Electronics & Synchronization

Another aspect of the discussion of the compositional process and synchronization is the electronics' role. If the composer views electronics merely as a detail rather than just as important as acoustic instruments, then it is clear their role will not be significant. In general, I argue that one should use the synchronization strategies to suit overarching compositional goals. I will be using the terminology discussed earlier by Croft (2007) and Frengel (2010) when appropriate.

[23] Although many consider *Jupiter* (1987) to be the first real-time piece (such as Cont, 2012), Risset (1999) commented that his *Duet* (1989) is the first real-time interaction between performer and computer entirely within the realm of acoustic sounds.

It is possible to ignore the issue of synchronization as part of a piece's aesthetic. Early mixed music pieces such as Varèse's *Déserts* (1954) and Maderna's *Musica su due dimensioni* (1952/58) had to ignore synchronization because of technological limitations. The problem was evaded by not having the instrumentalists play simultaneously as the fixed media. Other composers, such as Klaus Huber, made a conscious choice of ignoring synchronization in the piece *…Inwendig voller Figur…* (1970-71) where Huber described the tape as "not meant to be coordinated with the orchestra" (Mahnkopf, 2010, p. 196). Ignoring synchronization is generally only possible in pieces in which the electronics assume the role of being a backdrop (or asynchronous in Frengel's paradigm), such as in the aforementioned piece by Huber or *Fields* (2016) by Thorvaldsdóttir. Fixed media is often the preferred synchronization strategy for this.

Mâche's music is an interesting case. His use of synchronization is included in the *écriture* of the piece, in how he uses the fixed media - which is generally natural sounds such as birds - as a starting point to compose. Mâche's compositional process actually starts with synchronization as one of the primary materials (Grabócz, 2013; Maestri, 2016). Acosta (2016) often works from tape to the score to help musicians of oral traditions to follow the music comfortably. John Luther Adams wrote *Mathematics of Resonant Bodies* (2002) first as a fixed media work, and then as a score. The fixed media is derived from the same type of material but heavily edited to sound like "angel voices" (Luther Adams, 2004, p. 176). These composers are exceptions to our compositional model developed in Chapter III since they created the tape first and use it as a starting point for the composition, but they are the exception rather than the rule.

The way a composer works with electronics and synchronization varies depending on the electronics' musical role. The compositional strategies one can use for electronics to change from the role of accompaniment to that of a soloist are different from using electronics as background sounds. Synchronization issues can arise due to the various media's temporalities and heterogenous time zones (Cont, 2012). Maestri (2016) asserts that if a composition is based on instrumental gestures, then live processing is best. He gives the example of *Traeittoria…Deviata* (1984), in which Stroppa still manages to shift the musical roles of the fixed media, as mentioned earlier. I believe this is an oversimplification that stems from the debate between real-time and deferred time as well as a question of *écriture* and synchronization. I would also say that any of the paradigms within Croft's (2007) and Frengel's (2010) systems can be attained with any synchronization strategy, although with varying efficiency and difficulty.

Live processing has become almost ubiquitous with modern mixed music. Some view this as an ideal synchronization solution precisely because everything is derived from the instrumentalist (Belet, 2003). However, it creates some strict compositional limits as the electronics can only be based on instrumental sound input. Tutschku asserts that only using live processing leads to typical musical gestures in which the electronics are delayed gestures from the instrumentalist (Tutschku & Nez, 2003). The material in the electronics cannot be preemptively played because it is limited to the input.

Cox (2006) views electronics as having three ways of helping acoustic performances. The first is that it has fewer limits than musicians. For example, rhythmically complex figures are not difficult to play for a computer. The second is that electronics do not have any errors in realization. This is often to the point of a fault and varies highly on the synchronization strategy. The computer can have a misstep in understanding what a performer is playing or a programming error, but it will execute the commands it receives. His third point is that electronics give complete control to the composer, but I would argue that the composer must have enough technical knowledge in order to use electronics to their fullest potential. A digitally-challenged composer will not have complete control over something they do not quite understand. Although I disagree with several aspects of Cox's claims, they represent commonly held views in the field and reflect his own aesthetics, which are strictly tied to Second Modernity (Cox, 2008).

The possible roles of electronics affect how affordances, synchronization strategies, and performance techniques contribute to a composition. It is far from being a one-to-one relationship. The music and role(s) of the electronics create different affordances for each synchronization strategy, making it impossible (or extremely difficult) to list all affordances for each.

4.2.3 Synchronization Affordances

The following sections will examine how synchronization strategies and performance techniques can represent affordances for the compositional process within various repertoires and historical periods. The solo piano repertoire, modern chamber repertoire of solo and small ensemble pieces, and larger ensemble and orchestral pieces present dissimilar challenges in the context of synchronization and composition. I have chosen a few pieces for each, which I believe give a good overview of the affordances within that subset of the repertoire. Looking at similar instrumentation and historical period allows us to see how the affordances of synchronization can vary despite using or having the same technological and instrumental means at hand.

4.2.3.1 Solo Piano Repertoire (1984-1994)

We will start to look at synchronization affordances by looking at the historical mixed piano pieces from 1984 to 1990. Due to technological limitations during this period, most composers only had the possibility of working with fixed media and cues. Few composers had the opportunity or economic means to be able to explore the strategy of following. Each composition tackles this challenge in various manners, showing how synchronization can affect compositional possibilities. The section will look at compositions by Stroppa, Smalley and Alvarez.

Stroppa's *Traiettoria...Deviata* (1984) for piano and fixed media is one of the more famous pieces in the repertoire. The piece prominently features pivot points— points in the music where it is easy to synchronize the electronics and performer. Tiffon (N.D.) reveals the composer could not create the fixed media part to *Traiettoria…Deviata* (1984) due to a lack of the needed technology as he composed it while at the CSC in Padua. Because of these limitations, Stroppa had to write the score and then the electronics later on. As a solution for coordinating the electronics which had not yet been composed, at several points in the composition the pianist plays figures that are easier to coordinate with fixed media. These pivot points are often based on the use of resonances in either the piano or fixed media. The resonances give the performer the possibility to listen to where they are in the piece, aiding their synchronization with the fixed media. The feedback loop between formalization and concretization was not present during Stroppa's writing, which means that his compositional strategies to tackle the issue of synchronization had to be developed early on. The notation of the piece includes chronometric time, although Stroppa mentions that the performer's ears will be the best judge in the end.

Although the piece is meticulously notated, there are musical variations in how Stroppa uses the electronics, which affects all actors' synchronization.[24] On page 10 of the score, which corresponds to 04:28-04:45 in Lan's (2014) recording, we can hear three compositional solutions. There are four musical events identified with letters on this page, as I have marked in Figure 15. During the first event, it is not too critical if the pianist ends the

[24] The piece explicitly cites using a sound engineer to create a live mix of the electronics during the performance. Since we are interested in the compositional aspects of synchronization, I will not discuss this aspect of the piece.

trill slightly early or late because of the density of the glissandi, and the following figure seems to emerge from the electronics. The second event begins after the glissandi-like figure in the electronics, which gives some leeway to the pianist. The third event has some deviation tolerance as long as the pianist holds the notes long enough to hear the glissando start. However, the fourth event requires the pianist to be precise.

Figure 15. Four events and use of fixed media in Traiettoria...Deviata (1984) p. 10

In these four events, the nature of the sounds used by Stroppa permits deviation in time by the performer to make the place breathe a bit more. This is also most probably planned beforehand as the musical figures that require the most precise synchronization are notated as such in the score. The use of chronometric time in the work is a consequence of Stroppa having to work on the score and electronics separately. Stroppa's *écriture* allows the electronics to elegantly morph between the functions of accompaniment, response, environmental background, and even verging on the instrumental.

Smalley used a similar technique in *Piano Nets* (1990) with music that moves between striated and amorphous as a musical and structural gesture. The musical gestures Smalley composes are not only pivot points, but also serve as an essential musical parameter that is developed. Each type of time and gesture becomes an important musical parameter that the composer slowly develops throughout the piece. Changes between backdrop, responsorial, and accompaniment are important compositional parameters, forming a structural arc. The electronics are as necessary as the human performer in the piece. There is no doubt that the synchronization between fixed media and the performer profoundly influenced compositional affordances in Smalley's process because they are so intertwined . The use of the same material and gestures between the two mediums reinforces this, as shown in Figure 16. In the second system of the figure, one can see that the material between the pianist and fixed media part are closely related, which has several functions for the synchronization. The pianist is not playing, only listening to the tape between B and C. By learning the tape by rote and listening to when the first cluster comes, the pianist knows when to move to the next chord. In the commercially available recording of the piece, this is heard from 01:03 to 01:08 (Mead, 2004). It is a pivot point. This technique is used throughout the composition in various guises. Although precisely notated, the electronics often fade in, giving the pianist enough time to react and, more importantly, stay synchronized.

Additionally, the related sounds between the piano and the tape give the listener the impression that it is tightly connected and perhaps even created live. By this point in 1990, pieces with real-time electronics were being played, but few composers had the opportunity to create them due to technological restrictions. By using a strict narrative within fixed media, Smalley makes the piece seem interactive, even though it is not. How tightly the synchronization is between the performer and electronics, and which musical solutions are used varies throughout the piece. For example, the first movement features longer sounds with fewer rhythmical cues than the second movement. The difference in notation and audial reference points are apparent.

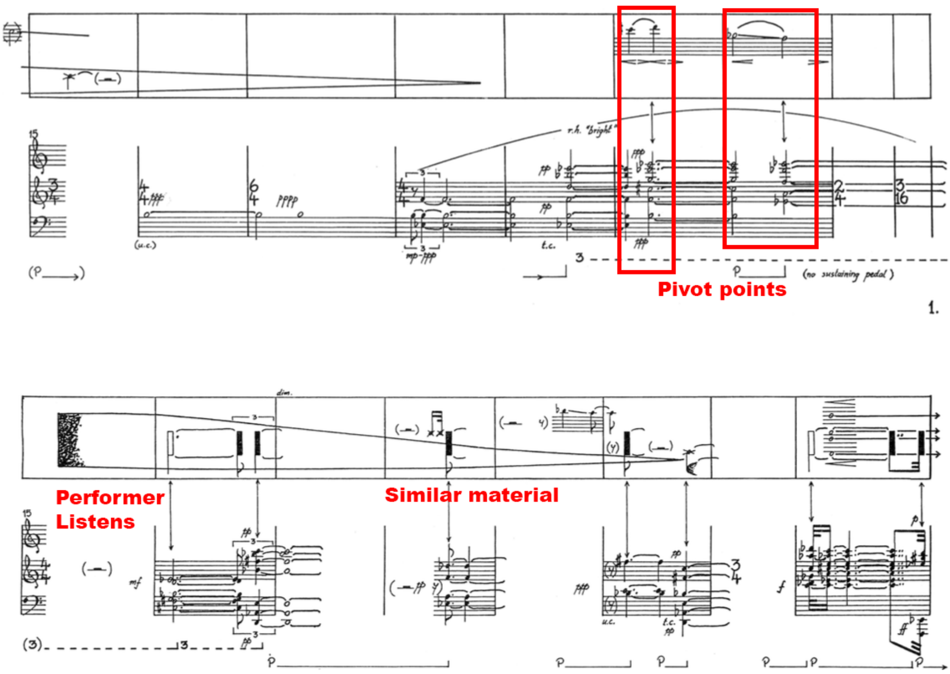

Figure 16. Two systems from the first movement of Piano Nets (1990).

These compositional strategies and uses of the fixed media strategy show that Smalley most likely composed both the score and the electronics together. The piece was written in collaboration with the pianist Philip Mead. From the resulting uses of synchronization strategies, I suspect that there were many instances of Smalley testing out ideas in rehearsal with Mead, moving between formalization and concretization within the compositional model presented in Chapter III.

Alvarez (1993) describes his compositional process for the piece *Papalolt* (1987) in some depth. He specifically did not want to use a click track in the free sections. Perfect synchronization was not aesthetically important for Alvarez, which gave him new creative possibilities. Alvarez began seeing fixed media as a rhythmical accompaniment instead. He explains further: "…if I used similar sounds to pair up with the live piano, any slight timing difference between pianist and tape would become immediately apparent…" (1993, p. 15-16). While writing the piece, Alvarez found this issue made it challenging to compose variations in the work. Because of this, Alvarez wrote relatively free sections as he found that "the tape part seemed to take on a life of its own" (p. 17) when not as tightly synchronized with the pianist. Effectively, the free sections provided increased compositional affordance, giving the tape part have more deviation tolerance with the performer. In the non-free sections, the music is tightly synchronized between the electronics and the pianist, requiring a click track to be as precise as possible. Unlike previous pieces in the thesis, the electronics in this piece are more rhythmical, allowing for minimal temporal deviation.

Traiettoria...Deviata (1984), *Piano Nets* (1990) and *Papalolt* (1987) used fixed media as a technological necessity. Nevertheless, the three pieces show each composer's unique approaches to synchronization because of the tape medium’s affordances. Although performance with tape often gets the label of being conservative, old or rigid (such as in Echeveste, 2015), these compositions show how this is far from being the case. Other pieces such as Emmerson’s *Piano Piece IV* (1985), Harvey’s *Le tombeau de Messiaen* (1994) (discussed in Chapter V) and Mâche’s *Nocturne* (1981) are examples from the same period that show various affordances and reactions to fixed media for each actor involved in the process. Each composer came up with strategies to tackle relatively low deviation tolerance. Stroppa, Smalley, and Alvarez used the same strategy, and two of them used the click track performance technique. However, the resulting music and how they tackled the difficulties of synchronization are vastly different even when technological means for mixed music were still limited. The same strategy’s deviation tolerance also varies because of the musical ideas chosen and explored by each composer.

All three composers use electronics within different paradigms of Croft’s (2007) system (discussed previously in 2.4). Moving in between paradigms allows the electronics to be used in fresh ways that can also serve as development within each piece. Despite Frengel’s (2010) claim that having several typologies and discourses can make a piece weak, Stroppa, Smalley and Alvarez show the contrary. The richness of their music is attained by how synchronization strategies and performance techniques are used to change the discourse of a piece and explore new avenues of their musical material both in the acoustic writing and electronics despite their limited access to technology at the time.

4.2.3.2 The Modern Chamber Repertoire (2000-)

The technology in these pieces is often more advanced than the previous section due to the proliferation of digital technology at the time, but some of the affordances are similar. Solo pieces are often used as étude for the composer to try ideas which they then further develop for various instrumentations (Tiffon, 1994). Chamber forces and above have more prestige attached to them and can, therefore, be more important for a composer's development (career-wise).

Composer Florence Baschet has written several chamber works in which synchronization strategies play an essential role. Her pieces *BogenLied* (2005) and *StreicherKreiss* (2007-8) both use sensor-augmented instruments that were developed in collaboration with scientists and programmers (Bevilacqua et al., 2006; 2012; Lemouton, 2009).[25] The latter composition took two years of research at IRCAM (Baschet & Lemouton, 2019). In both pieces, the electronics are based on the gestures of the performer. The form of *BogenLied* (2005) builds on this concept—the sound processing is mapped to recognizing specific gestures that the violinist plays and sections II, IV and VI are used to teach the computer how the violinist triggers the electronic gestures. Sections VIII and IX are based on the computer recognizing the bowing styles and then moving between the various presets (Baschet & Lemouton, 2019). A summary of the form and how it is based on gestures and bowing styles can be seen in Figure 17.

Essentially, the piece's form gives time for the electronics to learn a more developed musical language. The technology's needs and the chosen strategy—gesture following in this case—forced Baschet to pair specific bowings in each section with specific processing techniques before mixing them. For example, during the second section of the piece, the bowing style *détaché* is used, the electronics analyze the technique through the use of audio descriptors and maps it to sonic parameters. By the eighth section of the piece, as the performer varies between *détaché*, *martelé* and *spiccato*, the computer is able to interpret which technique is being used and assign the correct mappings to various parameters in the granular synthesis of the electronics.

[25] Recently *BogenLied* (2005) was re-programmed to use audio descriptors instead of the augmented violin making the piece more comfortable to play. See Baschet & Lemouton (2019).

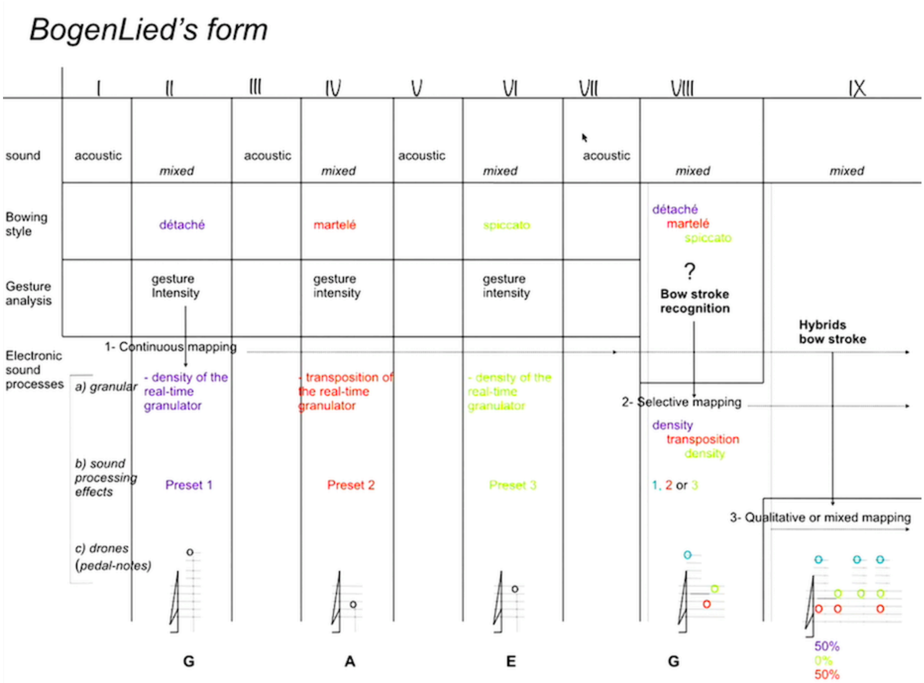

Figure 17. A comparison of the form and gesture recognition of BogenLied (2005) from Baschet & Lemouton (2019).

StreicherKreis (2007-8) uses following similarly to *BogenLied* (2005), but with a string quartet. In the first part of the composition, each instrumentalist controls their live processing through physical gesture, while in the second part, each member of the quartet controls the three other members' live processing. In the third part, every musician controls the live processing together as a unit (Lemouton, 2009).

Because Baschet is dependent on the computer's recognition of bowing techniques, her use of bowing is more limited in these pieces (Bevilacqua et al., 2012). Despite these technical limitations, Bachet managed to create an artistic work that fits her aesthetics. Donin (2017) explains that this is also due to Baschet's understanding of electronics as well as how Lemouton and Bevilacqua were heavily involved in the compositional process by commenting on musical possibilities. In Baschet & Lemouton (2019), the composer replies to Lemouton explaining possibilities with the electronics, that she did not want to go further down that road. The composer had limited herself to specific artistic ideas for the piece, meaning that she chose specific affordances given by the synchronization strategy and chose to compose the music with that in mind. This is an example of a composer willfully putting limits on herself and how this can affect the relationship between the compositional process and synchronization.

For both pieces mentioned by Baschet, the composition process involved much movement between concretization and formalization between the sessions at IRCAM described in Donin (2017). Baschet probably had to have sketches ready for the sessions which were tested, and then the results of the technical tests influenced her next composing session (Bevilacqua et al., 2006). However, it is doubtful that Baschet did any programming herself, so there was probably more time between the programming and composition within the formalization stage. Her questions, comments and history as a composer present her as someone that needs a RIM to be able to have electronics. In cases like this, both the electronics and the composition may require compromise on pragmatic, technological and compositional grounds.

Unlike Baschet, Blondeau is a composer that does the programming himself. His research has resulted in the compositions *Namenlosen* (2017) and *Tesla ou l'effet d'étrangeté* (2014), in which following is an aesthetic ideal as a primary synchronization strategy (Blondeau, 2017). Unlike previous examples, Blondeau uses score following and the IRCAM Antescofo software. He is a composer influenced by Manoury's concept of virtual scores and their possibilities when brought to the extreme of different temporal layers (explained more later). *Tesla* (2014) is based on several synthesis systems including synthesized sounds, physical modelling programmed in Csound, two delay systems, a freeze effect, reverb, and fixed media files. Blondeau (2018) explains that most real-time changes are based on how the performer plays the piece. Antescofo compares what the musician is playing with a pre-submitted score, meaning that launched events can have modified end times as the tempo is calculated often (Buroiu et al., 2017). At several points in the piece, four to six layers of synthesis surround the performer as other parameters are changed by the performer's actions (Blondeau, 2018). The flexibility of Antescofo and Blondeau's compositional language affords complex temporal relationships between the score, performer and electronics.

In these works by Blondeau, the electronics are mainly processes instead of fixed events. The musician playing a section of the piece triggers the start of a process influenced by how they are performing. These processes can also become independent of the performer. It is also entirely possible to vary between these two types of relationships, which is often used in *Namenlosen* (2017) and *Tesla* (2014). These gestures and processes are an essential part of Blondeau's aesthetics. Additionally, he always develops the electronics and acoustic composition simultaneously since they are tightly connected (Blondeau, 2013; 2014). It is not easy to think in such an abstract way, especially since the electronics are processes instead of specific linear events. In these pieces, it is impossible to separate the electronics from the acoustic composition, and the writing process seems to have moved often between concretization and formalization to make sure the processes work as intended while gathering data from the musicians. These processes and flexibility also allow Blondeau to shift seamlessly between accompaniment, responsorial and instrumental paradigms in the electronics.

These examples show how synchronization can affect the compositional process. Synchronization and its affordances are complex since it is so intertwined with a composer's aesthetics, in most cases. Saariaho often moves between the conception of the score and the electronics (Campion, 2017) because it is a central aspect of mixed music. The conceptualization of the piece by the composer is significant in how it shapes both *écriture* and synchronization.

4.2.3.3 Ensemble & Orchestral Pieces

Mixed music literature has often focused on the repertoire of soloist with electronics, partly because there are numerous pieces for this instrumentation (Tiffon, 1994). Larger instrumentations present other challenges, which this section will address. The use of synchronization strategies and performance techniques for larger sets of instruments is entirely dissimilar. One difference is the need to be more pragmatic with larger ensembles as rehearsal time is generally more limited and expensive. It is more difficult to tell a 70+ piece orchestra to wait while fixing the electronics than to a solo performer. The orchestral repertoire is perhaps safer because of these difficulties.[26] In many orchestral pieces, only a few instruments are processed by electronics (Bonardi et al., 2017). The acoustically complex sound of the orchestra might be one of the reasons why this is common. Additionally, it is difficult to workshop the integration of electronics with full orchestra for the same reasons. It might be possible with select members to test the electronics, but having several orchestral sessions is problematic for financial reasons.

In *…auf… III* (2007), Andre uses convolution on the string instruments to change their timbre (Feneyrou, 2011). In his piece *Wunderzaichen* (2013), the electronics are limited to

[26] Opera seems to be in a class of its own, which may be due to the long rehearsal periods. I have not seen any studies comparing different mixed music operas at this point, although it would be an exciting avenue of study with composers such as Berio, Manoury, Neuwirth, and Saariaho having written several operas with electronics.

only a few instruments: the first trumpet, piano, soprano, tenor and some percussion. The use of electronics is mainly convolution, amplitude modulation, spatialization and some feedback with resonant filters. Andre's sound world is about "deconcretizing" the sound sources one perceives. In this context, the use of convolution—which adds an additional "room" over the acoustic room—makes sense (Haas, 2019). Andre artistically utilizes unrealistic resonances and acoustical phenomena. Andre's use of electronics, especially their planning and development at the start of the project, is often the starting point for his orchestral compositions (Jeschke, 2019).

Although synchronization is never mentioned explicitly in the literature on Andre, references cue sheets lead me to believe that he is using cues extensively (Haas, 2019). The development of some of the electronics beforehand is probably to give himself strict limits on what is possible before Andre can begin writing the orchestral score without needing to revising acoustic music because certain aspects of the electronics do not function properly in context. The use of cues also affords security in which the electronics can drastically change yet are not necessarily as dependent on the temporalities of the music as the strategies of longer fixed media files or following.

Following has recently started to be used more within the context of ensemble music and orchestral music. In Schubert's *Point Ones* (2012), the conductor's movements trigger fixed media files and live electronics using a Wiimote in each hand (Moore, 2020). Thordarson's *Kuki No Sukima* (2019) is another example of following and live processing for a larger ensemble. In the piece, the conductor controls most effects with a conducting glove. The piece uses gesture following and cues that the conductor triggers with the glove (Thordarson, 2019). This glove and its associated electronics give the conductor flexibility, which suits Thordarson's ecosystem-like compositional ideas. He had considered using a camera, but issues such as light sensitivity made Thordarson create an X-OSC system that communicates with Max for Live,

Nordin's *Sculpting the Air* (2015) is an interesting example. In this piece, the conductor's gestures control several aspects of the electronics by using a Kinect360 camera and Gestrument software (Bacot & Féron, 2016). The system triggers effects and samples. In section I-0, for example, the conductor starts the sounds alone, *senza misura* (labeled as A in Figure 18). Eventually they will start to conduct, and the Bb clarinet comes in, as shown at point B. In the score, both hands of the conductor are notated because they control the electronics. Bacot & Féron (2016) describe the process of this piece as "a long creative process with a strong collaborative dimension between the composer, the conductor and the computer music designer...” (p. 451). Test sessions were done with a conductor to set the compositional possibilities and parameters for Nordin to commence writing the piece. These sessions tested the technology's affordances and if the composer’s ideas could potentially work with the required synchronization strategy.

Figure 18. Example from Nordin’s Sculpting the Air (2015) taken from Bacot & Féron (2016, p. 461).

Although they do not discuss the piece in terms of synchronization strategies and performance techniques, Bacot & Féron (2016) illuminate affordances between the technology and composition. The presence of a conductor with this technology gives a possibility for flexible use of both temporally rigid and more free-flowing sections. Additionally, the article documents the exchange of ideas between the composer and the technical team, as Nordin moved between formalization and concretization. In this specific case, much of the conductor tests happened early on to set the limits of the piece. Nordin also used similar technology and ideas in *Emerging from Currents and Waves* (2018) for orchestra.

The Norwegian composer Knut Vaage only agreed to write the orchestral piece *Futuration* (2015) after the orchestra included a day of recording to test out the electronics. This permitted him to set all the amplification needed for his live processing and create a mock-up. The electronics were developed in collaboration with Thorolf Thuestad, with whom he has worked for twenty years. The use of cues allowed shifting between various panning and effects and the ability to minimize feedback quickly. An additional conductor was also used to help the technicians stay synchronized with the music, as it was not possible to see the chief conductor enough.[27] Economically speaking, hiring an additional conductor is prohibitively expensive for most ensembles/composers.

4.2.3.4 Murail's Ensemble Work

Composer Tristan Murail's work may give a good overview of some possibilities and developments within ensemble writing, as he has been writing mixed works for well over twenty years. Murail felt he needed a click track for the synchronization of *Désintégrations* (1982) despite how this gave the conductor little rhythmical freedom (Smith, 2000). Initially, the piece was on tape until being remade with the help of Joshua Fineberg as fixed media on a hard drive. The tape part was created using the 4X, meaning it was limited to thirty oscillators at a time to produce all of the partials, forcing Murail and Gerszo to do several rounds before combining them (Smith, 2000). At the time, it would not have been possible to do this with anything else than fixed media because the 4X did not have enough oscillators to use in real-time. In this context, I would argue that the synchronization strategy was mostly a compositional response due to technological limits. The fixed media was composed after the score (Cohen-Levinas, 1999). It is impossible to know how much the electronics and synchronization affected his compositional process.

The use of the click track reduced the need for pivot points throughout the piece. The conductor's beating of time, especially the strong beats of each measure, often corresponds to new electronics events. The conductor's presence lets the musicians rely on them instead of synchronization strategies, creating a buffer between the musicians and electronics where the conductor performs the critical role of listening to the click track. The integration of the electronics within the harmonic fabric of the piece also leads me to believe that Murail

[27] Private conversation 9th of January, 2021.

worked on the score and electronics simultaneously. They are so intertwined and elaborated in complex ways, that I doubt the electronics were done after the fact.

With *Allégories* (1989-90), Murail wanted to expand his pallet. Although the composer has mentioned synchronization problems within this piece in an interview with Cohen-Levinas (1999), he did not remember this when asked about it recently.[28] Murail wanted the electronics to follow the conductor (Smith, 2000). He believed it would be easier for the ensemble to play. He considered using live electronics decided against it because it was "(…) too dangerous. That would take too much time in the rehearsal and in the concert hall itself, so I didn't think that it would be realistic." (Smith, 2000, p. 14). Of note here is that the piece has six musicians, yet he considered live electronics as too risky at the time. Additionally, although the piece's tempi are relatively rigid, there is quite a bit of leeway for interpretation (Cohen-Levinas, 1999). The electronics are triggered in cues by a synthesizer player sitting within the ensemble, effectively following the conductor. In 1999-2000, a new version of the piece was created where there was now no use of a synthesizer, but only fixed media. This shows that the synthesizer perhaps was unnecessary in such a small ensemble and that the RIM could take care of this aspect.

L'esprit des dunes (1993-1994) is a piece for a large ensemble of eleven musicians with fixed media. Murail compares this piece to *Désintégrations* (1982) because he used partial calculations for creating the fixed media. He explained that he did not want a perfect blend between the acoustic and electronic elements for this piece (Smith, 2000). There are three versions of the electronics, all of which use fixed media triggered by cues from a MIDI keyboard on stage. Initially, the keyboard's velocity could influence the playback's volume, but this was removed for the 2001 version by Carl Faia and Denis Lorrain. Technical documentation states that this was because it was not stable and not used by most RIMs in practice. This is possibly because the keyboard player is not in a reliable position to monitor the amplitude of the electronics. Additionally, traditional dynamics on a keyboard translated poorly to playback amplitude.

The separation of the sound files can be seen in Table 5. With the use of shorter files, the cues are used to trigger sound files. The composer uses pivot points more actively in his *écriture*. The rhythmic activity tends to be in either the electronics or the acoustic instrumentation to make synchronization easier, but never both simultaneously, which eliminates the need for a click track. This type of synchronization-influenced composition

[28] Private conversation, April 2019 at Mixtur Festival in Barcelona, Spain.

suits Murail’s compositional style, which is often based on gestures. Many of the sounds used are more important in terms of their timbres rather than rhythmic content, meaning tight synchronization is not as crucial as *Désintégration* (1982).

Table 5. Sound files for L'esprit des dunes (1993-94) by Murail.

Section	**Number of fixed media files**
Introduction	14
A	5
B	25
C	47
D	18
E	38

Winter Fragments (2000) is another ensemble piece for five instruments and electronics by Murail. The program notes show the increased amplification of instruments and number of speakers compared to Murail’s earlier pieces. Reverb is used on the instruments and electronics to simulate putting them in a similar acoustic space. Murail admits the use of reverb is mostly dependant on the acoustics of the performance space (Smith, 2000). Once again, a keyboard player triggers the various sections of the fixed media files and the video’s playback. The original plan was to have live electronics, but this did not materialize because of technical difficulties. The electronics’ role is mainly to recreate several instruments' overtones and frequency content as it develops throughout the piece (Hirs, 2009a). Murail also uses more free-flowing electronics organized through gestures and layers than in earlier pieces. Some of the more rhythmic material is written in a way to have deviation tolerance, which suits Murail’s use of the cue strategy.

The use of electronics is central to Murail’s style and aesthetics. Electronics are an extra colour layer that surrounds the acoustic ensemble, and they are rarely at the forefront. However, as mentioned in Cohen-Levinas (1999), the electronics help the musicians with microtonality as it gives them a reference point. His writing became less rigid in the electronics with time, and his increased nuanced use of pivot points proves this. It also permits him to write music closer to his style within his acoustic works. Starting points are a critical synchronization strategy in Murail’s *écriture*—if there is deviation after the start of the file, it is often not too critical. However, the start point must be synchronized with the musicians. Therefore cues with fixed media files work well for him. I argue that the use of fixed media files suits Murail’s compositional process better than many other synchronization strategies. He is one of the composers that has had the opportunity to work with RIMs since the 1980s, and although he has mentioned wanting to work with live electronics, I believe that the reason he has not done so is mainly related to his established compositional process, and possibly a reluctance to integrate the risk of live processing into his *écriture*.

In most ensemble and orchestral repertoire examples, composers and their assistants take risk mitigation more seriously compared to the soloistic repertoire. There is little research on aspects of ensemble coordination with electronics compared to the soloistic repertoire. Through his interviews with musicians, Thordarson (2019) shows that performers in ensembles often fear feedback and feel disconnected from the electronics. This alienation seems to be more present than studies like Féron & Boutard (2018) that looked at the soloistic repertoire. Writing for larger ensembles is already challenging, with relatively short deadlines and often few possibilities to have workshops or extended testing, which heavily influences the compositional process. The amount of time and effort required for writing larger pieces can perhaps be a deterrent for the inclusion of more time-consuming live electronics and synchronization strategies. It is also more complex to balance electronics with large ensembles for audio engineers instead of for smaller combinations of musicians. Because of these issues, mixed music's most significant compositions tend to be for forces smaller than ten to twelve musicians (unlike the traditional classical music repertoire).

4.2.3.5 Comparison Between Repertoires & General Trends

Although section 4.2.1 does not cover the whole repertoire, it is possible to draw some trends and outlines. After Tiffon's (1994) thesis, few articles have tried to create an overview of the mixed music repertoire. Although making a general outline is not the main point of this thesis, it might serve as a valuable point for analyzing synchronization strategies within the repertoire.

Table 6 shows the number of compositions mentioned in this thesis and their primary synchronization strategies. Table 7 shows a comparison of the synchronization strategies as spread throughout the repertoire. In Table 3, solo means a soloist with electronics, chamber music is up to a quintet, ensemble 6-25 musicians, and orchestral is self-explanatory. Table 4 and Table 5 show the predominance of the various performance techniques listed in Chapter II in different instrumental genres. It is impossible to have all of the details for every piece mentioned in this thesis; therefore, there are some anomalies in the numbering.

Table 6. Overview of synchronization strategies in the repertoire.

Strategy	**Number**
Fixed media	38
Cues	33
Following	23
Total	95

Table 7. Overview of synchronization strategies by genre.

Genre	**Fixed media**	**Following**	**Cues**	**Total**
Solo	11	11	12	34
Chamber	15	6	5	28
Ensemble	10	4	7	21
Orchestral	2	2	8	12

There are more pieces for smaller forces mentioned in this thesis. The differences between synchronization strategies are interesting. There are fewer pieces that use following than any other strategy; however, cues and fixed media are approximately as common. Following is the least common synchronization strategy for ensemble and orchestral pieces. I believe this is related to pragmatism issues and especially rehearsal time, as discussed in section 4.4 and Chapter VII. Although many of the soloistic pieces are almost like an étude, parts of the repertoire are also highly experimental, such as Manoury and Stroppa and more recent pieces like Tutschku's *Zellen-Linien* (2007).

Most pieces in all categories mix together several strategies. Fixed media is often included but might not be used as a strategy in itself. Recorded samples from the performance, for example, are heard in many pieces as it reinforces the audience's perception of liveness and interactivity in performance (to be discussed later in 4.5). Fixed media is also often be used in a supplemental role so that not all of the electronics depend on live processing. There are relatively few modern pieces that do not use at least two strategies in one form or another.

Live processing is used extensively in many work of the since the ubiquity of computers. The use of processing has many affordances on both the compositional process and rehearsals due to being more challenging to test without a musician. However, the use of live processing can also give the musician more power and agency over the performance, in the sense that they feel more included in the final sonic result.

Connected to this idea, most of the pieces give control of the synchronization to the musician, often through the use of a MIDI pedal or through the use of following. It was only in a minority of the pieces in which a RIM was the main person responsible for the synchronization strategies and techniques. In many cases, the RIM is there for insurance—to make sure everything is working properly in performance. The role of the RIM will be developed more in Chapters VII and VIII.

Table 8. Overview of performance techniques by genre.

Performance Technique	Solo	Chamber	Ensemble	Orchestral	Total
Click track	4	6	5	0	15
MIDI pedal	7	3	5	1	16
Gesture following	0	1	2	1	4
Human following	1	2	0	4	7
Audio descriptors	8	3	1	0	12
None	8	4	3	4	19
Unknown	6	5	6	1	18

Table 8 shows the spread of performance techniques across the repertoire. For several of the pieces mentioned in the thesis, I have not been able to get more details on the performance techniques. The prevalence of the MIDI pedal within the soloistic repertoire is notable. The click track is used in every repertoire except for the orchestral. This is perhaps due to such a large ensemble's acoustics, making it relatively unlikely a conductor could adequately hear the click without it being too loud. On the other hand, orchestral pieces often use human following, which might be the alternative composers have thought of as most pragmatic (or idiomatic). Audio descriptors are also more in use within the soloistic repertoire.

4.3 Electronics & Time

This section will look at how time influences the compositional process and the structure of a piece. As Cont (2012) and Risset (1999) point out, there are several heterogenous times when performing mixed music. As mentioned earlier in Chapter II, we times relevant to mixed music are compositional time, the time of the electronics, performance time, and musical time.

4.3.1 Heterogeneous Time Zones

Heterogeneous time zones—a plurality of simultaneous musical tempi—have been an interest of composers for over a century. Early experiments such as Ives' *The Unanswered Question* (1908) paved the way for composers like Carter in his *String Quartet No. 2* (1959). Experiments with time, as shown in the writings of composers such as Boulez and Stockhausen, became a standard tool of the Darmstadt generation resulting in pieces such Stockhausen's *Gruppen* (1955-57) and *Carré* (1959-60) as well as Ligeti's *Poème symphonique* (1962).

With the advent of electroacoustic music, temporality could be drawn out in entirely new territories as one did not need to worry about performability. Playing around with temporalities is a crucial aspect of contemporary music in all genres, as presented in Glover et al. (2019). Because of the presence of both paradigms, it is possible to have a coexistence of two heterogeneous times, such as in *Økofanfare* (2011) by Thoresen, which does not try to relate the electronics to the acoustic sounds. Coexistence can also be achieved by having electronics or live processing functioning in entirely different time scales than a performer. Manoury has used heterogeneous temporalities between performers and electronics for years. In *Pluton* (1988-89), there is a motif with several metronomes that each have their own temporality (Clarke, Dufeu & Manning, 2020). The motif can be heard throughout the piece and established some of the irregular rhythms. We will come back to his pieces in the next chapter.

Blondeau has implemented these concepts within the styles of the younger generation of composers, especially in the piece *Namenlosen* (2017). In the piece, four soloists, an ensemble and the electronics are separated into groups and temporalities. These four soloists each represent a topology, which the composer explores throughout the piece, with the electronics interpolating between the various tempi and regions (Blondeau, N.D.; Fassol, 2017).

As technology evolves, there is no doubt that there will be more exploration in the use of layers and heterogeneous temporalities. For example, it would be possible to combine several synchronization strategies and performance techniques simultaneously to control electronic layers, creating an independent musical whole. This idea is perhaps similar to the ecosystems which composers such as Di Scipio are exploring. In pieces such as *Two Pieces of Listening and Surveillance* (2009-10), he creates an environment that creates music from the room's resonances (Di Scipio, 2018).

4.3.2 Electronics in Various Time Scales

The use of electronics makes the possibility of combining time scales more straightforward. The use of electronics permits the composer to use smaller scales or larger scales than the meso and sound object scales, which are the most common (Roads, 2001).

Live processing can take a musical gesture from the sound object to the meso or macro time scales. This change from shorter to longer scales can be going from striated to amorphous time. Some examples of digital signal processing are sending a musical gesture being sent to an infinity reverb, such as in Saariaho's *NoaNoa* (1992). The length of the reverb can extend the gesture from a sound object to the macro. Delays with feedback can work similarly. Additionally, the use of feedback can sound like a canon in multiple overlapping temporalities. Convolution is unique because it can confuse the boundaries between time scales, types of time, musical roles, and sound sources. Essentially, convolution gives some of the timbral and morphological properties of one sound to another. The instrumentalist might be in striated time, while convolution creates rhythms and new timbres, making it quasi-amorphous.

It is also possible to go from the sound object scale to the microscale with granular synthesis effects. With modern effects such as Hadron, Grainflow or Munger~, it is possible to control individual grains lending them to be a part of a compositional strategy or process such as setting grain transposition to follow a specific sieve order.

Another example is time stretching. If taken to the extreme, an entire composition could be just a single gesture, and there are no limits to which time scale it could be stretched. Sampling can also influence time scales, especially from the sound object, towards the meso or macro scales.

It is exciting both from a synchronization and compositional point of view that these differences in time scales and types of time can change throughout a composition and within the same gesture. Today, limits are mainly due to our limited compositional imagination, not technology. The examples could be used simultaneously and changed at several points within a single composition. Precisely how these layers and temporalities change is part of a composer's compositional paradigm (or a specific composition).

4.3.3 Perception of Time

The perception of time may vary from what is notated in a score. Glover et al. (2019) show how trained composers and musicologists can experience musical time differently. Composers and scholars such as Schaeffer (1952) and Oliveros (2005) have discussed how listeners interpret sound. As discussed in Chapter I, there are three distinctions of time: written time, interpreted time, and perceived time.

If there are multiple simultaneous layers of temporality within a single piece of music, our perception of the result can vary significantly between individuals. The analysis of a piece (especially only from recordings) can be challenging because of these layers. Discrepancies between absolute and relative time when working with programming electronics can change perception, especially for the performers that generally do not conceive music in absolute time.[29] These variations in perception may influence how a composer should use synchronization strategies as well.

4.4 Pragmatism for Performance

Pragmatism is not a word that one often reads in the earlier literature on mixed music. Technological development remains an essential aspect at institutes like IRCAM. Pragmatism comes into play in various guises: notational pragmatism, compositional pragmatism, performance pragmatism (to be discussed further in Chapter VII), and technological pragmatism. Additionally there is presentational pragmatism—whether it is possible to get a piece performed at all. This section will look into these pragmatic aspects and discuss their influence on compositional processes and synchronization strategies.

Perhaps the most important pragmaticism issue is the synchronization strategies and their affordances on the performer. The technological savviness of the composer (or the RIM) may be a guiding factor. If a piece demands difficult coordination with or use of electronics, many performers will shy away from it. Tutschku (2014) has been quite vocal about this, sometimes preferring to limit his compositional possibilities to make the piece available on an iPad. He does this precisely to ease the rehearsal process and concert preparations for performers. Saariaho asserts that technical choices often have to be pragmatic in order for musicians freely perform the music without specialized engineers or RIMs (Campion, 2017).

[29] Although much contemporary music has also required musicians to use stopwatches as the music is not notated traditionally.

Servière (2012) summarizes the craft of composition as inherently including a sense of pragmatism regarding which choices one makes compositionally. One could also say that compositional pragmatism is often necessary for a composer's works to be performed.

IRCAM has significantly shaped the repertoire of mixed music. Much mixed music cannot be performed without one of their engineers, who can be prohibitively expensive for many ensembles. Except for tours with musicians/composers from the institution, its music is not performed often outside of France. Many of the pieces created there have only been performed once and use exclusive technology that might not be available or is prohibitively expensive (Hewett, 2016). Baschet's *BogenLied* (2005) and *StreicherKreis* (2007-8) were difficult to perform, as they required bows with sensors. Although several separate projects exist for similar bows, they might not be portable. Additionally, they are not commercially available.[30] Arroyo had to have custom string instruments explicitly created for his project (Houlès, 2017). The composer admits that it is impossible for almost everyone, making the music prohibitively expensive to play for most quartets. Manoury (2012) explains that many composers are dependent on products that are not necessarily commercially viable. Hence, they often go out of production, which can be the death knell of mixed music compositions until they are reprogrammed with other solutions. In combination with the lack of commercial recordings for much contemporary music, this can make it challenging for musicians to reach a wider audience, essentially limited mixed music to a specialist, somewhat academic genre.[31]

The choice of a synchronization strategy can also be made out of pragmatism. It can also be a case that a strategy still is not perfect but still be better than other options. An example is *Einspielung I* (2011) by Nunes. Pages (2003) states that originally this piece is often played with two RIMs to trigger everything. The following might not be perfect with a score follower (described in Daubresse, 2015), but this would still be cheaper and more pragmatic in performance than using two RIMs.

4.5 Interactivity

Interactivity is a large and loaded term within the arts and music, as shown at conferences like The International Conference on New Interfaces for Musical Expression

[30] The company Keith McMillen Instruments has a K-Bow, however, it is not available for purchase, and they do not expect it to be possible to purchase one in the foreseeable future. Personal communication on the 23rd of October 2018.

[31] Although the philosophical debate on this issue is far beyond this thesis's scope, I see it as necessary to mention that if this music had a wider reach, it would perhaps be played more by performers and taught more in educational institutions around the world. As it is now, one has to be "initiated" into it.

(NIME) and The International Conference for Live Interfaces (ICLI). In this section, we will look at how scholars have looked at the concept of interactivity within mixed music. Since the late 1980s, mixed music has often been an ideological battleground between real-time and deferred time, as earlier discussed in this chapter. Although this has become less of an issue thanks to new technology, it can still be seen to a certain extent within the context of interactivity. As Jensen (1998) and Strommer-Galley (2004) raise, the term interactive in itself is problematic. The latter discussed how the interaction between people and machines are two concepts. Jensen argues how interactivity implies exchange, interplay, and mutual influence. He establishes interactivity as a continuum with several dimensions that may influence each other. Laurel (1986; 1990) argues that the frequency, range, and significance of agents' interactions guide the number of dimensions. Paine (2002) discusses these concepts as related to music and technology, and he establishes how cognition is at the heart of genuine interaction. In this thesis, interactivity refers to the interaction between various actors and electronics.[32]

The concept of liveness or interactivity is still omnipresent in much mixed music literature. Hagan (2016), for example, created an axis of interactivity that can be compared to Jensen's (1998). She argues that "live" and "real-time" are different, with the former having more to do with construction than execution. Emmerson (2007) has also discussed similar topics using the term agency. Croft (2007) and Frengel (2010) both have liveness and interaction as essential aspects of their analytical systems, although the former reveals a limited artistic use for liveness. Frengel argues that liveness does not make a piece objectively better. Mixed music is an intrinsically live genre of music since the classical recital lies at its heart. Therefore, interactivity in this context generally refers to the relationship of electronics with the acoustic musician. This is a philosophical and aesthetic battleground since interaction can be relatively fixed with few possible musical outcomes depending on how data is used, just like fixed media can also give the illusion of interaction. Many of the previously discussed pieces from the 1980s and 1990s that use fixed media actively try to give an illusion of interaction. Therefore, it is not a surprise that theories and paradigms often discuss or address interactivity. However, I find it problematic that interaction between human and machine can often be portayed as intrinsically superior to other artistic possibilities despite the many technical difficulties associated with such possibilities.

[32] Electronics can also be various agents interacting with each other as is becoming more common with the influence of artificial intelligence.

For example, Tan (2019) explains how, in his opinion, the practices of the SWR Experimentalstudio are “more live” and, therefore, better than IRCAM because the RIMs do not use presets.[33] This statement is somewhat superficial because neither is inherently better than the other. Additionally, I doubt that a non-expert audience perceives any work from the SWR as more interactive than those from IRCAM. They are merely different modes of working. SWR’s working method has historically been problematic such as trying to preserve the electronics Luigi Nono’s works (Boutard, 2019).

The interaction between algorithms and digital technologies permits us to not think of music as necessarily fixed, but rather that there can be genuine interaction between an acoustic performer and electronics (Couprie, 2015). The use of the word algorithm can be defined as “a procedure for performing a complicated operation by carrying out a precisely determined sequence of simpler ones (…) [algorithms] exclude all personal judgement” (Strachey, quoted in Alsop, 1999, p. 89). Manoury’s concept of the virtual is similar to the previous definition. The constituent’s parameters are, generally speaking, the score. The musicians know precisely what to play. However, the electronics will react and, to a certain extent, be cognitive of how the musicians are playing.

The critical aspect here is how interactivity changes the compositional process into a non-linear process, as seen in the composition process model from Chapter III. It is a more complex, ecosystem-based idea of creating—making a new sonic world for each piece. This process is a shift in thinking for composers because they might not have control over everything within the electronics. The boundaries between formalization, concretization, and actualization can change. Testing the electronics of a piece becomes dependent on the performers and is inherently more challenging (see Chapter IX). The use of interaction here is not qualitatively better than other methodologies; it just provides various affordances and challenges for composers. Through interaction in various ways between human and machine, composers can explore new and exciting areas of music.

How does interaction relate to our synchronization strategies and performance techniques? Fixed media is sometimes perceived as the antithesis of interactivity, but this is a half-truth. The fixed media part might be fixed, but the instrumental part is generally not fixed due to interpretation. Aleatoric music and other related styles can be used with fixed media, for example. Essentially, the amount of interactivity is not directly correlated with the

[33] Other chapters in the book refer to precisely the opposite, but the SWR RIMs still feel it is important to “play” the electronics part.

synchronization strategy and performance techniques. As Manoury (2007) remarked, it is genuinely in the department of the composer's self-imposed limits. Some interactions can be more complex depending on the technology, but it is not a one-to-one relationship. Additionally, wanting interaction within the composition affords various compositional possibilities. These may be used with various strategies depending on whether or not it is genuine interaction or a perceptual illusion.

Although the typical use of cues is to have a MIDI pedal, which will either trigger fixed media files or preset changes, there are many other possibilities. One can also see triggering presets or smaller sound files as a limited amount of interaction. Cues can also use other, more complex processes and algorithms. It can open up statistical calculations of which notes are being played, which can then be synthesized afterwards. The use of cues in a call-and-response styled dynamic may also give the illusion of interaction.

Following also has a similar paradigm to start. It seems that many use following mainly as a way to trigger cues more musically. However, it opens up the door to various compositional affordances. In gesture recognition, for example, indeterminate lengths and pitches are easily something to include delineated by certain gestures that the computer can easily understand. However, in general, following is the only strategy that may inherently include the concept of cognition, which is a requirement for multi-dimensional interactivity.

Therefore, I believe that interaction within mixed music is not related to the inherent quality of music. The primary influence it has is on how composers work on sonic materials and whether the performers or electronics take the lead. In the context of linking gestures to sounds or other more ecosystem-like compositional ideas, how one maps parts of a composition to electronic processes is of utmost importance. Interaction, like many other aspects and parameters, gives various affordances to the composer and the performers. Interactivity does not give inherent quality to music. Its most interesting aspect is how it may create interesting dialogues and topologies within the artistic production. Likewise, the illusion of interaction can be just as powerful as actual interaction. The important aspect is that it functions musically. As it relates to synchronization strategies, interaction or the lack of interaction (whether illusion or real) is mainly related to the compositional affordances and issues of pragmatism in performance. It is, however, essential that to discuss synchronization strategies further, we acknowledge the artistic and historical importance of the discussions on interaction.

4.6 Mapping

Mapping is often discussed within electronic music and digital art. It has become a large field. In its simplest form, mapping is linking a specific input to an output. In our context, the input will generally be sound, while the output can vary. The relevance of mapping within mixed music is threefold. Firstly, principles from digital instrument design may be applied (Burtner, 2002). In many pieces, the electronics effectively function as an extension of an acoustic instrument. Secondly, algorithmic ideas are becoming more common, and mapping has been an essential part of this practice (Doornbusch, 2002). Thirdly, mapping can also be thought of as a way to upscale or downscale mixed pieces depending on the venue. We tend to create electronics (and acousmatic music) in small controlled environments when the concert environment wildly varies. Mapping concepts can help composers to create electronics that are more stable in changes to spatialization aspects.

Hunt & Wanderley (2002) define mapping as “used widely to indicate the mathematical process of relating the elements of one data set onto another” (p. 98). In general, this will mean using data or a parameter from one sound to affect a control parameter, often using physical aspects of sound such as frequency or amplitude. Hunt & Wanderley (2002) note the differentiation of three categories within mapping:

- One-to-one
- Convergent: many parameters are mapped to a single parameter
- Divergent: one parameter is mapped to many parameters.

Additionally, one can map in various ways. It is possible to map linearly, along a scale, or any other mathematical model one can think of. One may also feel the need to filter out some of the information either in time or in extreme values. Through mathematical processes such as these, it is possible for the composer (or RIM) to have a more predictable result or to map any parameters together essentially.

Mapping has been used for many years, although it has become of more interest in more recent years because of the increased technological possibilities. For example, audio descriptors can be a powerful tool for mapping real-world parameters to musical effects. These mappings can be as obvious or subtle as the composer wants. By definition, most mixed music features elements of mapping. For example, elements of mapping are how one can control how much the amplitude of the solo cellist’s signal is sent to X or Y effect, with or without equalization. In Barrett’s *Utility of Space* (2010), the XY spatialization coordinates are mapped to effects such as pitch-shifting and filtering (Barrett, 2012). Effectively, spatial areas within the piece's 3D environment have specific parameters for effects. The important aspect here is that the mapping of effects is a compositional parameter that is often part of the structure of the composition. Due to its nature as an important musical element, mapping becomes vital to see the relationship between composition and synchronization. Many of the examples in Chapters V, VIII and IX feature mapping.

This section explores how mapping can function with synchronization.
We will also be looking at a few mapping examples ranging from diverse parameters affecting others in musical ways. We will also discuss how mapping may be used to down or upscale works depending on the concert venue effectively.

Mapping is often used as a part of the following strategy. For example, the use of audio descriptors to analyze a string player's articulation is the use of the following synchronization strategy (see section 4.2.3.2). In many cases, mapping is not used as a prominent music element for the electronics or as the primary form of synchronization. Mapping can also be used with discrete output, which could then be used as a cue. For example, using absolute points in a performer's gesture to control cues. In this case, the following strategy is still the highest layer, but cueing is also actively used as a strategy. In Manoury's *Jupiter* (1987), the flutist's attack controls the frequency of 28 oscillators in sections VI and XII (May, 2006). In these sections, the primary synchronization strategy is a mix of score following and cues. As the flutist plays, cues are triggered.

Increasingly, the use of mapping is with audio descriptors. Descriptors result from an analysis of the audio signal by amplitude, loudness, chroma, and spectral flux, among others. Envelope followers and score following are concepts based on audio descriptors concentrating on amplitude and pitch, respectively. Malt (2017) sees the development of the use of audio descriptors as a continuation of the tradition of using a physical understanding of the world in music.

An example of audio descriptors is *Dispersion de trajectoire* (2014) by Fernandez. In this piece for saxophone and electronics, the spectral centroid is used to control a wavetable's reading frequency, and spectral variation is used to turn on or off a spectral freeze. The table's reading frequency affords the possibility of a non-linearity. Malt (2017) explains that using descriptors often requires a long trial and error process. Calibration and testing are paramount to their use.

Down- or upscaling musical gestures in the electronics depending on the concert venue is another mapping aspect. To illustrate this issue, let us look at a spatialization example. If a room is only ten meters wide compared to thirty meters wide, changing the spatialization position within a cartesian plan from 0 to -50 on the X-axis will differ significantly in both halls. Assuming that the listener is in the sweet spot, 0 to -50 will be more drastic in the wide hall. Therefore, such movements' values should be upscaled or downscaled depending on the acoustics of where the music is performed to translate to the same musical and dramatic energy.

There is no easy solution to the up- or downscaling issue as it will vary depending on the type of gestures, the length of the reverb in the room and other acoustic phenomena. The critical aspect is that composers and RIMs are conscious of the issue. For some gestures, a change in the curvature of a movement might be enough. Depending on the PA system's placement in a large hall, changing the value of a sound on the X-axis from a linear curve to a sine or other shapes can form the same musical gesture. These dissimilarities also influence the cognitive dissonance we see on the stage (a musician's physical gesture) and what we hear. The discrepancy between a numeral form of data and its musical gesture is crucial in every form of mapping. The influence of mapping on composition and synchronization is still relatively rarely mentioned.

I have used some strategies in my own works to have a relative variable that one can up- or downscale as needed instead of always working with absolute values. The use of perceptual parameters such as azimuth and aperture has been helpful for spatialization, although it is not perfect. When working with fixed media, I usually work in ambisonics instead of with discrete channels to counter this. Although it is possible to a certain extent to anticipate how a room and PA system will react, I find myself having to adjust specific parameters in the room.

4.7 Conclusion

This chapter has established the importance of synchronization and how it affords the compositional process. This complex relationship is in direct contradiction with the traditional constructivist view of technology and composition. The composer's process has affordances with the synchronization, but these may change they go between composition and testing the electronics. Additionally, choices based on aesthetic judgements will have affordances. The concept of time and its omnipresence within electronics has also been explored. Pragmaticism in composition was also brought up as an important affordance. Interactivity and liveness were developed as concepts often found within the mixed music literature and how synchronization strategies fall within this debate. The concept of mapping was broached as a compositional possibility within synchronization and the compositional importance of up/downscaling electronics.

Elements such as aesthetic practice, interactivity, mapping, time, the musical role of the electronics, technological possibilities, pragmaticism, and many more have a part in the affordances between composition and synchronization. This complex relationship makes it difficult to approach the subject. The examples discussed in the text attempt to show some of these relationships. This chapter establishes a link between synchronization and compositional processes. The vocabulary from the first three chapters has also been extensively used, and we have begun to see some of the technologies that afford various compositional possibilities through the use of synchronization strategies.

From Chapter V and onwards, the examples to show these relationships will focus on case studies. I hope that by looking at these issues from both a macro and micro perspective, the complex nature of synchronization will be highlighted and better understood.

Chapter V: Case Studies

Scientific creativity, like musical creativity, is distributed, which explains both why it is so entangled with the rest of the project, and why it acts as such a stimulating force. By the end of the project, significantly, no one was able to discuss scientific, technological and artistic outputs as separate entities

-Nicolas Donin (2017, p. 81).

5.1 Introduction

Chapter IV explored aspects of synchronization and composition by creating an overview of various repertoires. This chapter compares and contrasts affordances of synchronization strategies in the case studies of works by three composers. These cases have been chosen to cover a broad use of performance techniques, synchronization strategies and instrumentations.[34]

For each composer, aspects of their artistic goals will be explored before focusing on specific pieces. For each piece, we will discuss:

- Synchronization strategies
- The musical role of the electronics and how they function
- Specific examples and speculations of how the synchronization might have influenced the compositional process

5.2 Philippe Manoury

Philippe Manoury was born in Thule, France in 1952. His pieces from the late 1980s, *Jupiter* (1987) and *Pluton* (1988-89), are two of the most discussed pieces within the scholarly literature of mixed music. Although Manoury has received attention for his musical and technical breakthroughs, there are relatively few complete analyses of his works.

His texts, appearances, interviews and music show his deep interest in the interaction between electronic and acoustic sound sources. It was vital for Manoury to develop electroacoustic music ideas in real-time and see what it could bring to his *écriture*. Many of Manoury's texts, especially early ones, are critical of music using fixed media. However, as we have discussed earlier, this was a normal stance among many composers at the time.

[34] Although I would like to look at more composers without institutional support, it is challenging to do so because few composers outside of institutions have much literature based on their music. We as a community should try to address this challenge in the repertoire we analyze and discuss.

5.2.1 Compositional Philosophy & Synchronization

The first important aspect to understand Manoury are his thoughts on the use of real-time in mixed music. Although his name is often associated with this idea of real-time he has mentioned that this terminology is a misnomer.

> *What we consider to be "real-time" in musical composition is a misnomer because the musical components are often already fixed, and we generally do not vary this from interpretation to interpretation* (Manoury, 2007).[35]

His ideas have revolved around making real-time electronics where specific parameters are fixed, while others are only determined at the time of performance. He defined this concept as virtual scores:

> *A virtual score is a representation whose constituent parameters are known in advance, but whose exact concrete manifestation is subject to variation. If such a thing is unknowable in advance, it is for the simple reason that there is some degree of dependence upon performance which, as we have seen, contains a degree of indeterminism* (Manoury, 2013, p. 67).

Manoury's music, use of synchronization strategies, compositional philosophy should be understood from this paradigm. The virtual score is a concept he developed in conversation with several other composers including Boulez in the 1980s (Manoury, 1998). Manoury's goal is to give more interpretation possibilities to all actors involved in the music-making process. Virtual scores include a critique of the rigidity of fixed media. For Manoury, real-time use means that specific cues will be recognized and serve as pivot points within the music to re-synchronize and move to the next point (Manoury, 1998). This concept also ties into the idea of mapping because it highlights how the electronics utilize both relative and absolute values based on performance data from musicians. When a given note is performed by a human musician, its dynamics and timing (in the order of milliseconds) are relative. The use of the electronics around this will use both types of values in order to function. Manoury's use of audio descriptors and their links to compositional processes and effects is an important aspect of his art.

[35] *Ce qu'on appelle alors « temps réel » dans la composition musicale serait un abus de langage puisqu'une part des composants musicaux est souvent déjà fixée, et n'a pas pour vocation à varier d'une interprétation à l'autre.*

Another important aspect is his use of time as a compositional parameter. He has been heavily influenced by Boulez's musical thought. He often plays with time and rhythm to change motifs to the point of not being recognized, such as *Pluton's* (1988-89) ending, where the Disklavier plays back the same figure as the pianist sixty times slower. His experimentation with time is closely tied with synchronization strategies as his explorations are often gestures that move from the performer to the electronics and vice-versa.

Écriture between electronics and acoustic sound sources is at the heart of Manoury's art. There is little doubt that the conception of the electronics and formal aspects of the composition are drafted simultaneously. However, he is always working with RIM and researchers. How much of the composition's plan is complete by the time he starts working with these RIMs? His article about *Tensio* (2010) reveals his debt to Puckette for several ideas even though Puckette was not his RIM for the piece (Manoury, 2013).

Although Manoury is one of the most well-known composers of mixed music, he began as an acoustic composer coming into the world of electroacoustic music. In most of his writings, he refers exclusively to acoustic composers. His Collège de France lectures were about repertoire composers and his music, with no references to electroacoustic music except by some guest lecturers (Manoury, 2017a ; 2017b, 2017c, among others). This is despite his interest in the GRM composers in the 1970s (Derrien, 1995). He took classes at GRM but was not impressed by their ideas or music (Manoury, 2019). However, Machover (1984) describes Manoury as inexperienced in using electronics at the time of his entry at IRCAM. In a recent interview, Manoury explains that he was more interested in instrumentality and started seeing its possibilities once at IRCAM (Clarke, Dufeu & Manning, 2020).

Manoury's use of electronics is based on a conceptual understanding of music as an acoustic art form. He is less interested in spectromorphology than the relationships between the acoustic and electronic sound worlds. Effectively, Manoury mostly uses electronics as accompaniment with an occasional soloist's role. Manoury uses electronics as an effect to colour acoustic instruments, but seldom uses electronics to change the instrument's fundamental acoustic characteristics or to create a hybrid/augmented instrument.

5.2.2 Jupiter (1987)

May (2006) analyzed *Jupiter* (1987) in some depth and explains that the score includes little information about the relationship between the flute and the computer. Initially, the piece used a MIDI flute, which was a project by Lawrence Beauregard with the help of Xavier Chabot. Magnetic sensors under the flute keys allowed the computer to understand the flutist's fingering, making pitch tracking quicker than analyzing an audio signal (IRCAM, 2003). Today, any flute can be used as the follower for the score by analyzing the frequencies of the musician's performance through a microphone.

The form of score following that Puckette had created for this piece was simple. The system would wait for the flutist to play each note, triggering the next cue. In the case of repeated notes, the system would detect a group of notes (IRCAM, 2003).

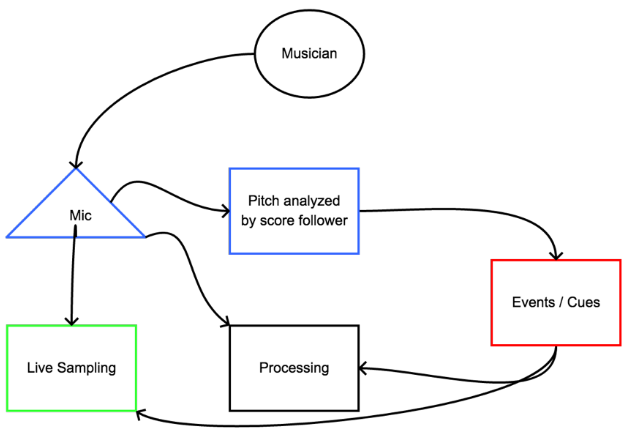

Figure 19. Synchronization in Manoury's Jupiter (1987),

Score following is mainly used to trigger effects and samples, as shown in Figure 19. Puckette asserts that the piece's form is relatively rigid and was dictated by the technology as they had to change disks in the 4X between sections (May, 2006). However, the use of real-time technology and score following is vital to Manoury's aesthetics, and he makes a point to mention how no pre-recorded samples were used (IRCAM, 2003).[36]

Manoury created *Jupiter (1987)* with the help of twelve RIMs and researchers (IRCAM, 2003).[37] Given such a large contingent of helpers, I question whether some of the RIMs might have proposed ways to work with the synchronization musically, influencing the *écriture*. The number of people involved also shows the prestige of creating such a composition at the time, and it is unlikely that a young composer would get a similar opportunity today.

[36] Despite the fact that the composition does use tam-tam samples as described in 5.2.2.1.
[37] Cort Lippe is listed later as a collaborator, but he is not listed as a RIM.

5.2.2.1 Example I – Rhythmic Interpolations

In a 1987 presentation, Manoury explained that one of the essential aspects of the technology in *Jupiter* (1987) is that it allows a more "constructivist or structural communication mode by memorizing and processing a whole section and, after that, by restoring the development coming forth from it" (IRCAM, 2003). For example, rhythms and pitches from sections II and VII are used in sections V and IX, respectively (see Figure 20). In section V, earlier material is used to trigger samples of a tam-tam, while in section IV, earlier material triggers cross-synthesis between a piano and tam-tam (May, 2006).

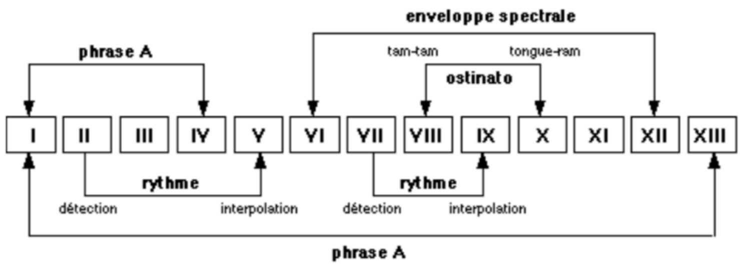

Figure 20. Structure in Jupiter (IRCAM, 2003).

The interesting aspect of this structure is that the synchronization strategy is used for something that happens later, which the audience will probably not perceive. However, I agree with May (2006) that after a few rehearsals, the flutist will be aware of this relationship, influencing the performance. The score follower afforded this possibility, which also influenced the form of the piece. This leads me to believe that the piece's compositional process was cyclical, with many rounds between Manoury and the RIMs since early performance parameters influence other sections. I believe this is also the first use of synchronization strategies in such a manner in the mixed repertoire.

5.2.2.2 Example II – Spectral Envelope

In sections VI and XII, the synchronization strategy of following is used differently—it is used to control the additive synthesis's direction and rate through a spectral envelope. May (2006) describes this as abandoning the use of the score follower, but in practice, this is not completely true. The strategy is still following, it is only being used differently with pitch information still acting as essential aspect of synchronization. Section VI of the work presents this possibility exclusively in an almost demonstrative manner, while section XII combines it with other DSP effects.

In the program notes on the new edition of the score, Manoury explains that this use of the spectral envelop mostly makes the electronics have common motion with the performer, except for a few exceptions at events 12 and 13 of section VI, which is mainly staccato pianissimo notes. Was this by design or by accident? The two exceptions show some compositional intention, but I find it surprising that this possibility was not used more actively in the work. Although both of these sections could have been composed before the synchronization strategies were implemented, I still think they were written while working on them. It is possible to think that the idea originated from one of the RIMs.

5.2.2.3 Closing Words

Jupiter (1987) is a historically significant piece that showcased the new technological possibilities of the late 1980s. Although much of the literature on the piece focuses on aspects of real-time and interactivity, I have attempted to show how synchronization strategies became so inherent within the compositional practice of Manoury. The highly developed and referential form of the work, especially within the electronics, reinforces how tightly synchronization strategies and compositional processes are linked. This piece standardized links between sections within the electronics. These relationships between macroform, synchronization, and electronics became more common in compositional practice afterwards.

5.2.3 Partita I (2006)

The next evolution in Manoury's œuvre, especially regarding synchronization, is *Partita I* (2006) for viola and electronics. This piece starts a new cycle of works with electronics which includes *Partita I* (2006) and *Partita II* (2012) for violin. There are two versions of the piece: one in which a gesture follower and score follower are used, and another that only uses score following. Lemouton (2009) described the gesture follower with sensors similar to Baschet's *BogenLied* (2005). The Antescofo website shows a revision of the piece in 2008. The patch version from 2012 features Antescofo and no usage of sensors. Audio descriptors are used to analyze the performance mainly through amplitude analysis, giving information about attacks, bow pressure, and certain bowing techniques, such as tremolo.

Manoury wanted to synchronize the instrumentalist's gestures with electronics directly to extend them. This is one of the rare times Manoury's use of electronics approaches the paradigm of the augmented instrument. According to Lemouton (2009), the technical aspects of the piece arose from discussions in 2004, but the piece was written between July and December 2006. It is fair to speculate that these discussions between IRCAM and Manoury influenced his compositional ideas. It is also probable that Manoury would send ideas to the RIMs to see if it could work. The piece's synchronization layers can be seen in Figure 21. One can see that despite using a gesture follower and audio descriptors, the piece also uses cues and fixed media. Although the follower is the highest layer, cues play an important role, as this section will explore.

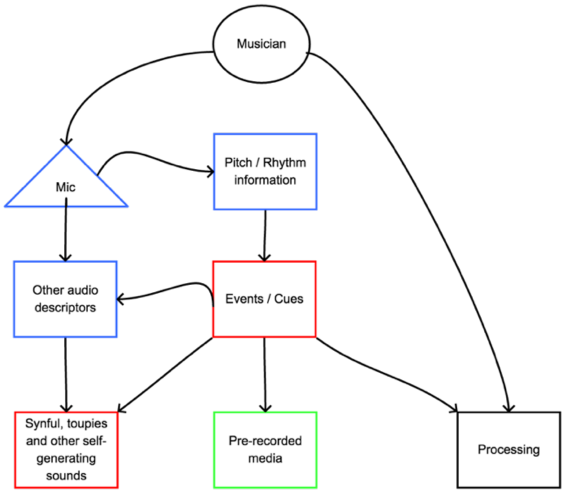

Figure 21. Synchronization in Partita I (2006).

As part of the piece's research, Manoury became interested in the physical modelling of strings. However, Lemouton (2009) mentions that this was not a realistic possibility at the time. Manoury was probably looking at the research of Demoucron (2008), which was actively used in *Tensio* (2010) (Manoury, 2013). Instead of Demoucron's concepts, he used a commercial sample modelling system by Eric Lindemann called Synful.[38] The 2011 Max/MSP patch of the piece also relies on the use of Synful. This is ironic considering Manoury's admitted fear of disappearing commercial products as mentioned in Chapter IV (Manoury, 2012).

The piece is separated into nine sections, where the first and the last are an introduction and conclusion. The other sections represent seven musical types of expression (not all of which are articulations) shown in Table 9 and Figure 22 (Lemouton, 2009; Manoury, 2017a). Each type of gesture and their order is the same between each section, but

[38] At the time of writing, Synful's website has not been updated since 2011. It is still possible to download a demo and even buy the software, but the demo does not seem to run on more modern OSX versions.

one musical expression takes the lead per section. The original gesture that generates the whole piece is IIA, which in the commercial released CD with Christophe Desjardins (2009) can be heard from 00:00 to 00:56. All further references to a recording are from this CD in which each section is on a separate track.

Table 9. Lemouton's (2009) description of the form of Partita I (2006).

Section	**Musical Expression**
1	Staccato rhythms with repeated notes / Introduction
2	Prelude/exposition of the seven musical expressions
3	32nd note regular phrases
4	Trills on shifting chords
5	Ricochets
6	Tremolo
7	Crescendo / "toupies"[39]
8	Two voice cadenza
9	Coda

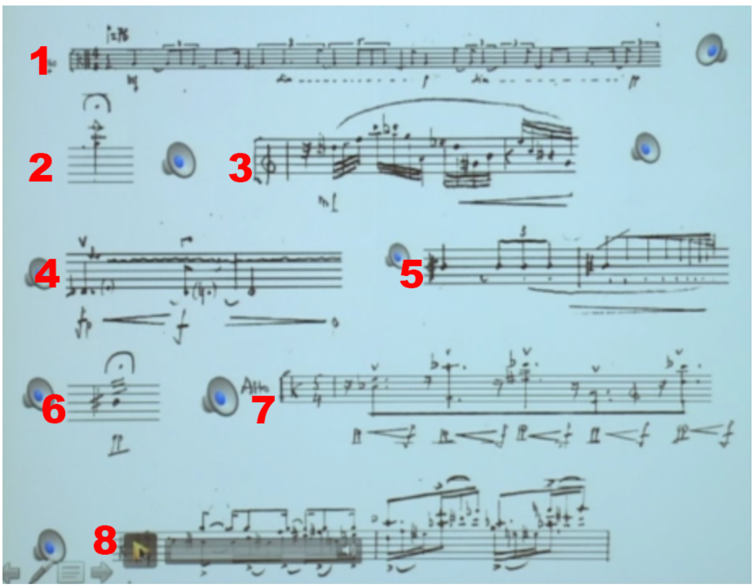

Figure 22. Generative grammar in Partita I (2006) from Manoury (2017a).

[39] A type of amplitude modulation.

The electronics include the use of Synful, phase-aligned format synthesis (PAF), harmonizers, delays, toupies, frequency shift, reverberation, real-time and spatialization. A "toupie" is similar to the Leslie cabinet sound, meaning amplitude modulation. In pieces like *Partita I* (2006) and *Tensio* (2010), this is used extensively, often with a shifting pitch, and performance parameters determine movement speed. The piece uses six speakers in concert, although the score has no stage plan. The score has a distinction between cues triggered through the score following automatically and events that much be triggered manually by the RIM. These triggers are likely constructed due to the difficulty that the electronic following has in properly understanding the input signal.

5.2.3.1 Example I – Introduction

How have these synchronization strategies and performance techniques influenced *Partita I* (2006)? Let us look at a few musical examples that can clarify how intertwined these concepts are with Manoury's compositional process.[40] The piece starts with the gesture in Figure 23. In the second event, Synful plays the same figure after recording the performer's rhythm using an envelope follower, turning it into an ostinato. The second system starts with a long silence from the performer, which might not be apparent on an audio recording (00:10 to 00:13 in the first section). Having the musician play a gesture and then repeating it in the electronics is a trope of mixed music. Physical modelling gives more freedom for the composer to change the parameters of a sample, such as the tempo and other characteristics.

Figure 23. The opening figure of Partita I (2006), Rhythm A.

In the third event, which is a double stop rhythmic figure, the rhythm is recorded. I will be calling this Rhythm B. From the end of Rhythm B, there are interpolations between this figure and the previous figure of Figure 23 (called rhythm A). Rhythms A to G are recorded and have various interpolations in the electronics moving throughout this first section. At various triggers, the physical modelling also shifts rhythm. This creates a type of

[40] Throughout the examples, I am looking at the electronics from the 2011 version with score follower. There may be some differences from the original version.

canon/pedal point where the rhythmic values and pitches are varied in real-time between the performer and electronics. Unlike delay-based canons, there is no risk of feedback.

This section (one can hear this especially from 00:13 to 00:35) to would not have been possible if it was composed without the synchronization strategies in mind and vice-versa. It would be possible to do it with samples, but the timing would not be as accurate, and it would not be possible to do the canons in such a seamless way. The piece's beginning shows how interconnected the performer and electronics are. The *écriture* of the piece is seamlessly integrated with the affordances of the following strategy and the use of physical modelling.

5.2.3.2 Example II – Section VI

A second example is in the sixth section of the piece, which begins with a trigger from the RIM while the performer is silent. Although this silence is short, it creates the impression that the electronics can lead the work as much as simply following the musician. This silence also reminds us that mixed music is a concert music as we cannot understand this device without seeing a concert. The sensors detect the tremolo’s speed, which controls the speed of the toupies (Lemouton, 2009). In the electronics that I have access to, this is not the case. Most of the speeds are determinate, while others have limited randomness. However, events 30 and 36 use audio descriptors to gauge the speed of the performer’s tremolo. This example shows us the discrepancies between compositional wants, pragmatism, and the available information.

The compositional idea of the section is quite clear: the tremolo's speed should translate to the toupies in a single gesture, creating a hybrid between the instrumentalist and electronics. The conception of this gesture is based on the following strategy. The importance here is on the following of the tremolo speed through a sensor. Without the sensor, the gesture is still present, but not as directly mapped to the original sound source. The question remains on whether a following strategy can achieve this perceptually as effectively as using an instrument sensor. Even if the audience does not hear the change, the performer likely will, depending on how intimate they are with the piece.

5.2.3.3 Example III – Sections VIIB & VIIC

A final example is in sections VIIB and VIIC (03:34 is VIIB and VIIC is 05:33).[41] The acceleration of the performer's bow longitudinally changes the harmonizers' transposition (Lemouton, 2009). Manoury composed six possibilities that can be played in any order (the systems labeled I-VI in the score). Each possibility has to be started and ended with a specific note played pizzicato, as seen in Figure 24 and Figure 25. Here again, we illustrate a difference between the documentation and the electronics themselves. The electronics have pre-determined harmonizers and speeds for the toupies in the current version of the Max/MSP patch. However, other events in this section use audio descriptors. In event 13, the bow's pressure is sent to an envelope follower and helps control the frequency shift on Synful.

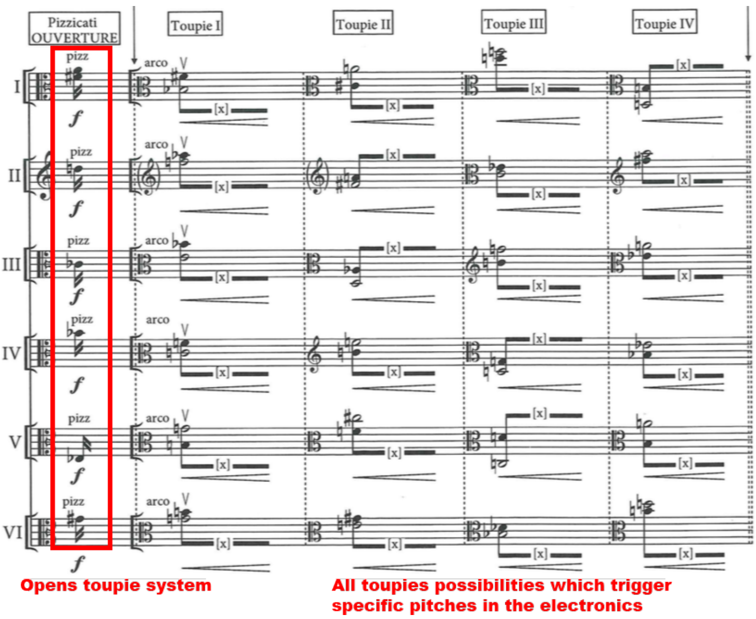

Figure 24. The annotated opening of VIIC in Partita I (2006).

[41] Note: There are substantial discrepancies between the score and recording of section VII. I am guessing that the score is a revision of the piece since it was published in 2011 while the composition is from 2006. I cannot find any mentions of revision or differences in the literature.

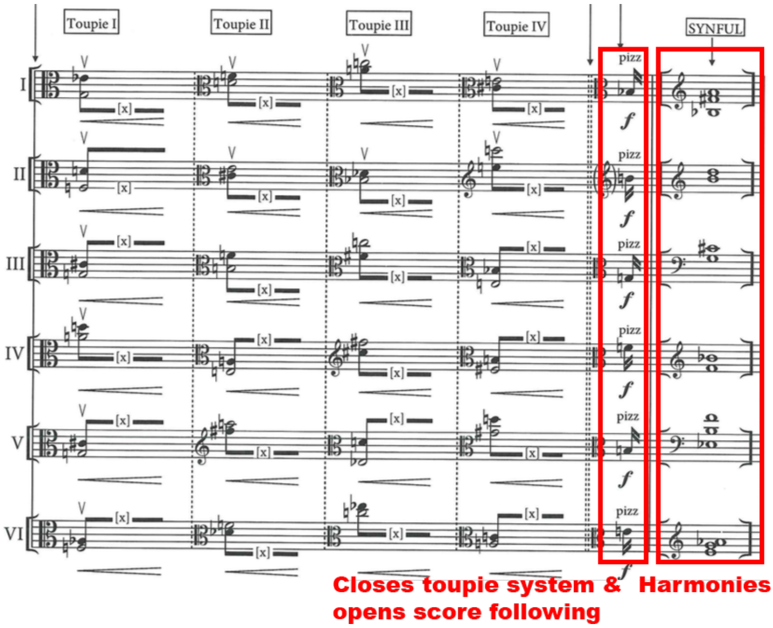

Figure 25. The annotated end of VIIC in Partita I (2006).

The following strategy here is used in a non-conventional manner. The section is meant to be non-linear, which presents a challenge for many synchronization strategies. The score following is shut down on the last note before this section and triggers an event (see Figure 24 & Figure 25). From here, a separate pitch tracker is activated and collects the detected pitches in a list. They are analyzed and then classified as to how long the toupies should be. The violist's first note opens a specific path with its own harmonization from Synful. Once one of the final pizzicati pitches is detected, the score following is turned back on. The affordances of this compositional paradigm made pitch and envelope following the most straightforward possibilities. The use of the toupies extends the violist's gesture, which leads me to believe that Manoury must have composed this section with information from his RIM about the possibilities of the Max/MSP patch they were working on. It is also interesting to note that there is a possibility to plot in a pre-determined order within the patch.

The section is an interesting view of affordances between various implementations of cues. Although following with a cue system is still the strategy used, a score follower could not have done the same.[42] Having cues or fixed media as the top layer would have made this section more demanding on the player, and it could not have been non-linear.

[42] At least with the possibilities at the time. The Antescofo language has now evolved and allows forms of non-linearity.

5.2.3.4 Closing Words

Partita I (2006) shows many possibilities of using synchronization to affect electronic parameters throughout the piece. The piece's compositional processes are tightly connected with the affordances of following and several parts of the microstructure are directly related to synchronization. Manoury shows in this work how synchronization and compositional thinking can be fused.

5.2.4 Manoury's Tensio (2010)

Tensio (2010) is Manoury's second string quartet. This piece is perhaps Manoury's most innovative piece since the late 1980s. The piece presents many of the musical ways in which synchronization can be used. It shows the complex nature of the affordances between composition and synchronization. Several processes from *Partita I* (2006) come back under new guises. This section will take an in-depth look at the use of synchronization in the piece. At this point, there has not been any complete analysis of the piece widely available. There is a presentation available on the development of the material by Grábocz (2012) and there is some information on the creation of the piece where Manoury (2013) describes his compositional processes and ideas. A documentary highlights some of the piece's compositional and practical aspects (Kaltenecker & Bahier, 2010). Other available resources include Manoury (2012) and Gerzso et al. (2012). The RIMs for the work were Arshia Cont, Matthias Demoucron, Serge Lemouton, Gilbert Nouno and Miller Puckette.

The score is available from Durand, and there are recordings available online, although not commercially.[43] Additionally, I have a Max/MSP patch of the electronics from 2011. For further analysis, the form of the piece between the various recordings is shown in Table 10 and Table 11.

Manoury's compositional process (as we have explored in Chapter III) is not described in the aforementioned articles. We know relatively little about how he tends to compose his music. There is no doubt that the RIMs around him play a prominent role in inspiring his ideas.

[43] The recordings I have listened to include:

- Quatuor Diotima – 17 December 2010 (premiere)
- Quartuor Diotima – 11 June 2012 (definitive version)
- Quartetto Maurice – 2 June 2015

Table 10. The form of Tensio (2010) with timings from three recordings

Section	Page #	Diotima – Premiere	Diotima – Definitive version	Quartetto Maurice
IA	1	00:00-00:10	00:00 – 00:12	00:00 – 00:19
IB	1-2	00:10-00:26	00:12 – 00:29	00:19 – 00:36
IC	2	00:26-00:38	00:29 – 00:43	00:36 – 00:50
ID	3-4	00:38-01:16	00:43 – 01:29	00:50 – 01:44
IE	5	01:16-01:34	01:29 – 01:47	01:44 – 02:03
IF	6-7	01:34-01:53	01:47 – 02:05	02:03 – 02:25
IG	7-8	01:53-02:18	02:05 – 02:31	02:25 – 02:53
IH	9-10	02:18-02:51	02:31 – 03:08	02:53 – 03:28
IIA	11	02:51-03:16	03:08 – 03:40	03:28 – 04:12
IIB	12-13	03:16-03:52	03:40 – 04:21	04:12 – 04:48
IIC	14-15	03:52-04:36	04:21 – 05:07	04:48 – 05:36
IID	15-17	04:36-05:27	05:07 – 05:50	05:36 – 06:30
IIE	18-19	05:27-05:50	05:50 – 06:14	06:30 – 06:53
IIF	19-21	05:50-06:49	06:14 – 07:15	06:53 – 08:14
IIG	21-22	06:49-07:12	07:15 – 07:41	08:14 – 08:37
IIH	22-24	07:12-07:51	07:41 – 08:22	08:37 – 09:25
II-I	25-29	07:51-08:56	08:22 – 09:23	09:25 – 10:35
IIIA	30-32	08:56-11:45	09:23 – 11:48	10:35 – 13:03
IIIB	32	11:45-11:49	11:48 – 12:04	13:03 – 13:09
IVA	33-35	11:49-13:18	12:04 – 13:25	13:09 – 14:46
IVB	35-38	13:18-14:16	13:25 – 14:17	14:46 – 15:45
IVC	38-42	14:16-16:18	14:17 – 16:22	15:45 – 17:57
VA	43	16:18-17:11	16:22 – 16:52	17:57 – 18:52
VB	44-45	17:11-17:57	16:52 – 17:51	18:52 – 19:45
VC	45-46	17:57-19:08	17:51 – 19:15	19:45 – 21:07
VD	47	19:08-19:37	19:15 – 19:35	21:07 – 21:35
VE	47-48	19:37 – 20:09	19:35 – 20:03	21:35 – 22:12
VF	48-49	20:09 – 20:43	20:03 – 20:35	22:12 – 22:47
VG	49-50	20:43 – 21:10	20:35 – 20:59	22:47 – 23:27
VH	50-51	21:10 – 22:02	20:59 – 21:42	23:27 – 24:22
V-I	51-52	22:02 – 22:17	21:42 – 21:59	24:22 – 24:36
VJ	52-53	22:17 – 23:09	21:59 – 22:47	24:36 – 25:30
VK	54-62	23:09 – 27:19	22:47 – 26:40	25:30 – 30:00
VIA	62-63	27:19 – 28:02	26:40 – 27:23	30:00 – 30:55
VIB	63-64	28:02 – 28:33	27:23 – 27:51	30:55 – 31:30
VIC	64-65	28:33 – 29:19	27:51 – 28:36	31:30 – 32:06

VID	65-66	29:19 – 29:58	28:36 – 29:07	32:06 – 32:42
VIE	66	29:58 – 30:12	29:07 – 29:25	32:42 – 33:08
VIF	66-67	30:12 – 30:52	29:25 – 29:59	33:08 – 33:43
VIG	67	30:52 – 31:13	29:59 – 30:20	33:43 – 34:12
VIH	68-69	31:13 – 31:58	30:20 – 31:04	34:12 – 35:04
VIIA	70-74	31:58 – 34:00	31:04 – 32:59	35:04 – 37:26
VIIB	74-79	34:00 – 36:17	32:59 – 35:11	37:26 – 39:40
VIIC	80-81	36:17 – End	35:11 – End	39:40 - End

Table 11. Length of each full section in 3 recordings of Tensio (2010).

Section	Pages	Diotima – Premiere	Diotima – Definitive	Quartetto Maurice
I	1-10	02:51	03:08	03:28
II	11-29	06:05	06:15	07:07
III	30-32	02:52	02:41	02:34
IV	33-42	04:30	03:58	04:48
V	43-62	11:01	10:18	12:03
VI	62-69	04:39	04:24	05:04
VII	70-81	05:52	06:26	06:40

Synful was used once again, sometimes to synthesize a string quartet within the electronic component. Additionally, Manoury uses Demoucron’s (2008) research on physical modelling. A new aspect that he explores is to work more with inharmonicity with 3F synthesis. The spectra are created by taking three base frequencies that have several operations (Manoury, 2013). These three base frequencies are taken from the quartet members, and who contributes to these frequencies will vary by section. 3F can be heard clearly in section V of the piece. One can hear how the synthesis varies from instrument to instrument and creates inharmonic textures.

Hagan (2016) specifies that the piece is notated precisely, undermining Manoury's claims of how performance variations can affect the electronics. She claims that the performances allow "for no changes beyond small normative interpretations" (p. 6). I argue that the three existing interpretations are different on many points, including the electronic part. It is difficult to know how the intentions of the musical actors in each performance result in the resulting discrepancies of interpretation. Additionally, section III of the piece features an open structure that directly contradicts Hagan's argumentation. The variations between recordings in other sections also support this—there are significant variations in phrasing, dynamics, and tempi. Each quartet has managed to make the piece their own, in keeping with the normal performance practice of the string quartet.

The critical aspect of this piece is how flexible the synchronization allows the performance to be. We will now examine how the flexibility of synchronization affected Manoury's compositional processes and, therefore, the result of the piece in five examples.

5.2.4.1 Example 1 – Section II

This section is perhaps the best example of heterogenous time in Manoury's catalogue and shows the profound influence of synchronization strategies. The score following works in relative time. For example, in IIB, the speed of the pizzicati played by Synful entirely depends on the quartet's tempo.[44]

As can be seen in Figure 26, the section begins with several tempi starting to coexist. A gesture is started in the physical modelling and then another with pizzicati played by Synful. The Tempo A gesture starts with the quartet. The Tempo B gesture starts independently in the electronics, which forces the quartet to listen to its tempo before coming in again. At this point, the quartet is separated into two entities with two tempi. This section has in total nine tempi (seven with associated letters). There are interpolations between these tempi, as can be heard at the start of IID and IIE. This creates a complex web of heterogenous time that sounds chaotic, despite most parts being relatively simple. The tempi that are started by the electronics are generally not influenced by the players, giving the illusion that the electronics lead. The tempi based on the players are always flexible and based on how they play.

[44] Technically speaking, it is only dependant on the first violin's speed, because Antescofo is exclusively processing the first violin.

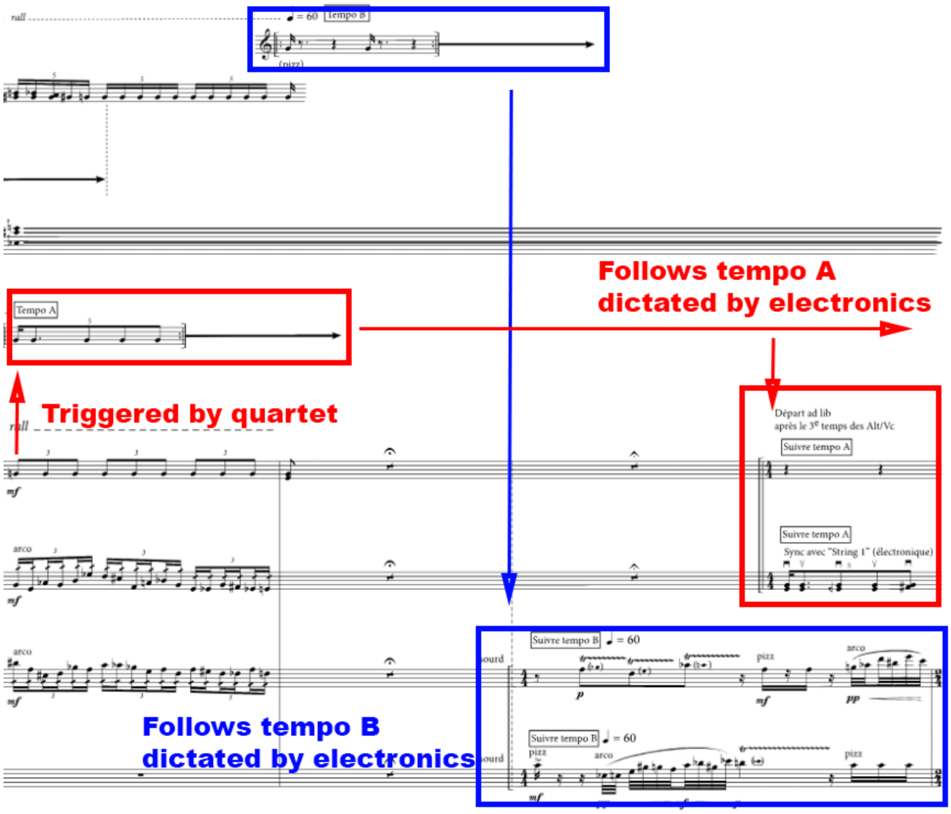

Figure 26. Tempo following in Tensio (2010, p. 13)

The temporal flexibility given to the player-controlled sections makes each of the recordings of *Tensio* (2010) unique. The three quartets have significant time discrepancies. This section is a great example of the complex relationship and affordances between synchronization strategies and compositional processes. Manoury probably had the idea of interpolations between tempi after writing *Partita I* (2006). However, I am sure that his RIMs played an essential role in what was possible and pragmatic and included this in his writing. The composition requires precise and flexible synchronization strategies and performance techniques, and the following strategy affords the musical possibilities of flexible tempi, interpolations, and strict tempi.

5.2.4.2 Example II – Section IIIA

This section is in open form. Manoury has done open sections in many previous works. It is almost a trademark or perhaps a way to show electronics' flexibility. The electronics take a slightly lesser role, and several gestures are looped. The processing is mainly harmonizers that shift to fixed harmonies and delay times to fill in the texture. The use of spatialization trajectories and loops is active according to the score, but this cannot be heard in any recordings since they are stereo. The similarities between the recordings show that most quartets have either chosen something similar—possibly because the electronics are not as flexible to different interpretation. Choosing a fixed open form is one of the ironies of choice discussed in Griffiths (2011) and Piekut (2011).

The Antescofo score for this section works by triggers from specific notes. In my own experience, this tends not to work well as events will be triggered too quickly. However, it is possible that the RIM would be triggering the subsequent events, possibly with a visual cue from the quartet's leader. It is not possible to know only from the score and recordings how the section was organized for the performances

This section is also interesting in its use of synchronization. The score following is used, but pizzicati notes in the first violin trigger the electronics' changes. Essentially, waiting for each note circumvents the problem of synchronization and linearity. Each pizzicato uses a pitch that is used within the previous open section. The score follower ignores everything except for those specific new pitches. It is possible that Manoury had to add these pizzicati as a compromise to help the synchronization. The other quartet members' gestures are sometimes notated more linearly, but the score follower and electronics ignore them.

What makes this section sound so active, and as if the electronics are following the strings, is the harmonizers that change at each event, transposing the players' gestures and delaying them. Additionally, three samplers play glissandi (with rests) of varying lengths, which are repeated throughout most of the section. This helps create the dense, chaotic web one hears and gives the impression of a tighter synchronization.

5.2.4.3 Example III – Section IV

Section IV presents more examples of the importance of synchronization in *Tensio* (2010). In the first part of this section (as seen in Figure 27), the electronics take the lead sonically, but they are actually following the musicians. The 3F synthesis is an important element of the texture throughout the section. All members play pianissimo point-based music, which triggers the synthesis and harmonizers, and creates a sharp contrast. It also sounds as if they take the lead. In the fifth event, soloistic lines are spread across the quartet, which triggers the 3F synthesis. Each instrument has then contributed a frequency to the 3F synthesis.

Figure 27. Section IVa in Tensio (2010, p. 33) featuring the use of 3F synthesis.

As shown in Figure 27, the electronics are not fully notated as they are not pre-determined. The harmonizers steer the music towards fixed harmonies. The electronic rhythms are the same as those the 3F synthesis will analyze. As the section continues, Synful and harmonizers' use increases, often following some of the pitch centers of the quartet. Most movements are in musical time and give the listener the impression that there is real-time polyphony between electronics and a quartet.

I believe Manoury's compositional goal in this section was to have electroacoustic timbres created directly from complex polyphonic writing on acoustic instruments. Shifting synchronization strategies for this section would be challenging. In the case of fixed media, the influence would be minimal and not fit within his aesthetics. The section is not entirely dependent on following as in others.

5.2.4.4 Example IV – Sections VIIB & VIIC

A final example of the link between synchronization strategies and compositional processes is sections VIIB and VIIC, which use many possibilities of following with toupies. These toupies move to and from specific pitches. However, the time taken can vary from instrument to instrument and is in musical time. An example can be seen in Figure 28. The timing is essentially reset at every detected event in the first violin.

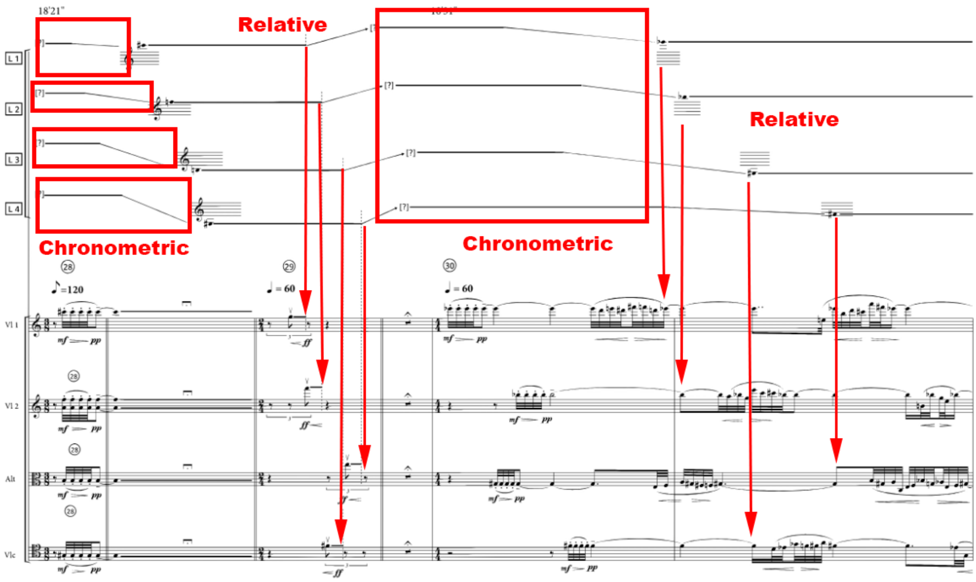

Figure 28. The use of virtual scores in Tensio (2010, p. 75).

These two sections show the flexibility that Antescofo's score following attained in the few years between *Partita I* (2006) and *Tensio* (2010). The electronics vary between musical time, chronometric time, and calculating the length and speed of change as an event is unfolding. The electronics' role is to accompany the quartet as well, therefore having the toupies follow the musicians and not vice-versa makes more musical sense. The synchronization here allows for musicians to feel as if they are leading the forward motion of the music together with the electronics. Using other strategies or performance techniques in these two sections could have made the resulting performance more rhythmically rigid and/or challenging to play for the quartet.

The strategy of following here affords increased personal interpretation since the events in the electronics are all based on the quartet. However, the compositional aspects of the section are very precise. This variance between flexibility and preciseness is one the most interesting aspects of *Tensio* (2010). It is not the first piece to vary between types of times, but I believe Manoury achieves a level of flexibility that is highly challenging to do without following. The gesture of shifting between the two times, both in performance and electronics, is an important compositional process for the section. Essentially, it binds the section, and it could not have been composed without testing possibilities in the electronics simultaneously or previously.

5.2.4.5 Closing Words

We have looked at *Tensio's* (2010) use of following and how it ties into Manoury's *écriture*. Although we have few precise details about the compositional process, it would not be surprising that he composed the piece in short periods in-between testing the electronics at IRCAM. This would then make his process similar to the model developed at the end of Chapter III. There is little doubt that the RIMs play a prominent role in helping conceive some of the ideas in the piece as they are so intrinsically linked to the programming (Kaltenecker & Bahier, 2010).

Although Manoury has generally attributed his ideas and concepts to explorations of real-time possibilities in music, it is the strategy of following that actually affords his ideas. Therefore, the importance of Manoury's compositional paradigm and philosophy is about synchronizing the musicians with electronic processes that are not entirely pre-determined. Manoury's music is all about the classical music concert performance happening in real time.

It is virtually impossible to analyze a mixed music piece without having several various recordings to compare. The recordings of this piece still vary significantly because of how they were recorded, where, and how they were mixed and mastered. In this piece, even with the recordings as a reference, several aspects of the piece can only be understood by looking directly at the electronics materials. My analysis of *Tensio* (2010) addresses many of the issues with traditional analyses of mixed music pieces, which are more adequately discussed from an aesthesic point of view. This analysis considers both poiesis and aesthesis, showing how intertwined synchronization strategies are with Manoury's compositional processes, and thus, with the sounding result in performance.

5.3 Jonathan Harvey

Jonathan Harvey (1939-2012) was a British composer of acoustic, mixed and electroacoustic music. He became an important composer in the 1980s with works like *Mortuos Plango, Vivos voco* (1980) and *Bhakti* (1982), created at IRCAM. He was also a vital scholar, having written an extensive early book on Stockhausen (Harvey, 1975) and another book on the sources of inspiration for composers (Harvey, 1965). The influence that spectralism had on his music is well documented, and timbre plays a significant role in his music and electronics (Harvey, 2000).

The reason for including Harvey as a case study is twofold. First, he presents a different view of the role of electronics compared to Manoury. This is an integral part of this thesis to show that synchronization strategies are also an aesthetic choice. Secondly, there is some literature on the composer, and it is not based solely on technical issues. Additionally, much of his music is readily available, which has led his music to be widely performed and discussed. Several of his older pieces have also been ported to modern technology (Coccioli & Bullock, 2005). In notes on a new version of *Bhakti* (1982), synchronization is explicitly mentioned as an essential aspect for having made more fixed media files than before. Many of the ports of the electronics, including the 2018 notes, were done without the composer or after his death.

The pieces *Le Tombeau de Messiaen* (1994), *String Quartet No. 4* (2003) and *Speakings* (2008) will be used as case studies. These three pieces represent three repertoires: solo instruments with electronics, chamber groups with electronics and orchestra with electronics, as discussed in the previous chapter.

5.3.1 Compositional Philosophy

In the 1980s, Harvey described electronics as a kind of surreal:

> *"I have suggested already that the tape represents another world, a world beyond, a world where the rules are different, an irrational world. The tape shows us the mirror of the orchestra…often we hear the same instruments, like the piano, the alto flute and the horn in the extract we heard, but their properties are changed. They can transform themselves, into one another; they can dissolve, becoming noises or definably electronic sounds. It is a magical world. And it seems to me important also that it is an unseen world, since our other unseen musics—the organ in a church where one does not see the organist, the bell that sounds from a tower—also have in our culture the aspect of the irrational"* (Griffiths, 1984, p. 12).

This is a different conception than Manoury, who sees electronics as an extension of the possibilities of instrumental composition. This use of electronics in an otherworldly manner is often heard in Harvey's music. It is also perhaps connected to his views on religion and his experience with both Christianity and Buddhism. Later on, Harvey does seem to have preferred live electronics as it brings both worlds together at once in what he termed a "theatre of transformation" (Harvey, 1999, p. 3).

For Harvey, electronics need to be understood as something that transforms the live experience.[45] Realism or "instrumentality" is not important, and the sound sources are often

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[45] Harvey discusses his views on the discrepancies between recordings and a live concert experience in Donin (2006).

not in the same room or spectromorphologically similar. An example is his use of reverb in *Madonna of Winter and Spring* (1986)—Harvey describes how “time is arrested” and “physically unplayable sound is heard (another world)” (Harvey, 1999, p. 4). He emphasizes how the reverberation is far from realistic. This is Harvey trying to attain transcendence (Felici, 2017).

Harvey’s compositional process has been discussed in the literature. Risset (2008) uses Harvey as an example of a composer that will often create the electronics after having entirely written a composition. This is probably an exaggeration, and moreover Risset seems to infer that composing the tape part after the score is inherently inferior. In contrast, Harvey sees electronics as adding colours. Tiffon (2005) classified both composers on the opposite ends of the possibilities of *écriture* in mixed music. We must analyze Harvey’s process from his point of view and skills. Faia (2014) shows that he was not a technology-savvy composer. Therefore, it was difficult for Harvey to work on the electronics at the same time as instrumental composition—he was dependant on residencies, such as at IRCAM, to have a RIM to help him with the electronics.

Additionally, Risset’s comment seems not to be accurate. The composer’s work process with Faia and Nouno seems to start with the written composition then the electronics, but this is not always the case (Faia, 2014; Harvey, 2008; Zattra, 2008). From these three sources, it is clear that the process was more nuanced. Although some compositions were written beforehand, many elements changed while working with the RIM. This often included working with the RIMs several times, between which Harvey would either continue to write the score or edit it. The conception of Harvey’s pieces perhaps does not inherently include electronics; however, they are still a central part of his artistic vision.

5.3.2 Le Tombeau de Messiaen (1994)

The first case study is *Le Tombeau de Messiaen* (1994) for piano and fixed media. The fixed media is a single track that plays throughout the piece. The notation includes approximate notation of the electronics' pitches to help the musician orientate themselves while playing the piece. Philip Mead, who premiered the piece, refers to it as a composition "in and out of exactitude" (Mead, 2013). This concept is vital to its synchronization and its structure. For example, the form of a *tombeau* (meaning tomb in French) is invoked in the title. However, Harvey is also referring phonetically to *tomber*, which means falling (Mead, 2013). This act of falling is an important gesture in the piece. Additionally, the electronics are based on electronic pianos tuned to the harmonic series—this results in a clash of tuning system between the physical and electronic piano (Mead, 2013).

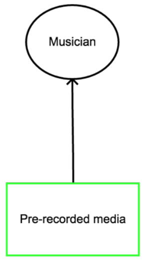

Figure 29. Synchronization in Le Tombeau de Messiaen (1994).

This exactitude aspect is relevant to synchronization because there is a single fixed media file without a click track. The piece's musicality does not demand that the performer is perfectly in time. The electronic and acoustic piano will come in and out of perfect sync, adding colour to the acoustic piano through the electronics. It is probably impossible for the performer to be perfectly in sync with the electronics, which is considered within the piece's *écriture*. All timings in this section refer to the recording by Phillip Mead (1999).

5.3.2.1 Example I – The Falling Gesture

Figure 30 shows an example of this moving in and out of sync. Mead (2013) asserts that this figure, in which the pianist's hands always have dynamics moving in contrary motion, is an important example of this gesture. The use of the pedal begins to obscure the chords, gradually making the composition more about timbre and colour (Mead, 2013). Additionally, this is always against the background of the chord in the electronics, which creates an interesting timbral effect that sounds almost otherworldly.

This gesture comes back several times in the piece. On the fourth page (at 01:40), the electronics are included in the gesture and move downwards with the pianist. The rhythms are simple, but due to the pianissimo dynamics, it is possible that the pianist will not hear the fixed media part, which might influence the synchronization between both. In later instances of the gesture, such as on pages 7-9, the electronics are rhythmically more complicated, making it difficult for the performer to play perfectly in sync. However, this is part of Harvey's aesthetics. Pivot points throughout the composition allow the performer to realign themselves with the fixed media. It also gives the possibility of a slightly more rubato feel in how the performer plays.

Figure 30. Systems 1-2 of Le Tombeau de Messiaen (1994, p. 2) 00:56 – 01:10

We cannot know how much this was planned beforehand without detailed information about the piece's compositional process. Even though the electronics were probably created afterwards, it does not mean that they were not an essential element in Harvey's compositional process. I believe that this "in and out" was already an element of Harvey's writing, therefore similarly, making the electronics was both an aesthetic choice and a pragmatic affordance for the performer. This order of events means that Harvey possibly could not test his ideas, meaning that several affordances and choices had to be made early in the process compared to the model proposed in Chapter III. The technological possibilities of the time (such as real-time) were not explored in this work, possibly for pragmatic reasons.

5.3.2.2 Closing Words

Le Tombeau de Messiaen (1994) is a good case study because it shows how fixed media pieces can also be composed with synchronization strategies at the heart of its elaboration. There is no doubt that Harvey was concerned with how the musician would be synchronized. This afforded many aspects of the composition as well as the electronics. Additionally, despite having no click tracks, the piece is relatively easy for the pianist to navigate.

5.3.3 String Quartet No. 4 (2003)

Harvey's *String Quartet No. 4* (2003) was created with Gilbert Nouno as RIM. The piece features an amplified string quartet, and there are six to eight speakers around the audience. Many of the treatments found in this piece, which Nouno presented to Harvey, also found their way into his later opera *Wagner Dream* (2007) (Harvey, 2008). This includes harmonization, time-stretching, granulation, amplitude modulation, and ring modulation. In the program notes, Harvey marks the importance of cycles in this composition. These can be heard in the structure but also in how he has worked with spatialization. The instruments' amplification is used to highlight sounds that are usually inaudible in concert performance.

Unlike the previous piece and much of his earlier repertoire, *String Quartet No. 4* (2003) features live electronics as its primary electroacoustic paradigm. The main synchronization strategy is the use of cues. The synchronization layers of the work can be seen in Figure 31. The RIM is present in this figure as the score indicates this role explicitly, instead of giving a MIDI pedal to the performers. I have not found any particular reason for this choice, as most of the cues could be relatively easily triggered by one of the musicians.

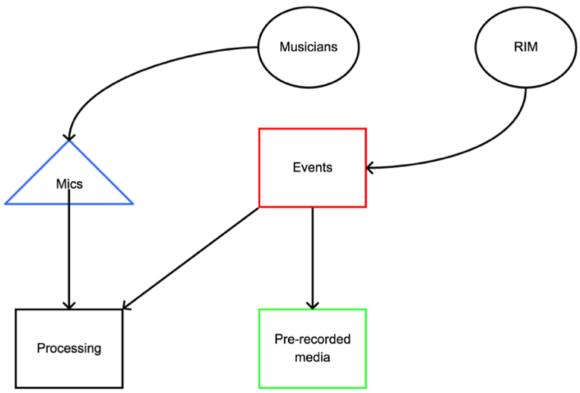

Figure 31. Synchronization in String Quartet No. 4 (2003).

Seo (2013) reveals that one of the initial activities in the composition of this work was Harvey and Nouno applying electronic processes to existing string quartets. This experiment was an essential aspect for Harvey as it reinforced the concept of blurring (Cross et al., 2004). It also reinforces the composition's place within a repertoire in the sense that he is writing within an established tradition that he is basing his work on. Seo (2013) reinforces the idea that Harvey is composing separately from the electronics, but this seems slightly incorrect. Nouno and other RIMs have given him composition tools over the years, which Harvey has used a lot when composing, as detailed in Faia (2014). He actively used Max/MSP patches by

Nouno to find the sounds he likes and what he wanted compositionally (Harvey, 2008). Additionally, after so many years of working with electronics, he probably attained at least a basic understanding of synchronization and composing with it.

Two examples of the relationship between the synchronization of the piece and its composition will be given. Many of these examples come back throughout the piece, primarily because it is written cyclically (Clarke, Dufeu & Manning, 2020). For a complete analysis of the piece, see Clarke, Dufeu & Manning (2020) and Seo (2013). I have not had access to the electronics for this piece, and there is little direct literature on their technical aspects. Therefore, these observations are made from listening to several recordings, the score and the information available from the few sources on this piece. All timing references refer to Arditti Quartet (2009).

5.3.3.1 Example I – Cycles & Layers

The first example is the conception of layers which evolve with each cycle. Harvey explained how the spatialization loops and the granulation are separate layers (Cross et al., 2004). Together, these elements form a slightly heterogeneous time with variations between striated and amorphous times, creating a slight tension. Variations between striated and amorphous time within the acoustic writing may also give the impression that the electronics are shifting towards a more active role. An example of synchronization between spatialization and the quartet can be heard at the start of the piece.

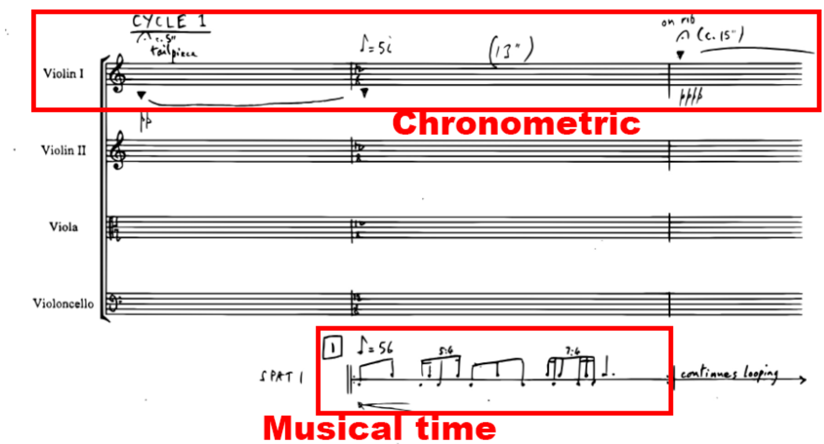

Figure 32. Time in systems 1-2 of Harvey's String Quartet No. 4 (2003).

As we can see, at event one in Figure 32, the electronics have a striated rhythm, which loops while the first violin is in amorphous time. The electronics are taking an amorphous acoustic gesture and spatializing it with a striated rhythm. Pitch, rhythm and timbre are disconnected from their causal relationship with the musicians. The first violin might not be perfectly synchronized between events one and two because of the variations between chronometric and musical time. This use of cues and looping is a compositional gesture that will continue throughout the piece. At first, the listener believes that the quartet and electronics will be synchronized, but there is a sharp division between both due to their asynchronicity, which establishes that these are separate layers. This separation is further explored in the composition with the electronics on page 21, where the two layers are in distinct tempi. The use of cues as a distinct and separate synchronization process works well for both the composition and the performance practice of the work.

I argue that of structural and dramaturgical importance of the layering means that the electronics and acoustic writing were tightly connected throughout the compositional process. I believe that this is one of the aspects Harvey discussed early on with Nouno on how to include it within the *écriture* and the electronics. This superimposition of rhythms between both sound worlds can give several challenges if both have to be perfectly synchronized. However, Harvey's aesthetics and conception of layers afford a less strict synchronization. The lack of precision at the start of the piece already primes the listener to accept having distinct layers with different tempi. The rhythms in the spatialized electronics are the same as the melodic rhythms throughout the piece (Clarke, Dufeu & Manning, 2020). The piece has many similar formal links between the electronics and *écriture* of the piece. Although it is difficult for a listener to perceive these links, they still play an important role within the compositional process.

5.3.3.2 Example II – Live Sampling

Another example of synchronization strategies in Harvey's *String Quartet no. 4* (2003) is the use of live buffers throughout the composition. These are not perfectly coordinated with musical events, rather, this extra layer "blurs" the music, which Harvey relates to the idea of Buddhist karma (Cross et al., 2004). At event seven, as shown in Figure 33, it is not so important which exact pitch the recording starts or ends on as the action of recording is done in chronometric time instead of relative time. The buffer is used for granulation, which blurs the gesture. This blurring with a chronometric buffer reinforces the independence between the layers, yet there is still a coherence and relation between them. If the buffer starts or ends too early or too late, the gesture's general shape is still present. The electronics are taking a musical figure and turning it into a gesture in another time and scale.

Figure 33. System 1 on page 4, String Quartet No. 4 (2003) – 03:55 – 04:14.

Previously, I mentioned how Harvey and Nouno had processed recordings of older string quartets. I believe that this practice is what lead them to using live sampling that would then be granulated. This prevents copyright and pastiche issues, but it also reinforces the live aspects and otherworldliness that Harvey strives for. It also fits within his layering concept from the first example. Harvey was probably not aware of precisely what would be recorded and how it would be granulated. However, he knew where he wanted musical gestures to be blurred together between the otherworldly and the worldly. Many of the cues also fall in natural places where a gesture starts or ends, which leads me to believe Harvey planned them. Therefore, this is also an example of how complex relationships between composition, electronics and synchronization can be.

5.3.3.3 Closing Words

This string quartet brings an interesting dimension to the affordances between synchronization strategies and composition. The synchronization here is mostly included in more abstract terms within the compositional rules Harvey set for himself while writing the piece. It is possible that Nouno had to place every cue in the piece. However, I think that Harvey's *écriture* - especially his use of layers and clear gestures – lends itself well to use cues. These more abstract and complex links are perhaps less explicit than some of the other examples in this chapter, but it shows how inherently related composition and synchronization are, however subtle they may be perceptually.

5.3.4 Speakings (2008)

Speakings (2008) is one of the last large works Jonathan Harvey composed, for large orchestra and electronics. It was released commercially, making it easier to analyze (BBC Scottish Orchestra, 2010). In the program notes, Harvey emphasizes how this piece is about "the purification of body, mind and speech." Human speech and orchestral textures as intertwined with live processing. The RIMs were Grégoire Carpentier, Arshia Cont and Gilbert Nouno.

This is the first and only piece by Harvey that uses Antescofo. However, Harvey did not use the score following possibilities of the program. The primary synchronization strategy is cues. Antescofo here is used as a code repository but also to detect the tempo of the orchestra. Nouno et al. (2009) goes in-depth into the processes used to create the samples and analyze formant information used extensively in the piece's composition. The synchronization is done using a MIDI keyboard by a musician following the orchestra's conductor, much like Murail discussed in Chapter IV. Human following is an important performance technique here as it affords temporal flexibility for the conductor. Additionally, a touchpad has been used to allow the RIM to do more live mixing. The synchronization layers can be seen in Figure 34.

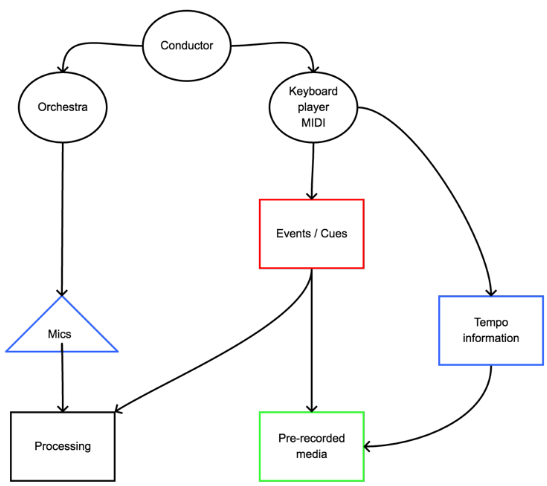

Figure 34. Synchronization in Speakings (2008).

We will look at two examples of the relationship between the piece's compositional processes and synchronization strategies. All timings given refer specifically to the previously referenced recording of the piece.

5.3.4.1 Example I – Samples

Right before the 02:00 mark in the first movement, one hears a baby screaming as the string section plays a tremolo figure. The keyboard player presses a key that will trigger this five-second-long sample. The marked tempo is 120 bpm, but there is no click track, which means that the orchestra is not precisely at 120 bpm. As Nouno et al. (2009) described, all samples use the SuperVP algorithm, which allows them to be realigned subtly. At 120 bpm, a five-second sample takes up ten beats. If the orchestra's tempo is slower, the sample is stretched to start and end in the same position. In most other pieces, samples start at a specific point in time, but the endpoint is not controlled.

This stretching is more complex in the second movement—at rehearsal letter Q (from 11:05)[46] with a sample called the “GOC_sample.” A phrase from T.S. Eliot’s *A Game of Chess* (1922) is uttered in this sample as shown in Figure 35. The poem must be strictly synchronized with the orchestra; therefore, the keyboard player is given a strict rhythm to follow, allowing the voice to be intelligible. This permits a tighter temporal link between the instrumental lines and the electronics.

I believe the use of cues as a synchronization strategy is mostly pragmatic. It is clear that Harvey wanted the samples to be perfectly in sync with the ensemble since every utterance in the sample is synced. However, the use of human following allows the electronics to sync with the conductor without any of the logistic issues that score following would have entailed. There is less possibility for error with this combination of strategies. I also believe this is the case because the samples used throughout the piece become another instrument. Their semantic meaning is not important to the piece as they are not mentioned in any program notes or information about the piece, including Nouno et al. (2009).

[46] On the recording referenced, one cannot hear these samples audibly but the section starts at this point. Details of the electronics are only available on the score with the Max/MSP patch, not on Nkoda.

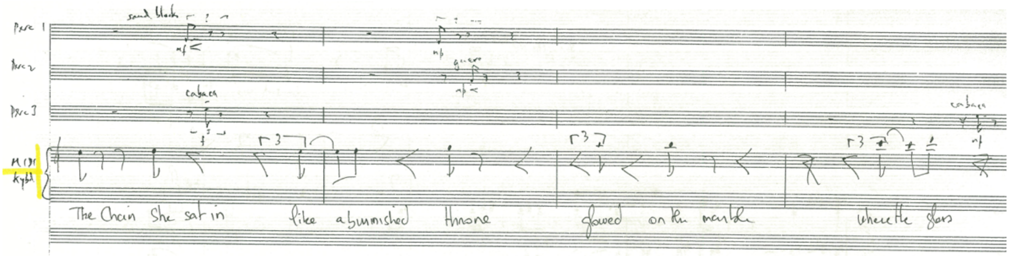

Figure 35. Game of Chess quote in Speakings (2008, p. 48)

5.3.4.2 Example II – Live Processing

The last example is the triggering of live processing. At the start of the second movement, most of the orchestra's signal is sent to formant processing (details on this can be read in Nouno et al., 2009), as shown in Figure 36.[47] The processing is not a time-based effect that is blurring the music.[48] The interesting aspect here is the use of the keyboard player to trigger these. Although it is impossible to see in Figure 36, the keyboard player cues this processing an eighth note in advance, letting enough time for the matrix to open smoothly. The orchestra is then sent to the formant processing as its texture thickens, adding an extra layer to the crescendo.

The use of cues here is crucial for live processing, which could quickly result in feedback if not careful. Timing can also be challenging. The use of the keyboard player solves most timing issues; it also allows the RIM to have more time to mix. With such significant forces, the amplitude of each amplified instrument can quickly overpower everything else. It is also easier for the keyboard player to follow the conductor than the RIM, affording relatively quick changes. Together, these two elements create more flexibility, which allowed Harvey to use to great effect live processing throughout the piece, both with formant processing and granular synthesis.

[47] Note: the handwritten score includes very soft strings, but in the recording of the piece, I do not hear them at all. The oboe is playing a solo before the processed tutti comes in. Therefore I assume that the recording of the piece is based on an edited version of the score, which is not available through Nkoda.

[48] Technically, the effect does have a delay due to the processing speed and vector size. By this I mean that there is little to no delay between what we hear and the effect. This delay also plays a role in a live context because of the time difference between when the orchestra's sound hits our ears compared to sound from the speakers.

Figure 36. Formant processing at the start of the second movement, Speakings (2008, p. 24) – 00:00 to 00:09.

5.3.4.3 Closing Words

Speakings (2008) is an ambitious, mature piece in Harvey's oeuvre. The conception of the piece is tightly connected with its use of electronics and synchronization. Although no source specifically mentions at what point synchronization strategies were worked on in the piece, the involvement of Arshia Cont suggests that Antescofo was involved early. This was still an early piece for the programming language, and it is understandable that the RIMs and composer did not take full advantage of the possibilities of the program. A more in-depth analysis of this composition would be exciting and could explore interesting aspects, such as the use of literature by T.S. Elliot and Jon Fosse in the work.

Although Harvey's aesthetics are different from Manoury's and often embrace deferred time, the importance of synchronization strategies is still pronounced in his work.

The influence of Buddhist thought and other Eastern philosophies make his music embrace a sense of flexibility. Harvey is an intriguing case because he is not a technician, by his own admission, yet his style is relatively consistent even when switching between various RIMs. His work with these RIMs is also well documented, but few analyses have gone in-depth into Harvey's use of electronics. There is no doubt that the RIMs he has worked with heavily influenced his *écriture*. His late music shows how he has often internalized that help to build his compositions. Although little of the literature directly addresses synchronization in Harvey's work, his use of synchronization strategies is often connected to the piece's aesthetics and extra-musical influences.

5.4 Hans Tutschku

Hans Tutschku (b. 1966) is a German composer who teaches composition at Harvard University. His music has been getting more attention within scholarly circles in recent years from a compositional and performative angle (Berweck 2012; Dufeu & Bonardi, 2014; Emmerson, 2016; Pestova, 2008; 2018, among others). The reason for including Tutschku as a case study is his focus on pragmatism. Tutschku wants his music not to be problematic for performers. This wish has deeply affected his *écriture* and its use of synchronization strategies and performance techniques.

Four pieces will be explored in this section: three works which are part of the *Still Air* series (2013-2014) and the string quartet *Behind the Light* (2011). Additionally, Chapter VI is a complete analysis of his piece *Zellen-Linien* (2007), which will show how much affordance synchronization, electronics, and performance have on a piece.

5.4.1 Still Air Series (2013-2014)

Still Air (2013-2014) is a series of three pieces written between 2013 and 2014 for wind instruments and electronics. Tutschku's program notes describes the series as: "As a stark contrast to many of my other compositions which explore speed and density, this cycle is meant to search for musical expression with very little activity". The series includes the following pieces:

- *Still Air* (2013) for bass clarinet and electronics
- *Still Air 2* (2014) for oboe and electronics
- *Still Air 3* (2014) for oboe, bass clarinet and four channel electronics

The third piece in the series is both previous pieces played together simultaneously with each performer having their own electronics. The electronics are fixed media controlled by an iPad or iPhone. Tutschku made a software application that can be bought for each piece. The application permits the musician to practice from home without needing a technician or any expensive equipment.[49] Tutschku (2014) argues that the normal situation gives the musician too few possibilities to rehearse with the electronics, making it impossible to integrate them into their musical flow. This also permits the musicians to be self-sufficient, an aspect explored more in Chapter VII. Although this application required to create a new environment for mobile use, it creates ease of use that is difficult to match for others. The standard in mixed music is still PD or Max/MSP (Dudas, 2015).

The primary synchronization strategy in these pieces is cues that trigger fixed media by using a MIDI (or Bluetooth) pedal. Additionally, the iPad's built-in microphone is used to analyze amplitude (Tutschku, 2014). The amplitude detected by the device then influences the amplitude and the pitch of sound files. Tutschku (2014) calls this a form of modulation on pre-composed sound files, further explaining that it sounds like live processing, but uses a more straightforward means. This creates a gestural link between the electronics and the musician. The hierarchy of synchronization in the work can be seen in Figure 37. Since there is no technician in these pieces, it is worth noting that the musician's perception of the electronics is only through monitoring and visual feedback from the app.

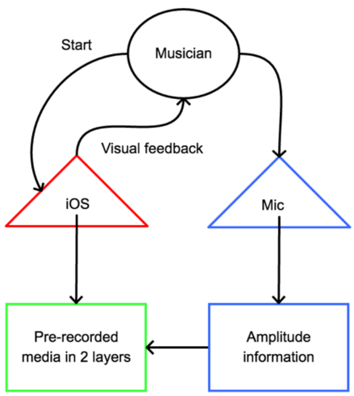

Figure 37. Synchronization hierarchy in Still Air (2013)

[49] One could argue that an iPad is a relatively expensive piece of equipment. However, the costs are still much lower than a good microphone, a sound card, and a laptop put together. Additionally, it's more likely for a musician to own an iPad than professional sound equipment.

The synchronization and conception of electronics are deeply embedded in the pieces in the *Still Air* series. Tutschku's idea of having gestural links with little activity from the performer limited his compositional possibilities. The acoustic writing could not be too rhythmic and had to retain strong gestural links with relatively simple fixed media. Secondly, in *Still Air 2* and *Still Air 3* (2014), the form is set in stone. Cues in the electronics need to be at the same position for the same duration. The third piece will be the main focus of this section. All references are to the video on Tutschku's website from the piece's by Sato & Acierto (2014).

5.4.1.1 Example I – Events Three to Six

The interplay between synchronization strategies and composition can be seen at events three and five. Most of the *écriture* in the piece is relatively amorphous with a few exceptions, such as the bass clarinet at event three and both instruments at event five. The use of amorphous time is likely due to the affordances of cues and not having an extra engineer. This type of time makes it easier for the musician to follow the cues without temporal discrepancies. At the third event, the first layer of the triggered sound files for the bass clarinet is a pad-like sound. The amplitude modulated layer is a noisy texture. As the bass clarinetist plays the striated figure, this layer is triggered rhythmically, creating the illusion of synchronization. This can be heard around 01:36.

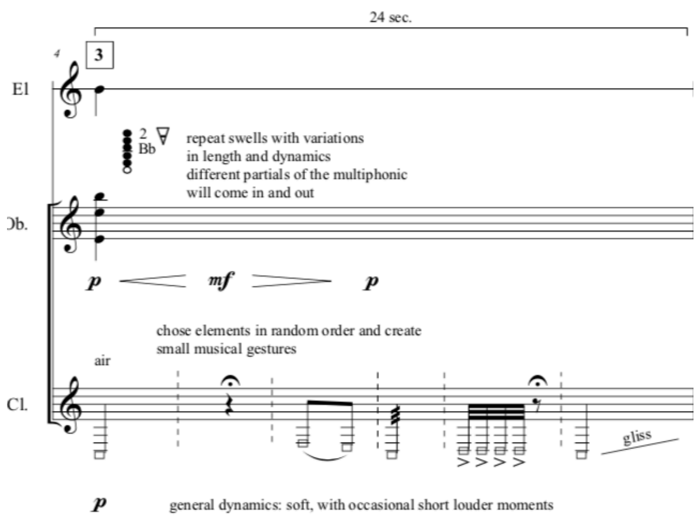

Figure 38. Event 3, Tutschku's Still Air 3 (2014) – 01:36-02:00.

In event five, both instruments are more free. The event's length is 54 seconds, in which time both instruments must first play all of the written gestures in both instruments, and then they may replay these gestures in any order with short rests. The length of the phrases are the same at first, but the striated end of each instrument's event is of a different length. These are identified in the Figure 38 as A and B. Both instruments will not be synchronized towards the end of the event, making the music sound increasingly chaotic. The bass clarinet's electronic part consists of manipulated sounds from the instrument which are panned. The modulated fixed media is a modified breathing sound from the bass clarinet. The oboe's fixed media file is manipulated breathing and multiphonic sounds and the amplitude modulated layer is a sound file of an Eb4 on the oboe. This can be heard from 00:02:37.

Both instrumentalists' playing will come back together as a pivot point with event six, which starts mostly amorphous but with slight variations in timbre and amplitude. The slight crescendo in the fixed media part of the bass clarinet at the end of event five reinforces the pivot point and how both instruments' rhythms come back together.

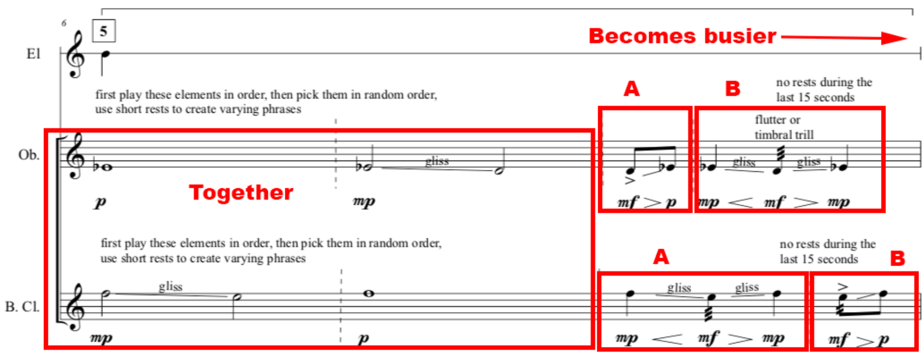

Figure 39. Event 5, Tutschku's Still Air 3 (2014) – 02:37-03:33.

In both sections (events 3-4 and 5-6), one has the impression of the instruments and electronics being together. Afterward, they start to sound more independent, but they are nevertheless following a rigorous timeline. This type of material is Tutschku's way of not falling into only using typical gestures and creating more tension in his piece. This is a difference between the compositional aspects and how the audience perceives them. Tutschku is also using the concepts of fusion and fission between various sound objects.

Due to the strict timing limits for each event, the piece's composition was probably highly organized. The timings could not be changed in *Still Air 2* (2014). Additionally, Tutschku had to work with both instruments' fixed media having modulations that would make musical sense together. This must have required significant trial and error to achieve the proper balance.

5.4.1.2 Example II – Events Sixteen to Eighteen

In this section, three events happen while the instrumentalists play the same material, as shown in Figure 40. The bass clarinet's fixed sound file is a multiphonic-like texture, while the oboe's file has a drone. These evolve relatively little throughout the three events. The oboe's modulation is the amplitude of a tone with a slightly rhythmical envelope directly correlated with the amplitude detected from the iOS device. The modulation for the bass clarinet is more diverse. The instrument's amplitude triggers a single tone in event 16, with each event adding more tones to the resulting chord.

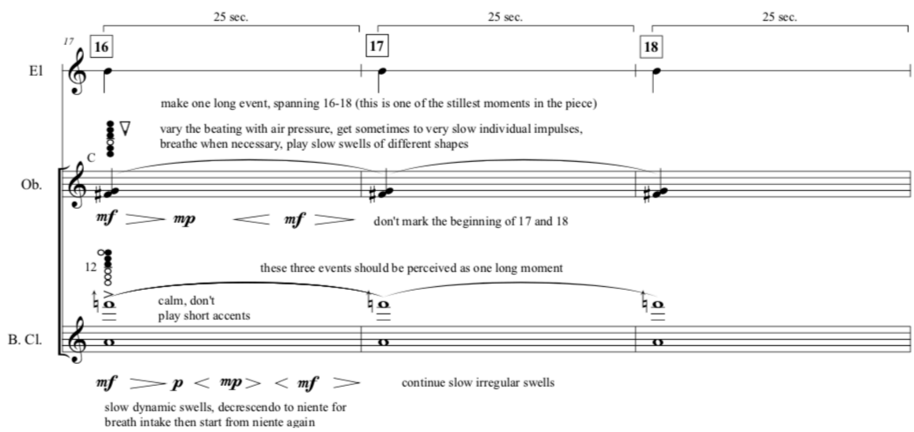

Figure 40. Events 16-18, Still Air 3 (2014) – 07:38-08:53.

The interesting aspect here is how Tutschku tries to give a more active role to the electronics through the use of layering. The acoustic writing in each piece is generally less active than in most other works discussed in this thesis. However, even in the somewhat calm acoustic writing, Tutschku attempts to shift musical roles without changing the synchronization strategy. Shifting cues within a single musical gesture creates the impression that the electronics take the lead. He accentuates this by having modulations in the events tightly connected to the performers, which gives the perceptual illusion of agency. This section's composition is probably influenced by its restrictions not only in the form but by the possibilities of what type of activity can be triggered within a single gesture.

5.4.1.3 Closing Words

The compositional constraints the composer put on himself for the sake of pragmatism make these pieces an exciting study in simple and effective strategies for connecting instrumental gestures to electronics. These three pieces feature none of the complex concepts compositions by Manoury or Harvey, yet they reach an effective use of technology and are much easier to perform with the electronics. I consider the two first pieces of this series to be essential pedagogical pieces to introduce musicians to mixed music. Additionally, these pieces are a good example of fixed media's flexibility within a more modern repertoire. The use of modulation also allows the electronics to take a more musically active role. Each cue essentially acts as a pivot point to synchronize between both worlds.

5.4.2 Behind the Light (2011)

Behind the Light (2011) is Tutschku's only string quartet. Like the *Still Air* (2013-2014) series, it features the use of an iOS app for the electronics. This piece is also interesting as Tutschku has changed certain aspects of the synchronization strategies since its conception. Specifically, the quartet's and electronics' alignment has changed.[50] This change has also been described as better synchronization by Tutschku (2014).

Behind the Light (2011) was the second piece Tutschku worked on with an iOS device. The electronics are mainly sound files that are triggered. Initially, these were automatically triggered by the iOS application. Synchronization thus happened by visual feedback from the iOS app to the first violin player. They then assume the role of the timekeeper for the ensemble. In the score, durations are notated for each event and visually marked in the iOS application. The sound files are short, processed and manipulated sequences recorded in the studio with the Chiara Quartet. Much like the *Still Air* series, the electronics are easy to set up and meant to be done without a sound technician's support. This piece also features an interesting development regarding synchronization strategies and their affordances. Tutschku explains that he opted for visual feedback because Bluetooth foot pedals did not exist at that point.[51] This lack of performer input created a challenge that had to addressed in the piece's *écriture*. The hierarchy of synchronization strategies for the work is shown in Figure 41.

[50] Private e-mail correspondence, 19 July 2018. Exactly how and when it was changed has not been mentioned.
[51] Private e-mail correspondence, 4 September 2018.

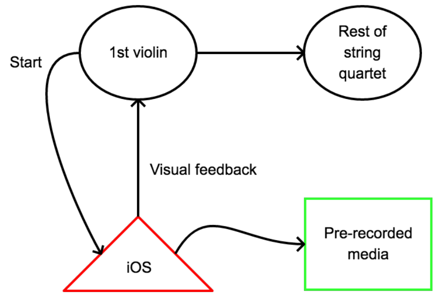

Figure 41. Synchronization hierarchy in Behind the Light (2011).

5.4.2.1 Example I – From Gesture to Structure

The piece is organized into short sequences with a total of 66 events in the electronics. Many of these sequences start with a tutti Bartók pizzicato in a 1/8 measure, which has several functions within the piece. The first function is as an essential musical material that shows the structure of the piece. This structural idea comes back later in the piece, such as at events 34, 57, 58, and 59. The second has to do with the synchronization—the gesture of the first violinist preparing for a Bartók pizzicato is a clear sign to the rest of the quartet of where they are, allowing them to synchronize together. The first violin is the only member with access to the visual feedback of the app, and thus leads the pivot points for the ensemble.

For the first five events, there is a Bartók pizzicato gesture from the quartet. Electronics also augment this gesture. Every event starts with a series of pizzicati, while there is a texture created from processing the quartet playing chords in the background. As we hear this five times, our mind starts associating these events together, perhaps perceiving them as a gestalt. The pizzicati do not start the sixth event, but we still have the textures becoming more processed. Tutschku starts a simple musical gesture in which he will then slowly shift parameters as the piece continues to unfold. I argue that Tutschku is purposefully trying to fool the listener into thinking that the fixed media is being recorded live. For example, at the end of the second event, we once again have the Bartók pizzicato gesture followed by a series of double stops. This tutti double stop is the texture we will then hear processed in the fixed media. Tutschku is actively playing with our expectations of what can be live and fixed in the electronics as a compositional trick.

5.4.2.2 Example II – The use of Amorphous Time

It is essential to understand how the electronics sound in the piece. The processed sound files are often backdrops in amorphous time, while the quartet plays mainly striated and sometimes pulsated time. This allows the performers not to be as concerned if they are not entirely in sync. The visual click track's presence permits the quartet leader also to get them back on track with the electronics, if needed. There is an inherent deviation tolerance in the electronics.

Often the start of the cue is more rhythmic as in cues six and seven. These amplify the Bartók pizzicato gestures. Afterwards, the electronics tend to be amorphous, adding texture and colour. These cues are a perfect example of a pivot point. Being synced at the start is essential, but afterwards is less important. In sections where the string writing is already amorphous, the electronics also assume this type of musical time to make it easier to play, such as in events 63- 65. In many sections, the start of musical gestures makes it easy for the quartet to synchronize themselves.

The use of a visual click track and fixed media have clear affordances on the piece. I argue that the use of these gestures and of amorphous time is a result of the synchronization strategy used by Tutschku. The gestures and use of the click track allow a relatively tight synchronization between all involved parties, allowing Tutschku to develop these parameters compositionally.

5.4.2.3 Closing Words

It is important to understand that Tutschku has structured his whole piece and its aesthetics around synchronization strategies that are easy for the musicians to understand and set up. *Behind the Light* (2011) is a rare piece of mixed music in how it is for an ensemble, yet the score and electronics are widely available. Using barebones technology, mostly when an interaction between performers and iOS, was complex, makes this composition an essential study for the thesis's goals. Tutschku manages to use the limits of the technology in a way that serves his aesthetics. In this piece, he also actively uses the tropes of electronics in mixed music to form clear gestures, which he then deconstructs.

Tutschku's music is an interesting case study because he has considered pragmatism and ease of setting up as essential issues in the last fifteen years. Through his self-chosen constraints on how easy the electronics have to be, he still manages to create exciting works that are often performed. Because he has written and discussed his pragmatism often, he seems to be the ideal case study for this aspect of synchronization strategies. These explicit constraints also make the affordances easier to see. Despite often using fixed media, he tries to create the illusion of agency. In Croft's (2007) system described in Chapter II, Tutschku is generally between the augmented instrument and responsorial paradigms. He concentrates his compositional processes and parameters around these two paradigms and tries to exploit all the affordances surrounding them. Additionally, we will be taking a more in-depth look with a complete analysis of Tutschku's piece *Zellen-Linien* (2007) in Chapter VI.

5.5 Conclusion

This chapter has focused on three composers to examine the affordances between compositional processes and synchronization strategies. Manoury, Harvey and Tutschku come from varied compositional backgrounds and schools of thought, which shows how far-reaching the affordances of synchronization strategies are. With Manoury, we looked at how the synchronization, electronics, performance and score together form his compositional thought. They are difficult to separate as each element, and their complex connections are inherent to his aesthetics. Somewhat more conventionally, Harvey uses electronics to colour his acoustic music. After many years of working with RIMs, his compositional process changed and included the electronics in the compositions' conception. Tutschku's music is inherently related to its use of technology. For him, making the pieces pragmatic is essential, and this has radically changed the use of technology in the compositions we analyzed.

Although we cannot precisely know how each of these composers made each of their works, their methods are likely related to the compositional models shown in chapter. This thesis proposes the model of mixed music composition that includes experimentation with electronics and their synchronization as a vital aspect of the creative process. I believe the examples in Chapters IV and V prove this point.

Although many of these pieces use the same strategies, performance techniques, and technology, these affect the compositions and performers in various ways. The affordances caused by technology and compositional choices are never one to one. These relationships are always complex and almost like an ecosystem. By discussing and analyzing these cases, my goal is that it may become easier to understand how synchronization issues influence mixed music at large.

Part II - Aesthesis

Chapter VI: Analysis of Tutschku's Zellen-Linien (2007)

6.1 Introduction

Zellen-Linien (2007) is a piece for solo piano and live electronics by the German composer Hans Tutschku. The composer gives a translation of the title as *Cells-Lines*. The piece evolved out of Tutschku's improvisations on piano with electronics in the piece *Das Bleierne Klavier* (1999). Other musicians who heard the latter and thought it was a finished piece. Tutschku was asked several times for a score to be able to play it, and this eventually became the through-composed *Zellen-Linien* (2007). Tutschku explains that the piece is based on his interest in making an electronically prepared piano (Tutschku, 2015).

I am analyzing this work because Tutschku is one of the few composers that discusses synchronization in mixed music. He has been open about his use of electronics and has specifically tried to approach electronics and issues of synchronization pragmatically. Tutschku has been vocal concerning the need for the performer to be able to rehearse properly with the electronics beforehand. The materials of the work are also accessible for analysis—the score and electronics are widely available, and there are several performances online hosted by the composer. The availability of these recordings makes it easier for other people to analyze and listen to the piece, therefore adding to the critical discourse of Tutschku's music and mixed music and contemporary music in general.

Zellen-Linien (2007) is also interesting in how it blends contemporary *écriture* and live processing to form a coherent whole. The work showcases several compositional possibilities in combination with electronics. Tutschku's use of synchronization strategies and their implementation is elegant and straightforward, making it possible to understand and appreciate for a non-expert audience, yet also detailed enough to satisfy an expert audience.

There is also an existing analysis of the work by Emmerson (2016) in the literature, giving a starting point in the literature to discuss the analysis and interpretation of the piece. Emmerson's analysis is based on a non-expert listener's experience, and therefore he does not explore the piece's poiesis much. As mentioned earlier in this thesis, I argue a combination of poeietic and aesthesic analysis can help us to better understand the work at hand. Emmerson's analysis uses the timings are based on Pestova's (2008) recording, which are slightly shorter than the Berweck (2011) recording on Tutschku's old website.

Throughout this analysis, my goal is to give a balanced perspective on *Zellen-Linien* (2007) through a balance of poietical, and aesthetical examination. Emmerson's (2016) analysis will be used to compare and contrast. Berweck (2012) and Pestova (2008) have also written about this piece, and their thoughts as performers will be taken into account.

Timings of events and structural sections of the work can be seen in Table 15 &Table 16 respectively.

6.2 Score & Electronics

The availability of mixed music scores can be an issue as many of them are not available from publishers or are prohibitively expensive. Certain publishers also ask for an additional amount of money for access to the electronics. The score for this piece is relatively affordable and the electronics are available for free as an application, which means that it is unnecessary to have a license from Cycling 74 to use the electronics. Once again, this permits for a broader and non-expert dissemination of the work. The score includes an in-depth explanation of how to use the electronics for the performer. It permits the musician to rehearse the piece at home relatively easily, therefore giving a better result instead of including the electronics at the last moment before performance, which is discussed more in Chapter VII.

Tutschku's notation is clear, precise and legible without too much information for the performer. What the performer needs to do to control the electronics is also clearly notated. Emmerson (2016) notes how precise the notation is. He argues this could lead to the piece being performed more because it avoids significant rhythmic complexity as in Ferneyhough's *écriture* and also does not suffer from lack of information about electronics in the score, as in Manoury's *Jupiter* (1987).

The electronics include the following modules and functions, which will be discussed throughout this analysis:

- Samples
- Spatialization
- Freeze
- Granular synthesis
- Delay
- A system called *hin-her*[52]

[52] German for "here and there".

6.3 Performances

One of the exciting aspects of this piece is the numerous available recordings. This analysis is based on four separate performances: two performances (2008 and 2018) at Rosza Center by Xenia Pestova, a 2011 performance at Piano+ Festival by Sebastian Berweck, and a 2010 performance by Franck Gutschmidt at Festival Tage Neuer Musik Weimar. Any time references in the text are from the Gutschmidt (2010) recording unless otherwise indicated. These multiple interpretations allow one to evaluate the contributions of the individual performers to the work, particularly regarding the details of performance practice, the interactivity with the electronics, and the possibilities inherent in how Tutschku programmed the electronics. This permits an analyst to go more in-depth when it comes to the electronics' temporal possibilities.

Emmerson (2016) mentions how interaction plays an essential role in the piece, but he does not mention interpretive and performative discrepancies between the Pestova recording from 2008 and the Berweck recording from 2011 despite his analysis being based on aesthesis.

An example of interpretive differences can be heard at mm. 8-10 between Pestova (2008) and Berweck (2011). The latter does not play the repeated E3s in measure eight, which effectively does not mirror the chord in the electronics at m.10. Each recording has its quirks, which also shows how these performers have internalized Tutschku's music in a personal manner. Overall, these various interpretations illustrate how Tutschku's electronics function well in performance.

6.4 Samples

The samples used in the piece are organized into fourteen *klangfamilie* (sound families). Notably, family numbers 6 and 16 are not used in the Max/MSP patch from 2018. In some events, samples' parameters are randomized—playback start point and sample selection—but these are always triggered through a gesture from the performer. Each performance can be different because the composer added a slight element of randomness. The envelope follower triggers the samples. There are seven variables that Tutschku changes during the whole piece, which influences how these samples are triggered.

Klangfamilie 1 are piano chords that are processed. One can still hear the attack and most pitches of the chord. Sounds are stretched and reversed.

Klangfamilie 2 are slightly percussive prepared piano sounds on various pitches. Because of the name of the file, including “Geld”, which means money in German, this implies that the samples were recorded with coins on piano strings.

Klangfamilie 3 can be organized into three groups. The first one is clear harmonics from a piano chord. The second is the sound of a piano being knocked on, which is called “res”. The third group is prepared piano samples with cardboard.

Klangfamilie 4 are samples based on Chinese percussion. Some samples are processed on them, often accenting resonances and overtones.

Klangfamilie 5 are short, percussion piano runs.

Klangfamilie 6 (which is not used) is called kitchen sink. One hears several percussive samples and strings resonating.

Klangfamilie 7 are samples that sound like they are being stretched. All the samples are heavily processed, but most of them are related to a piano. They vary from tonal sounds to slightly percussive. These are based on motives in the piece.

Klangfamilie 8 are heavily processed samples that are somewhat inharmonic.

Klangfamilie 9 is composed of three upward-moving piano gestures. These are taken from mm. 269-271.

Klangfamilie 10 is once again composed of heavily processed samples that give a sense of movement. The melodic elements are derived from motives.

Klangfamilie 11 is mainly composed of short “stinger” sounds. It also includes sounds derived from orchestral recordings that are heavily processed (and probably resynthesized). All of these samples are inharmonic.

Klangfamilie 12 are prepared piano sounds. This time the piano is prepared with glass, which heavily accents the overtones of the piano strings.

Klangfamilie 13 is composed of three groups. Some of the samples are from grinding glass on the piano strings. A more extended sample is processed and gives some movement when it is triggered and sounds inharmonic. The third group is called “Spuletief” which means kitchen sink. It sounds like piano strings which are convolved with a reverb impulse response from a sink.

Klangfamilie 14 is made of resynthesized samples of what sounds like a piano with additional reverb. These samples were probably created with IRCAM’s Diphone Studio from the file names. This klangfamilie includes mm. 40-44 and 70-79, but temporally reversed.

Klangfamilie 15 is composed of processed sounds. Most of them have drastic spatialization and movement between the two speakers. Many of them are clearly derived from piano sounds, either from playing on the keys or strings.

Klangfamilie 16 is composed of samples of a string instrument. Every sample is playing the same note but with slightly varying attacks and aftertouch. A detailed summary of when each klangfamilie is used in the electronic cues or events can be seen in Table 12.

Table 12. Events and Klangfamilie in Zellen-Linien (2007)

Event	Klangfamilie	Event	Klangfamilie
1	1	**17**	10
2	1 (inactive)	**18**	5
3	1	**19**	8
4	1	**20**	3
5	1	**21**	3
6	1	**22**	14
7	1	**23**	2
8	1	**24**	12
9	4	**25**	12
10	13	**26**	5
11	14	**27**	9
12	14	**28**	8
13	1 (inactive)	**29**	8
14	11	**30**	13
15	15	**31**	14
16	7	**32**	14

These samples play an integral part in the piece's sound and often starkly contrast what the pianist is playing (at m. 163, for example). Many samples use motives that have been played earlier or that will be played in the piece. One could argue that the samples serve as a form-making mechanism throughout the composition by reinforcing the acoustic materials of the work with the electronics.

Another important aspect is the live recording. Throughout the piece, two systems record samples—the first is for the granular synthesis and the second is for the hin-her system, which will be discussed in the next section.

6.5 DSP effects

Zellen-Linien (2007) has many modules that can be separated into several categories. In this section, we will look at the DSP processes that are active throughout the piece.

The first and perhaps most significant digital signal processing in the piece is the use of granular synthesis. Tutschku designed his synthesis engine in Max/MSP. Some of the more essential variables he uses to create variation are the grain duration (which varies almost continuously and is slightly randomized), interpolation time, grain phase, grain pitch randomization, grain speed, and selecting which samples are sent to the engine. The system is elegant and practical, giving a significant set of possibilities for resulting sounds and textures. One can hear the granular synthesis in events 4-9, 11, 14-24 and 26-31. The granular synthesis engine's inputs are both the acoustic piano and a mono version of all the currently played samples.

The second DSP effect is what Tutschku has called "hin-her," which contains two DSP effects in a subpatch. The first one is a simple delay of fifteen seconds that is active throughout most of the piece. This delay receives its input from the acoustic piano and a mono version of the granular synthesis. We can hear this delay at events 8-10, 20 and 30.

The second part of the hin-her subpatch is slightly more complex, as seen in Figure 42. Through cycles of eleven seconds, there is a variation between two buffers that are recorded and played (both forward and in reverse). The playback speed is slightly randomized. This process starts at the beginning of the piece. The input to this hin-her system is the acoustic piano and the mono version of the granular synthesis. The events in which one can hear this processing are 4-11, 15-18, 20-22, 24, and 26-30.

The last DSP effect is the freeze function. This function uses the FFT capabilities of Max/MSP and a creative use of Jitter matrixes. Tutschku's effect is on the surface, similar to most freeze effects. However, it does have a few exciting additions:

- The freeze function is activated through the envelope follower, meaning it is performer/gesture activated.
- It is possible to have different lengths of the freeze function.
- It is possible to add harmonics to a frozen sound.

The last two are never used to their full potential since all events have the same settings. Most of *Zellen-Linien's* (2007) effects come from a large patch Tuschku has worked on for years for use when he improvises. It is part of his daily Max/MSP practice.[53] The events that use this effect are events 19, 23, 31 and 32, making it the least used of all the DSP effects.

There is no doubt that the construction and use DSP effects is crucial to Tutschku's composition. It is interesting to note that the effects are modular and open to randomness,

[53] Private conversation in Belgium, August, 2019.

perhaps to enhance the idea of interactivity (Emmerson, 2016). Figure 43 shows which effects are used in which events of the composition.

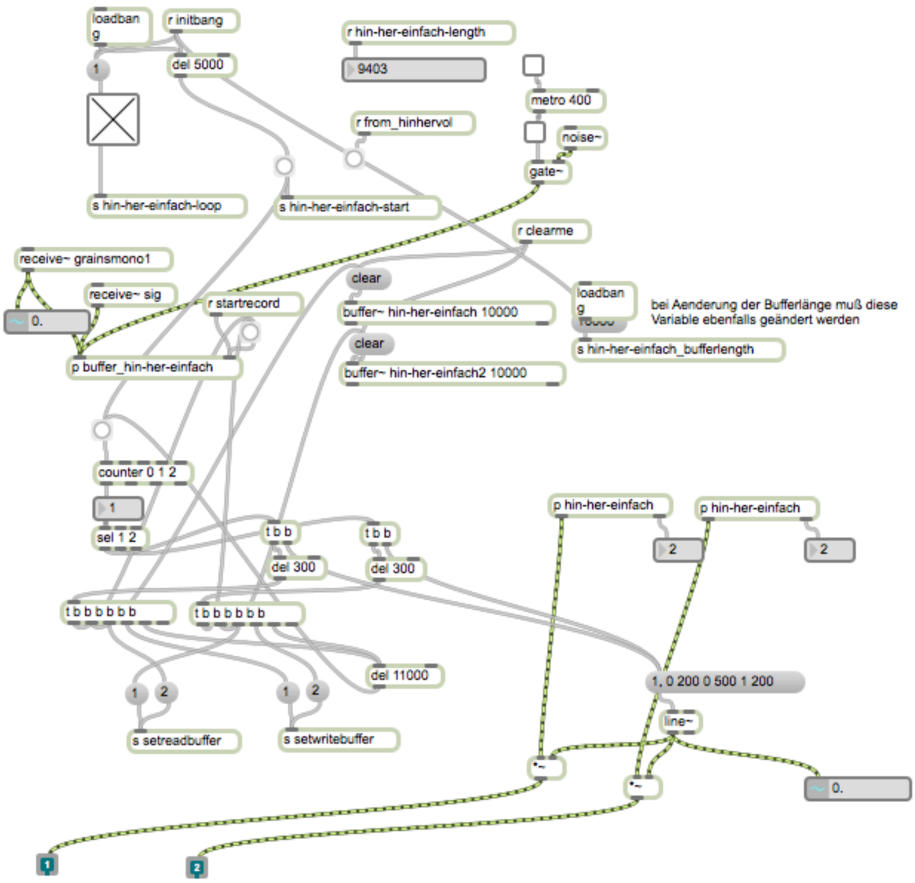

Figure 42. Tutschku's "Hin-her" system in Max/MSP

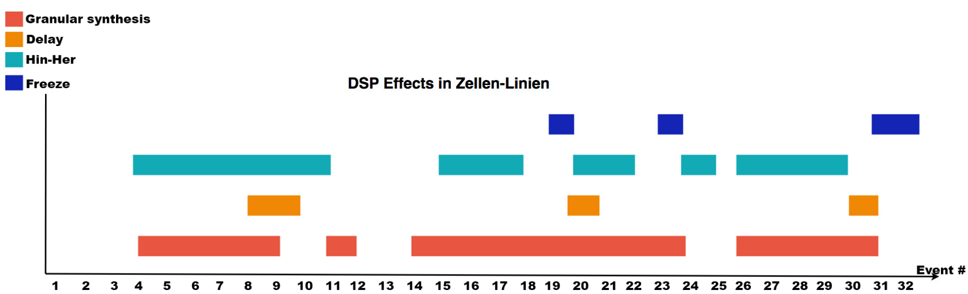

Figure 43. DSP effects by event number in Zellen-Linien (2007).

6.6 Spatialization

The piece can be played on either an eight, six or four-speaker system. This shows that spatialization is crucial to this piece. The patch uses the ICST ambisonics externals. However, the panning is done with the VBAP technique, which controls eight sound source signals. The speaker array discussed for this section will be the eight-speaker array arranged in a circle around the audience, with speaker number one is at the top left and the numbering continuing clockwise. The sound sources are not separated from each source, meaning that each sound source can include various elements of the electronics, as shown in Table 13.[54] The acoustic piano sound is not included in these sound sources and is directly routed to the DAC in channels 1 and 2.

Table 13. Sound sources in Zellen-Linien (2007)

Number	Sound sources
1	Freeze, grain
2	Freeze, grain
3	Hin-her, delay, freeze, grain
4	Hin-her, delay, freeze, grain
5	Sound files
6	Sound files
7	Buffers
8	Buffers

The discrepancy between sound files and buffers in this context is which files Tutschku places in the various sound source pairs. These sound files are only six fixed media files, while the rest are in buffers.

Throughout the piece, sound sources are given azimuth values from the various events. These values are often controlled by randomization. Tutschku created a system in which three values are provided—the tempo of that sound source's movement, and the minimum and maximum azimuth values. In some events, the minimum and maximum values are the same, essentially being precise values of the azimuth for that specific event. The movements can vary between these points several times at various tempi, such as sound sources seven and eight during the events one to three.

[54] Events 31 and 32 include multichannel sound files which are routed directly to the DAC.

The controlled randomness of the piece's spatialization is interesting. In practice, this makes the piece never sound the same between performances. Although there are random elements, these movements sound through-composed. For example, the spatialization at event twelve can be seen below in Table 14.

Table 14. Spatialization in event twelve.

Sound Number	**Tempo (in ms)**	**Min (degrees)**	**Max (degrees)**
1	10000	0	360
2	10000	0	360
3	10000	0	360
4	10000	0	360
5	1000	0	0
6	1000	45	45
7	10000	0	180
8	7000	180	360

An essential aspect of the spatialization is that it opens up more acoustic space for the electronics to inhabit, creating a clearer divide between the live performer and the electronics. This demarcated difference suits the music and gives the listener a better idea of the electronic gestures in person more so than in the stereo recordings.

6.7 Compositional Material

Zellen-Linien (2007) has most of its compositional material presented at the beginning of the piece. The first three gestures are also discussed in Emmerson's analysis (2016). The first material is the chords that start the piece. These are generally played in isolation; however, their timbre is changed by the electronics. The harmonies have a prevalence of seconds (mainly major) and fourths (mainly diminished and augmented). The original chordal material of the piece can be seen in Figure 44.

Figure 44. Example of harmonic material. (mm. 1-2)

This material has a few changes throughout the composition. Emmerson mentions that the chords are generally isolated, which is true in certain parts of the composition, such as the start and the end. However, I see several developments in the material related to these chords, such as the rhythmic chords at mm. 46-47 (03:37-03:40), shown in Figure 45. Additionally, these chords evolve into clusters in mm. 118-119, as shown in Figure 46.

Figure 45. Example of harmonic material (mm. 46-47).

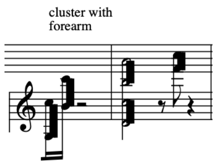

Figure 46. Example of clusters (mm. 118-119).

All of these motives play the same role within the compositional context. By looking at their intervallic composition, it is clear that they are related to the compositional material already presented in the first three measures.

The second type of material is the repetition of single pitches, often accompanied by an accelerando or ritardando. This material's rhythm is essential as it varies in complexity and development. This material is often isolated rhythmically and has several timbral changes using electronics. Additionally, at several points, such as m. 164, the performer must mute the piano's strings to obtain variations in timbre from the same material.

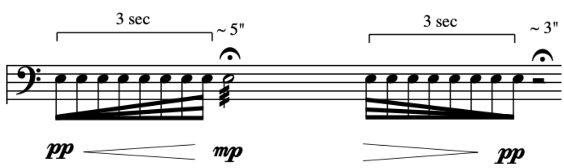

Figure 47. Repetition of single notes variation 1. (m. 3)

Figure 48. Repetition of single notes variation 2. (m. 66)

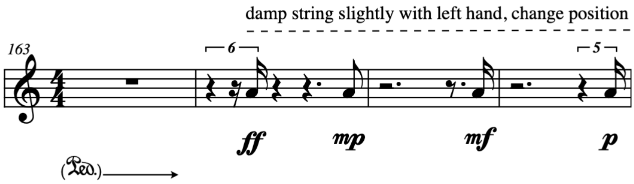

Figure 49. Repetition of single notes variation 3. (mm. 163-166)

The third type of material is more gestural and rhythmic. The material can be seen as two primary gestures called A (m.13) and B (m. 16). Although initially played separately, they are quickly combined by m. 20. Emmerson (2016) points out that this material is octatonic, starting on the pitch G, but omitting Ab. In many later sections of the piece, one can still hear whether the material is closer to A or B, or sometimes a combination of both. The material in A has more prominence of thirds, fifths and octaves. The material in B primarily contains seconds, sevenths and ninths.

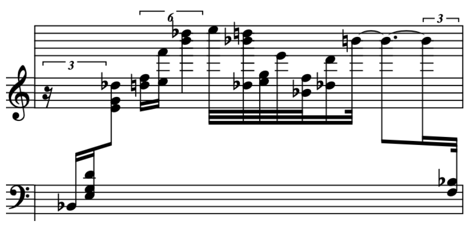

Figure 50. Gesture A. (m. 13)

Figure 51. Gesture B. (m. 16)

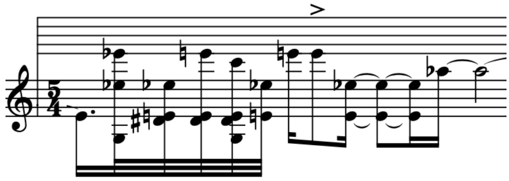

Figure 52. Inversion of gesture A (m. 62)

More development of these gestures can be seen in mm. 246-294. Tutschku also uses develops his harmonic motive rhythmically, as in Figure 53.

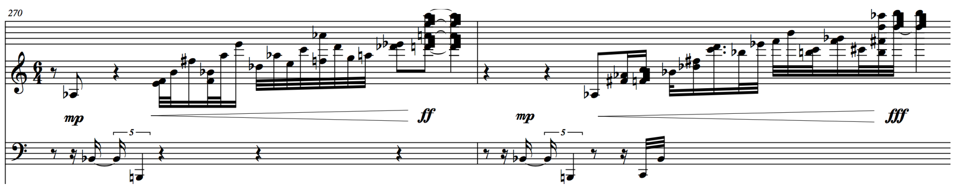

Figure 53. Gestural development (mm. 270-271).

6.8 Structure

The score of *Zellen-Linien* (2007) gives no structural indications. The score has 32 events which the performer can forward or rewind. These are shown in Table 15. These effectively work as rehearsal numbers for the pianist.

Table 15. Comparison of event times among available recordings.

Event #	**M.**	**Gut 2010**	**Ber 2011**	**Pes 2008**	**Pes 2018**
1	1	00:00	00:00	00:00	00:00
2	3	00:24	00:24	00:34	00:30
3	4	00:35	00:36	00:50	00:42
4	7	00:48	00:49	01:04	00:57
5	8	01:00	00:59	01:19	01:10
6	11	01:45	01:44	02:04	01:56
7	19	02:19	02:12	02:31	02:25
8	23	02:47	02:36	02:50	02:46
9	44	03:30	03:21	03:22	03:27
10	49	03:46	03:39	03:38	03:45
11	55	04:05	03:54	03:54	04:06
12	69	04:52	04:34	04:33	04:48
13	80	05:47	05:18	05:19	05:38
14	110	07:23	07:03	07:15	07:43
15	120	07:51	07:37	07:48	08:16

16	126	08:01	07:51	07:56	08:26
17	130	08:10	08:03	08:07	08:37
18	135	08:25	08:14	08:23	08:51
19	147	09:05	08:51	08:58	09:30
20	163	10:10	09:56	10:15	10:35
21	183	11:04	11:05	11:19	11:39
22	195	11:43	11:49	12:03	12:24
23	207	12:21	12:32	12:44	13:07
24	216	12:36	12:51	13:00	13:22
25	227	13:04	13:25	13:27	13:53
26	246	13:49	14:13	14:14	14:41
27	256	14:17	14:43	14:38	15:08
28	260	14:31	14:59	14:49	15:19
29	271	15:10	15:43	15:27	16:00
30	287	15:53	16:24	16:02	16:42
31	295	16:18	16:49	16:25	17:10
32	323	18:06	18:36	19:01	19:28

Emmerson (2016) has split the work into eight sections, which often coincide with these 32 events. However, Emmerson seems to be slightly uncertain about his choice of sections, as he mentions "about eight" (p. 344). He also notes how these sections are based on a variant of the three types of compositional material, effectively characterizing the piece as a set of variations.

My view on the formal aspects of the composition is similar to Emmerson's. However, I separate the piece into more formal sections as the form is somewhat episodic. The use of repeated motives, gestures, and samples often references other areas of the work, which concretizes the piece's macro structure. The use of electronics and harmonic material also gives structural coherence. For example, in measure eight, the listener can hear the piece's ending chords in the electronics.

Section A is an introduction. All of the compositional and electronic material for the work is presented here. Emmerson (2006) states that it ends at m. 70. However, I disagree because the material's development already begins at m. 31. By m. 31, Tutschku has already presented all of his compositional ideas that he will develop throughout the piece. The A section goes through all of the material, and the development starts after the ending gesture of m. 30.

Section B introduces a chordal gesture from m. 31. The use of the delay is an expansion of the blurring technique that Tutschku often uses. The repeating note is stretched out in time, and the performer must now damp the strings. The repeated note in the electronics changes from a low E to a high B. Later at m. 56, this note moves to E again, however, this time to E4. The chordal passages in this section use mainly fourths, sevenths and ninths. The gesture of delaying the left hand by a single time unit (mm. 31, 52, 53) is also introduced. The A gesture is played without changes in m. 54 before being transformed in m. 62. The gesture in mm. 63-64 sounds closer to the B gesture.

Section C is quite whimsical, as Emmerson notes. It lessens the tension that has built up in section B before in turn becoming more tense. This section differs from the two previous with its minimal use of electronics, although it still features some prepared piano samples for event twelve. Event thirteen practically turns off all electronics. This section focuses on developing the repeating note motive, creating tension in gesture A and a release of tension in gesture B. The repeating note in the electronics goes once again to a high B. The gestures A and B are developed as an interpolation between the chordal and gestural sections in mm. 91-92 and 96-97. A simpler version of gesture B is then played again in mm. 101-102 before slowly dovetailing and ending the section in m. 107. It seems logical for the section to end from the dovetailing (last note being the D4) and with gestures A-B introducing the new section D. The gesture's presence increases the tension, which will be an essential feature of the next section.

Section D becomes chaotic in the development of the motives and electronics. After the short introduction, the hin-her system and granular synthesis come back in. The loudest sample in the whole composition is triggered. It is of note here that Emmerson mentions how "the electroacoustic and piano sounds are constantly trying to overcome each other" (2016, p. 344). This is especially the case for the Pestova recording, which Emmerson analyzed. It is difficult to assess this on recordings that are probably primarily meant as documentation. The events in this section either trigger loud samples or processed sounds and motives, which create a sense of confusion, chaos and blurring. The section develops the chordal material, which becomes saturated by using thirds and seconds until becoming clusters in m. 114. There is a sense of tension and release between the gestural figures and the use of clusters. The clusters tend to move upwards, much like the original gestures.

Section E is not a resolution of the chaos but a suspension of it. The section's start has a G# trill, which resolves into the chord that we heard in the electronics at m. 8. This suspension leads to the new repeated note of A. In essence, this section is a transition between sections D and F. This is the first section that uses the freeze effect. This section's structure is reminiscent of the first sentence in the whole piece: chordal, repeated note, chordal. The use of the freeze effect enhances our perception of the harmonies as blocks of sound.

Section F has little musical tension compared to sections A-E, but contains more dissonance between what one sees and hears. The pianist stands up demonstratively to play the strings inside the piano. The delay is activated here, which results in a blurring texture. The granular synthesis plays some samples in reverse and forwards at different speeds. The listener can hear the electronics' gesture clearly. Section F is the only development section in the piece (other than J, a coda) that uses a single compositional material. Tutschku effectively shows that it is possible to have an electronically prepared piano and other timbral possibilities through minimalistic means.

Section G is a brutal awakening with the low staccato notes in m. 207. This section re-establishes the link between sound and performer. We hear a new version of gestures A and B, but less saturated than in section D. Like other sections, this episode is arch-like and features previously head rhythmic figures and development. The music sounds as if it is unravelling. The absence of any DSP especially accentuates this effect, except for the few samples being triggered.

Section H is where the tension rises again. This section is divided into two sentences. It features the hin-her and granular synthesis modules and is concentrated on gestures A, B and the chordal material.

Section I continues this rising tension and is the second part's climax (the first climax being section D). The listener has already heard the material in this section as a sample in m. 256. The motive from section H is condensed to form short sentences that end on tense chords. After four of these sentences, the tension/release of the final chord is withheld for one measure. The next few measures can remind one of a recapitulation. We can hear gestures A and B played without any modifications. Each chord sounds as if the electronics are breaking it—the delay at event 30 highlights that somehow, all of this tension will be resolved.

Section J is the end of the piece, and it is chordal, evoking the sonorities of the electronics from m. 8. As Emmerson notes, this final section is lighter in touch. The use of granular synthesis and the freeze effect blurs the harmonies together. The piece never really resolves; it just becomes suspended in time.

Table 16. Comparison of Emmerson (2016) and my structures.

Emmerson (2016)				Lacroix			
Section	**Mm.**	**Pes 2018**	**Ber 2011**	**Section**	**Mm.**	**Pes 2018**	**Ber 2011**
A	1	0.0 – 4.49	0.0 – 4.34	**A**	1	0.0 – 2.46	0.0 – 2.36
B	70	4.49 – 7.31	4.34 – 7.03	**B**	31	2.46 – 4.49	2.36 – 4.34
C	110	7.31 – 9.05	7.03 – 8.25	**C**	70	4.49 – 7.31	4.34 – 7.03
D	139.8	9.05 – 10.35	8.25 – 9.56	**D**	107	7.31 – 9.05	7.03 – 8.25
E	164	10.35 – 13.07	9.56 – 12.33	**E**	139.8	9.05 – 10.35	8.25 – 9.56
F	207.8	13.07 – 14.41	12.33 – 14.14	**F**	164	10.35 – 13.07	9.56 – 12.33
G	246	14.41 – 17.13	14.14 – 16.49	**G**	207	13.07 – 14.41	12.33 – 14.14
H	295	17.13 – 20.05	16.49 - 18.45	**H**	246	14.41 – 15.40	14.14 – 15.20
				I	266	15.40 – 17.13	15.20 – 16.49
				J	295	17.13 – 20.05	16-49 – 18.45

6.9 Synchronization

Zellen-Linien (2007) uses two strategies to synchronize the piece, as seen in Figure 78. The first one is the cue strategy with a MIDI pedal as the performance technique. The second strategy is following the amplitude of the piano signal to trigger certain events, such as a sound file. The use of an envelope follower to trigger sound files is related to the electronics' role in the piece. Tutschku (2015) describes the piece as his attempt to create an electronically prepared piano. He thought about using a pitch tracker, but piano notes are too noisy in the frequency content of their initial attack to be easily processed by a pitch tracker. Instead, the tracker would have to have a latency of approximately 30 ms as the sound of a strike stabilizes into a more tonal sound to properly function, according to Tutschku (2015).

The amplitude envelope follower allowed Tutschku to have less latency in the electronics of the work and more stability between the electronics and the performer. It would have been possible to use a cue system; however, this would have drastically increased the number of events, possibly making the piece more intimidating for performers. Having a lower number of cues can also make it easier for a non-specialist technician to follow the performance and correct any triggering mistakes. Considering that pragmatism is an essential aspect for Tutschku (2015), his system is well implemented for this specific composition.

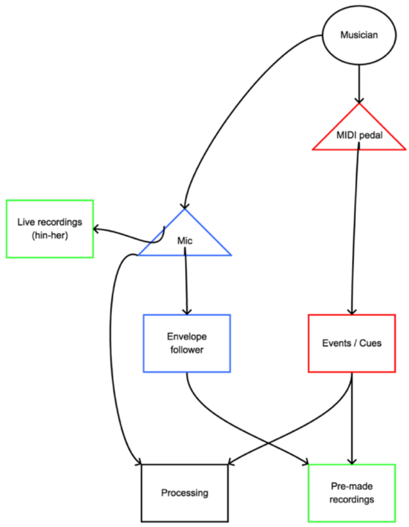

Figure 54. The synchronization strategy hierarchy of Zellen-Linien (2007)

The *écriture* in the piece is intertwined with synchronization strategies. Because Tutschku intentionally worked with technical limitations before the composition process, giving him restrictions to ensure the synchronization of the piece worked properly. Wanting to have a digitally prepared piano had specific affordances for synchronization as there is low deviation tolerance—a significant sync error between the piano and electronics can break the perception of a single hybrid instrument. As a listener, I argue that Tutschku worked on both the score and electronics simultaneously, like the model in Chapter III. This also fits his aesthetics as an improviser and programmer.

6.10 Notes on Pitch Organization

Zellen-Linien (2007) is a post-tonal piece. There is no functional harmony. I would describe the piece as gesture-based, and as Emmerson (2016) mentions, percussive. Emmerson explains further that he considers the piece to be octatonic. I do not believe the piece is built on octatonic scales. It flows more and stems from improvisational practice than within a set scalar formalization.

I agree with Emmerson that in many sections, one can hear that Tutschku is trying to make the piano sound inharmonic, possibly inspired by gamelan instruments. Several samples also hint at the use of inharmonicity as a compositional parameter. Additionally, the electronics' often influence how consonant or dissonant certain chords or sections sound through juxtaposition.

There are, however, certain interval constructions that persist throughout the piece. For example, there is a significant emphasis on seconds (especially minor), fifths, fourths and major elevenths. The chords towards the end of the piece at m. 296 also show the prominence of certain intervals. Sonorities based on fifths and fourths especially have an interesting harmonic relationship and can often remind a listener of inharmonic, percussive instruments.

6.11 Role of the electronics

Throughout this thesis, we have discussed the role of electronics within various compositions. Tutschku (2019) mentions his wish to create a piece with the idea of an electronically prepared piano (a dream for piano tuners!). Because the effects Tutschku creates and uses do not have an analogue in the real world, I argue that the piece actually goes further than his original desire of an electronic prepared piano.

Let us consider the electronics' role in relation to the piano throughout the piece using Lalitte's (2017) topologies discussed in Chapter II. Lalitte's topologies here are helpful to discuss the role of the electronics after already having discussed other poietic and aesthestic issues. The first topology is communication. The use of granular synthesis and the freeze coexist and are in dialogue with each other.

However, Tutschku's use hin-her, delay, and samples are different. The hin-her samples are done in absolute time, not musical time, therefore not having necessarily musical relevance or causation. This puts the hin-her closer to the inexistence since these sounds become obscure and, to a certain extent, lose their harmonic and gestural meaning. The delay, on the other hand, does not lose its harmonic or gestural meaning. It can be heard as a cause even though it is in absolute time. The delay's length does not vary from how quickly the performer plays, for example. Therefore, the delay as a gesture obscures what is happening, but maintains a level of clarity. The samples in the electronics are often in dialogue with the material played by the performer.

The second typology is identity. Most of the electronics and sections in the piece fall into the hybrid, which is in line with Tutschku's compositional goals for the work. The third and last typology is complementarity between the two sound worlds. The granular synthesis and freeze effects create a densification because of harmonization. The hin-her and delay are closer to densification, although they are less complimentary. Nevertheless, they are still more complex than just an aura. Many samples that come closer to the prepared piano idea are higher on the spectrum as an extension.

In general, the use of electronics enhances and changes the timbre of the piano. However, event 14 is different. This event triggers a loud sample that dominates most of the spectrum until event 15 (m. 220) and that reappears in variation in events 16-17. This loud and noisy sample could be considered the introduction towards the evolution of gestures A and B as the pianist progresses from playing denser chords (m. 112) to clusters (m. 114).

The use of spatialization in the electronics could be as a response to the format of the traditional classical music concert. The spatialization fits with the idea of interactivity in the piece and also gives a new life to electronics by varying at every performance.

6.12 In-Depth Analysis of Sections

To better understand the compositional strategies used by Tutschku, it seems relevant to study two sections in-depth. Many of the same strategies and gestures are used throughout the composition as well. Looking closely at the following two sections can explain how Tutschku has built the form of the piece. We will be looking at how the gestures form sentences and phrases. In post-tonal music, gestural actions become critical for sentences and phrasings since functional harmony is not present. Wishart (2000) argued that even with non-pitched sounds, we can form sentences and phrasing.

6.12.1 Section A (mm. 1-30)

This section introduces the piece. It presents all of the compositional material, gestures and developments that Tutschku will do throughout the work. By the first four measures, one is already presented with many of the material of the piece. One hears the prepared piano as the chords sound out (especially the second chord) and the reversed sound as the repeated note gestures begins in m. 4.

The first sentence starts in m. 1 and ends right before the electronic chords in m. 8. The first two chords establish an octatonic-sounding harmony. Although the first three measures go from C#-F-G-D to D-E-C#-F and back, the electronics give the first chord a different colour both times. Time is then stretched by the reversed sample and the repeating Es of m. 4. Afterwards, one hears new chords that are closely related, especially in their use of fourths. The electronics are a precursor to everything we will hear later in the piece. The hin-her system and the granular synthesis are turned on and blur the transition between the first and second sentences.

The second sentence starts from mm. 8b-11. It is the only section of the work with clear and unprocessed chords in the electronics. It is also the most indeterminate section because of the possibility of choosing a free order of rhythmic elements for two measures. The performer has to react specifically by mirroring one chord in the electronics. This indeterminacy hints how Tutschku's piece is based on earlier improvisations and how it is influenced by his practice as a performer. There are two other interesting aspects in this short sentence. The first one is the chord triggered at event five is the same chord that introduces section J and ends the piece. It is an interesting chord as it is primarily tertiary, featuring the pitches C-G-A-F#-B-D-Gb. It includes a major seventh interval of G-Gb between octaves, a prominent interval throughout the piece. The other interesting aspect is how event five triggers a sound file of mm. 296-315, once again alluding to the piece's end. Tutschku uses fragments from earlier in the piece, and these will be heard throughout the piece. The Berweck recording here differs from all other recordings in the ordering of the events of this sentence.

The following sentence is the first to introduce gestures A and B (mm. 11-22). The first gesture already features several elements we have heard. The octave is added to a major seventh, forming the E-E-Eb figure. The next chord is formed by fourths A-Eb-Ab. This gesture is an introduction to the components of gestures A and B. First, we hear A, then a slight pause, then B. The electronics in this phrase once again refer to the eight chords derived from both previous sentences. The granular synthesis and hin-her systems are also on, creating a blurring effect. In combination with the prepared piano sound files, we will hear this type of sonority in many other sections. This phrase ends with a repetition of gestures A and B combined.

The last sentence of the section is transitional before Tutschku further develop the material already heard. In mm. 23-24 there are chords with prominent fourths. Afterwards, the more melodic material in the piano is derived from gestures A and B.

6.12.2 Section H (mm. 246-265)

Section H has good examples of motivic development, which is one of the strong points of *Zellen-Linien* (2007). This section can be broken down into two sentences, in mm. 246-255 and 256-265, respectively. One of the main differences between these two sentences is the electronics. In both cases, the electronics create a texture in the background. The first texture is somewhat reminiscent of much mixed music from the 1960s. The first sentence samples are piano notes, which sound similar to the use of FM synthesis, and ring modulation in Stockhausen's and Nordheim's music. The second sentence starts with samples of mm.

269-271, which can be seen as the final development of the motives found in section H, of gestures A and B, and the chordal material. The ending of section H features resynthesized chords from event 28 onwards.

Both sentences in section H are structured in the same way: They are first reminiscent of gestures A and B with the same forward energy that moves upwards. After a short pause, this upward movement is harmonized using prominent seconds, thirds, fourths and sevenths. The development's structure reminds me of classicism, as explained in Caplin (1998)—the rhythmical ideas propel the music forward, and the motives become shorter and shorter until they are resolved in m. 260, reminding me of an inverted version of m. 30.

6.13 Conclusion

In this chapter, I have analyzed a single work using the framework of synchronization hierarchy. Considering the synchronization strategies of the piece opens aspects of analysis that consider the piece holistically instead of only looking at the score or the electronics. An understanding of synchronization strategies and performance techniques can give insight regarding performative aspects of the work and how gestures or smaller structures within the piece function in practice.

Tutschku's piece shows how a well-thought-out composition will work compositionally, performance-wise and in the electronics. Each element comes together to form a whole that the listener can appreciate. It shows how deeply related synchronization strategies and performance techniques can be in mixed music. The *écriture* and the technical/musical aspects of this piece are connected in many layers. In this sense, *Zellen-Linien's* (2007) study is a useful example of the complex affordances between synchronization strategies and composition. I argue that these networks of relationships form the very identity of the piece, highlighting its unique qualities.

Chapter VII: Performing Mixed Music

> *The composer . . . must first assemble the combination of local and flown-in gear which will permit the piece to be played. If time remains, the piece will be rehearsed and adapted to whatever hardware changes were made. It is at this moment that the player meets her accompanist . . . for the first time . . .*
>
> -Miller Puckette & Zack Settel (1993, p. 136)

7.1 Introduction

This chapter focuses on mixed music from the performer's perspective. Initially, most of the literature on mixed music was about technology or composition. However, there has been a surge of recent literature written by performers specialized in the medium. Some of the composition literature has also started to focus more on this repertoire's pragmatic and interpretive aspects. It is essential to analyze and reflect on performance to have a more balanced view of synchronization strategies and their complex relationship to compositional processes. Electronics and synchronization are always in relation to the performers and should therefore be part of the discussion. The chapter focuses on the following elements:

- A short introduction to the literature about performing mixed music
- A look at specific issues in the performance of mixed music
- How synchronization strategies affect musicians
- How synchronization performance techniques affect musicians
- The role of musical time for musicians
- Perception of musical and live elements in mixed music

7.2 Performing Mixed Music

The quote at the start of this chapter is used in McNutt's (2003) article to dramatic effect, illustrating many musicians' views on mixed music. McNutt and Kimura (1995) present some of the earliest examples of performers speaking openly about their experiences. Although some points have become perhaps out of date, many of the issues they bring forward, such as the alienation caused by technology, remain relevant.

Recently, many theses and articles focus on performative aspects of mixed music, such as Berweck (2012), Enns (2017), Féron & Boutard (2018) and Pestova (2008; 2018). Their observations and practices will continuously serve as a backdrop in this chapter. Most of the literature focuses on the solo performer and electronics repertoire. There has been a considerable lack of literature on how multiple performers work together with electronics, or on the effect of the number of actors involved in a production. Throughout, I will try to extend observations and practices to how they might affect both soloistic and ensemble performers with and without a conductor. Additionally, I will draw upon my own experience as a RIM and composer to comment when appropriate.

Bahn et al. (2001) claim that chamber music's intimacy is of critical importance for musicians. Intimacy has rarely been explored within electroacoustic music literature. They claim further that composers often try to reinforce the larger-than-life and immersive aspects of the music. This claim seems somewhat counterintuitive when most of the repertoire is for a single musician and electronics (Tiffon, 1994). Additionally, although many pieces use amplification in a way that dramatically expands from the acoustic situation of chamber music and not just as sound-reinforcement, this does not necessarily destroy intimacy. For example, Saariaho's *Nymphéa* (1987) and Crumb's *Black Angels* (1971) both use amplification without sacrificing any of the intimate aspects of chamber music. Additionally, one can also augment intimacy through amplication by making a sound source sound much nearer, such Einbond's *Resistance* (2012) (Katz, 2004). There are examples of the opposite as well. Andriessen's *Facing Death* (1991) and much of Romitelli's works use the amplification to have more volume, often referencing rock and jazz music. Hence, I find Bahn et al. (2001) to be an oversimplification.

Mixed music is a specialized field, and it is common not to have any possibility for education on playing this type of music either as a soloist or within an ensemble. Some specialized programs are starting to exist. Many workshops around the world are starting to include lectures about performing with electronics. However, Berweck (2012) notes that few performers have received any training on this type of repertoire. It remains a specialized practice (within the already specialized practice of contemporary music) rarely included as part of classically-trained musicians' education in conservatories and universities. McNutt (2003) remarks that electronics sometimes actively go against what these musicians have practiced for years, giving the example of non-musical sounds such as throat sounds for flutists. Mixed music, like much other contemporary classical music, often involves extended techniques that depart from traditional instrumental training. There is an important historical and musical relationship between extended techniques and electroacoustic music which leads into aspects of surrogacy, source recognition and mimesis (O'Callaghan, 2015; Underriner, 2017, among others). It also feedbacks into various compositional processes from Chapter III. Hence, education is needed to reassure performers and give them a standard arena to address issues, questions and establish a standard practice.

This educational problem has been a central issue discussed by practitioners such as Enns (2017; 2018) and Lizère (2018), especially when working with younger performers or those unfamiliar to the medium. There now exists, however, a quickly growing repertoire of mixed music for children. Pieces such as Lorieux' *Branche, étude électrique 1* (2008) and Barrett's *Push-me-pull-me* (2001) play a vital role because they are written with a younger performer in mind. These composers understand the technical difficulties of mixed music and how to circumvent these to make the repertoire accessible.

For many performers, the issue of self-reliance is vital, but works with technology require further demands and skill sets from the performer to achieve this. Berweck (2012) explains how troubleshooting Max/MSP patches can be time-consuming and demanding if executed by the performer. Enns (2017) asserts that a composer cannot expect the classical musician to be savvy with technology in any way, shape or form. She also notes that many performers who specialize in mixed music also happen to be composers, which might not be an accident. In addition to maintaining their practice and specialization performing their instrument, the autonomous performer of mixed music must also stay up to date with the often rapidly-changing hardware and software required to perform the music. This is perhaps one reason that mixed music has a higher threshold of participation for classical musicians.

7.3 Six Issues in Mixed Music

Mixed music is a challenging genre of music to play with a myriad of issues. Some of these are well-known, while others are more subtle and nefarious. I will try to present some solutions when possible, but it is essential to know that there is no one-size-fits-all solution. Several of these solutions require structural changes.

7.3.1 Unfamiliarity with Electronics

Unfamiliarity with electronics is perhaps the biggest issue for musicians. Enns (2017, p. 6) summarizes the situation as:

- *Professional musicians have demanding rehearsal and performance schedules, experience psychological stress and physical discomfort or injury, and face financial difficulties related to job security. As such, musicians may have limited time and resources to explore new performance practices and participate in teacher training workshops.*
- *It is common for teachers to transmit what they were taught. (…) Since electronic-acoustic music is a relatively new area of study, teachers likely received no private or institutional instruction. Therefore, they may exclude it from their own teaching practice.*

- *There is limited time in private lessons and fundamental skills must be prioritized. One hour per week of instruction, for example, may be insufficient without careful lesson planning and long-term strategies.*

Universities and schools do not have the needed resources (economic, material and lack of expertise), though this does not always reflect lack of interest from student performers or their instructors (Féron & Boutard, 2018). Bringing in external resources, especially later in the process, can be stressful for the student, teacher and institution. Because mixed music is a highly specialized performance practice, many composers (myself included) use relatively technical language (often in short-hand) to explain what the electronics will do. In order to approach and understand such works, musicians may require significant technical training.

In practice, composers ask musicians to perform at their best without having access to their usual safeguards. Firstly, because of limited access to equipment, as mentioned in Enns (2017), Berweck (2012) and Féron & Boutard (2018), it might be difficult — if not impossible — for the musician to rehearse with the electronics at home. Secondly, the electronics may not be designed with efficient rehearsal in mind, if they are available during the rehearsal process at all. Performers are lucky if the concert patch is working, as Berweck (2012) remarks, especially for premieres of new works. If any issues arise in a rehearsal patch, the performer will generally not know how to fix them. Thirdly, if the piece is interactive, it might be difficult for the musician to start at specific sections. Knutsen declares that playing mixed music pieces often gave her the feeling of needing to depend on an extra person to rehearse (Knutsen, 2020). Fourthly, in cases where the musicians are not operating the electronics themselves, as typically arises in larger formations, they may not have access to or information about the electronics at all.

Unfamiliarity can also be an issue for conductors, who similarly rarely receive training in working with electronics. The conductor's job is to balance and synchronize, and electronics may destabilize the conductor's familiarity and comfort. It is not uncommon that neither the musicians nor the conductor will hear the electronics at all until the first rehearsal. In my own experience, electronics are often an after-thought in such situations.

7.3.2 Rehearsal Time and Space

It is challenging today for ensembles to survive by playing contemporary music, mainly due to financial and logistical difficulties. The situation varies from territory to territory, and it is outside of the scope of this thesis, but often this impacts the resources ensembles have to sufficiently rehearse, and mixed music more often than not simply requires more rehearsal time.

For solo pieces, rehearsals might be different. If a rehearsal patch is not available and the electronics consist of more than a single fixed tape part, rehearsal time will be tight and critical. The performer might be dependent on having a RIM present to rehearse, making scheduling more difficult and costly. The most common rehearsal locations for this music are relatively dry studios or practice rooms. While these spaces are useful for rehearsing because they are easier to set up microphones in (less chance of feedback), they can be problematic for classical musicians since it becomes more challenging to project one's sound and they do not typically provide a good representation of how the music will sound in concert. Setup time might also be limited, and in the worst-case scenario, one might have a different RIM between the concert and rehearsals.

Part of performers like Enns' (2017) decision to work self-sufficiently may be from inconsistent experiences with technicians and RIMs, who may only be involved in the last stages of a production. Often the sound technician and hall will only be available for the dress rehearsal and the concert, and in the worst case, this means the entire piece will be heard for the first time during the dress rehearsal. It is also not abnormal to meet the sound technician on the last day of production (Berweck, 2012). These issues can of course vary depending on a hall's size and the complexity of the setup, but they remain challenging concerns reflecting the general lack of resources usually available for performances of mixed music. In the absence of the means to have a dedicated RIM or even sound technician to bridge the complexities of the acoustic situations on stage, in the hall, and in the rehearsal space, soloists of mixed music often choose to take these matters into their own hands.

In my years working with both the Trondheim Symphonic Orchestra (as a stagehand) and Trondheim Sinfonietta, it seems like the standard is often to have two or three rehearsals and then a general rehearsal before the concert. Having a time and place to rehearse tutti can be difficult and expensive, and the additional resources often needed for mixed music can exacerbate the situation. Unfortunately, it is rarely realistic to rent the same concert hall for four days with a sound technician.

For most pieces of mixed music, the ideal situation would be to rehearse in the same hall, with a dedicated RIM and a sound technician, but this is unrealistic for most projects. Some of the performers interviewed by Féron & Boutard (2018) compared the rehearsals of a mixed music piece with a dance or theatre production because of the proliferation of different artistic roles in the production. At worst, rehearsal woes may lead the instrumentalist to learn their parts without ever having heard the electronics, and this is especially common in setups with real-time electronics (Tutschku, 2011). It may also result in the musician or conductor actively ignoring the electronics' sound in order to focus on their own performance, which reduces the interactivity between actors.

7.3.3 Notation Problems

Notation within contemporary acoustic music is a vast field. Types of scores, such as graphical scores (à la Feldman) or prescriptive scores (à la Lachenmann), are two possibilities that have become standard practice. On the other hand, the ethos of electroacoustic music is often about composing through listening rather than the abstract conception of a score. Mixed music inherits the problems, affordances, consequences, assumptions, and standards from both of its musical 'parents', and these can sometimes be in contradiction with one another. Pestova (2018) lists three types of scores within mixed music: descriptive, prescriptive, and hybrids. Descriptive scores include "graphic and visual or descriptive scores" (p. 131). She links this paradigm mainly to simplify synchronization with fixed media, although she also mentions newer pieces with live electronics. I do not believe that a specific type of score is inherently related to any synchronization strategy. The repertoire contains examples of each synchronization strategy for each type of notation. However, since this is closer to traditional scoring, a prevalence of fixed media pieces might be a historical fact but not a causal relation. Additionally, it is a possibility that various types of composers prefer certain scores due to their familiarity. Perhaps an electroacoustic composer might prefer descriptive notation due to its similarities to the traditions of the diffusion score (Harrison, 1998).

A prescriptive score is often compared to tablature, as it shows how to create a sound. Additionally, Pestova states this includes "cue-based notations (…) place emphasis on the actions required to trigger a sample or start and stop sound processing rather than describing the nature of the sounds" (2018, p. 147). The hybrid score can be a combination of these two or other newer inventions.

Berweck (2012) notes that in *Zellen-Linien* (2007), the pianist cannot understand what the electronics will do because they are not notated. The pianist must learn from playing the piece. Pestova's (2018) solution is for the composer to create a separate study score with detailed information about the electronics. This solution can work in many cases, but in my own experience, musicians often prefer to simply 'learn by doing' by practicing the work rather than consulting detailed technical information about the electronics.

Graphically illustrating the electronics brings up another critical point. Much electroacoustic music is based on spectromorphological elements far removed from the kinds of sounds traditional notation was created to realize and so composers' graphical notations are often unique to themselves. Without a standardized notation system, approaching a graphically notated piece may represent additional learning hurdles for performers. Just defining the word timbre is difficult (Agus et al., 2019). Timbre is at the heart of many discussions with purely electroacoustic music, and several scholars such as Roy (2003) and Thoresen (2006; 2009; 2010) have tried to create graphical systems based on listening. However, these systems are designed for analysis rather than performance, and may be too complex to be repurposed toward prescriptive notation. Graphical illustration of timbre can give some clues to the musician, but it may remain challenging for them to imagine what the sounds will be.

7.3.4 Lack of Haptic Sensation & Physical Elements of Electronics

Musicians spend years learning their instruments, often from early childhood, making the physical relationship with their instrument personal. Bahn et al. (2001) remark how haptic and sonic feedback is essential to instrumental technique. Details in how one holds the instrument or places their fingers will change its sonic response. This section will develop two essential aspects: the relationship a performer has with their instrument and the physical relationship between the musician and synchronization performance techniques.

Pestova (2008) shows the relationship with an instrument with two simplified models of interaction shown in Figure 55 and Figure 56. The model is only for fixed media, but it highlights some of the challenges for all synchronization strategies, such as how sonic feedback from the instrument typically occurs through the intermediary of stage monitors, which necessarily creates a distance from the sound and its source. Additionally, the instrumentalist is typically divorced from the sound the audience hears, with no control over what comes out of the speaker array, or even the means to hear it properly.

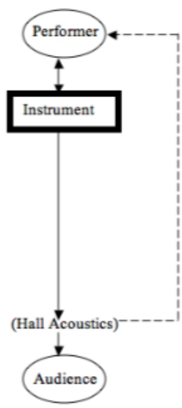

Figure 55. Traditional model of interaction from Pestova (2008, p. 16)

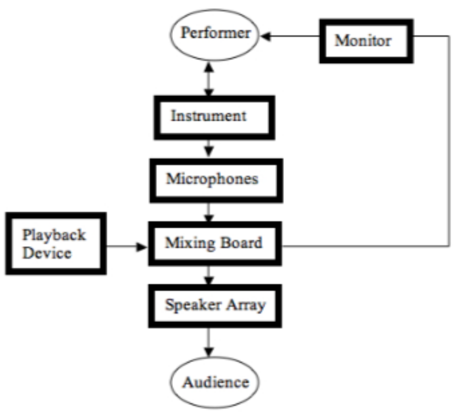

Figure 56. Fixed media model of interaction from Pestova (2008, p. 16)

By asking the performers to use electronics, composers are changing their usual haptic sensations and natural monitoring. Their amplitude will influence live electronics, and other physical aspects might not change the sounding result. They might get some feedback from using monitors (which we will discuss later), but it breaks the acoustic and physical relationship they have cultivated for years. As Bahn et al. (2001, p.2) explain: “much of the physicality of musical performance is a result of these mediations between feel and ear,” which is directly related to how that specific instrument conducts touch, amplifies it and “sonifies physical gesture”. Berweck (2012) remarks that for professional musicians, kinaesthetic or tactile learning is of utmost importance. Therefore a revised model of interaction for a performer might look like Figure 57. A model similar to Pestova's (2008) would look like Figure 58.

In both models, the chain is separated into distinct elements: the musician, the instrument, perception and augmentation. Acoustic instruments are built to naturally amplify their sound by using resonance surfaces, which gives the musician their natural monitoring. When adding electronics, there are more elements at play. The amplification equipment might have its own colour.[55] The microphone and its placement will also significantly affect the sound. Finally, the sound will be further affected by the frequency response of the monitors and speakers. This sound is then naturally amplified by the hall's acoustics, and it is only through all of these transformations that the musician will hear back their instrument.

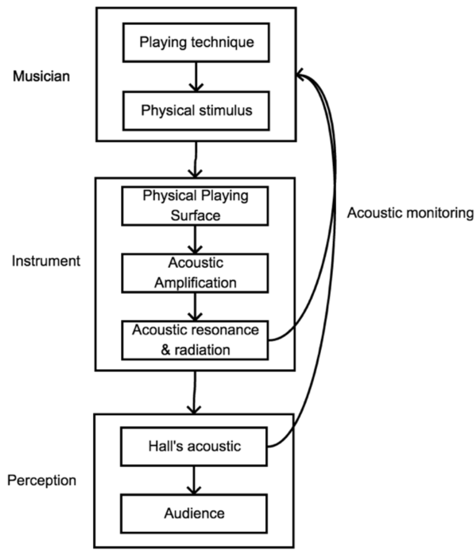

Figure 57. A proposition for a revised model of interaction with acoustic instruments

[55] Although amplification today with high-fidelity equipment is often close to "neutral" in terms of its frequency response, amplification always changes the sound, and may be done so consciously and intentionally such as the sound of a specific "analogue-style" pre-amp.

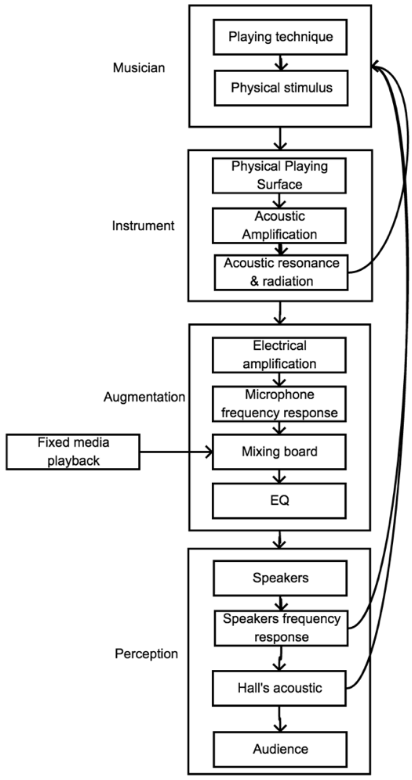

Figure 58. Revised interaction model with fixed media

It is easy to see the dissonance between a performer's usual acoustic situation and mixed music. It can be shocking, perhaps even disturbing to the performers to hear their instrument in such an alien way than to what they are accustomed. There might also be a time discrepancy between the acoustic and reinforced sound, and then again between those signals and any effects or treatments in the electronics. Although it seems most performers in Féron & Boutard's study (2018) emphasize the electronics, some performers find that ignoring the electronics is a solution or necessity for their practice. Many of the performers in the Féron & Boutard interviews are experienced mixed music soloists, yet often feel as though they have to ignore the electronics in order to successfully realize their instrumental performance. My own experience working with performers corroborates that this sentiment is rather common.

The other aspect related to haptic feedback is how to control the electronics through performance techniques. The literature focuses mainly on the use of MIDI pedals. The lack of haptic feedback from the pedal can lead the performer to question if they have activated the trigger (Berweck, 2012; Pestova, 2008; 2018). The few milliseconds when the performer wonders if they have pressed the pedal can be catastrophic, such as leading the performer to accidentally double-press. Musicians are used to hearing instant feedback from their acoustic instruments, but the event they have triggered might not be audible for several seconds (if at all). Berweck explains that the missing feedback is apparent while rehearsing the piece as it conflicts with "professional performance practice" (2012, p. 105).

Pestova (2008) suggests that pedal use might be more natural for instrumentalists such as pianists, especially if the cues are spaced sufficiently to make them a natural gesture within the music. However, some pianists prefer using a small MIDI keyboard to trigger the electronics because they are already doing so much with their feet. A pianist will also likely have spent years perfecting the finesse of their pedalling, including techniques such as half-pedalling to link chords together. Most MIDI pedals do not account for this kind of finesse and function more-or-less as an on or off switch. For these reasons, performers often prefer to work with a RIM operating the cues rather than negotiate these significant differences themselves, as Pestova chose for her own performance of Tutschku's *Zellen-Linien* (2007).[56] In my own experience, most pianists feel relatively comfortable with MIDI pedals, as long as it is carefully placed, and the triggers are not too rhythmically demanding.

7.3.5 Monitoring

Monitoring is relatively ubiquitous in mixed music but its role is rarely directly discussed. In the traditional music repertoire, performers are used to playing without monitors.[57] Speakers are still not able to replicate radiating patterns like instruments.[58] The signal sent to the monitor will often be one-dimensional because of the monitor's radiation and close miking, leading to the loss of depth of sound, especially in ensemble works with many microphone sources, potentially leading to phasing and balance issues from the time differences between instrumental groups.[59]

[56] Private conversation with Pierre Michaud in Montreal, Canada during the first International Conference on Mixed Music Pedagogy, Sunday 18th of November 2018.
[57] There are some exceptions, such as when performing film music, theatre and opera. Many concerts of classical music do not have a sound technician, and microphones usually only enter the picture for archival sound recordings. A soloist might be amplified slightly to give extra "air", but this is not enough to disrupt the performer's usual acoustic situation.
[58] It is relevant to mention that several engineers have tried to create this, for example, at IRCAM with La Timée, or the Orbophone.
[59] I have written about this in Lacroix (2016). See also King (2017).

More monitors on the stage also necessarily contribute to overall loudness, which has consequences. Firstly, feedback could become a problem, which is a fear for many performers (Enns, 2017; Thordarson, 2019). Feedback is especially likely in high-gain situations like amplifying soft sounds. Secondly, more sound on the stage means that bleeding might become an issue. For example, if only the string section is being sent to an electronics effect, a loud blast from the brass section will most probably leak into the string microphones. While these possibilities may be addressed at the compositional stage of a work, they can also be significantly influenced by the placement of the ensemble and microphones on stage. Thirdly, in extreme cases, the loudness of monitors might cause localization issues, making it difficult to identify the source of the sounds, representing a significant challenge for ensemble playing. Fourthly, in the case of works performed with conductor, their position relative to the monitors may not allow them to have a good idea of the room's balance: the presence of monitors and speakers may offset their acoustic balance. And so, ensuring balance often becomes the task of the RIM, who, unlike the conductor usually does not need to be on the stage to communicate with the musicians and so can be situated in the front of house (FOH) position or the centre of the hall among the audience, letting them balance the ensemble's sound effectively from the audience's perspective.

Although headphones might seem like a good alternative for stage monitoring, they also have their problems. Firstly, they necessarily alter how one hears their surroundings even if the musician has them only on one ear. Berweck (2012) notes that headphones are challenging to balance between too loud or too soft. Instead, he recommends using sound isolation earphones, which is surprising because of the considerable affect they have on one‘s ability to hearing one's instrument and environment. In my own experience, many classical musicians' intonation can also suffer from the use of headphones. At this point, however, there is little published research on how monitoring affects classical musicians.

7.3.6 Visual Dissonance

The visual element in music performance is often underestimated, but there is an increasingly significant field of research around these issues with articles such as Davidson (1993; 1997) and Davidson & Goode (2002). Recent studies have also shown how much the visual aspect of performance can affect the audience's perception (Tsay, 2013). Acousmatic music by definition has no visible performers, unlike traditional art music.[60] There is always at least one performer on the stage in mixed music, which influences the audience's experience. The balance of visual weight can vary from how many actors are visible, how active they are, how much electronics there is, how many speakers and many other elements. The visual and sonic weight can have some profound implications for the musicians. Naturally, a larger ensemble on the stage might create more weight for the acoustic part as the musicians on the stage capture the audience's attention. Pieces such as Walker's *Eye-Masking* (1997) actively play with visual cues and weight.

In the case of a soloistic piece, there are often expectations of the classical recital. "(…) [T]he focus of a live performance visually and musically - is the performer." (Smalley, quoted in Bates, 2009, p. 167), meaning that the audience's eyes will be mainly on the performer. If what the audience sees and hears is radically different, there can be visual dissonance. Much of the dissonance is due to the audience's expectations in music-making, traditionally as we expect the sound we hear to be a direct cause of what our eyes see, which is often referred to as source bonding (Emmerson & Egermann, 2018; Godlovitch, 1993; Smalley, 1997). Issues related to integrity, causality and agency can be a challenge. If the electronics are based on the same sound sources as the performers on stage, or if they are otherwise acoustically similar, the dissonance can be more substantial. This can also make the solo performer slightly uncomfortable, as if playing with their double. Here there is also a question of aesthetics, as Croft (2007) raises. In some mixed music (and electroacoustic music), it is an aesthetic point to amplify small sounds that we would not typically hear. A performer's extraneous sounds, such as breathing, might become an integral part of a piece. Stockhausen's *Mikrophonie I* (1955) and *Mikrophonie II* (1956) are two of the most renowned examples.

As alluded to earlier, performers on the stage capture the audience's attention, which can become problematic in compositions when the performer might need not to play because the electronics are taking the lead. The action of not playing (especially alone) on stage can be uncomfortable. Some composers have included solutions in their pieces, such as in *Dialogue de l'ombre double* (1985) by Boulez, in which the lights are turned down when the electronics lead. It can also be used in a theatrical sense. Barrett describes the theatrical aspect of her piece *Symbiosis* (2002) as:

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[60] In practice, there often is a visual component to acousmatic music, such as the practice of loudspeaker diffusion, though this rarely occurs on stage. The performance aspect of this practice has been studied by Raboisson & Couprie (2017).

> *(…) this is one way in which I balance the elements: to give both parts solos and to have both coming together at important meeting points. In those three minutes of solo computer, the performer has to find a way to "compose" herself. Everybody is looking at her, and she is a performer having to listen. In that section the theater (sic) emerges as she demonstrates the act of listening and not just sitting there waiting for the next thing to happen (Quoted in Bates, 2009, p. 167 from Barrett et al., 2007).*

One must balance the theatricality of a piece, what the piece needs musically, and the performers' comfort. Much of this balance is tied to the *écriture*. For example, the use of multichannel electronics around the audience could help offset too much of the performers' visual weight by having sonic weight towards the back. Smalley & Austin (2000) declare that considerations such as the visual weight of performers on stage reduce one's possibilities in using electronics. They argue that the eye will naturally want to follow what is happening on the stage, which can, in turn, reduce attention toward acousmatic possibilities.

However, I cannot entirely agree with this. Even though an ensemble will give more visual weight, it will also diminish the amount of cognitive dissonance as the audience's eyes will not necessarily catch all of the gestural details in how the ensemble is playing. However, there is no doubt that it can be awkward for the musicians and the audience when they are asked to sit silently for long periods.

The audience's expectations can perhaps be changed by how the stage looks and the RIM's presence. Although I am not aware of any research on the RIM's visual presence, one could extrapolate that their presence on stage could help mitigate issues of agency and causality as it becomes part of the visual aspect of the concert, similar to diffusion performance in acousmatic music. The same could be said for technology around the stage if it is especially conspicuous. The otherworldliness of the electronics could also be an important part of the performance and dramaturgy of the piece. For example, having subtle electronics being emitted by speakers inside the piano might surprise the audience such as in *Chambered Music* by Steen-Andersen (2007). In such cases, the weighing of acousmatic versus acoustic sound becomes a sensitive issue.

7.3.7 Closing Words

Many elements can influence a performer's ability to interact with mixed music, and some can act as barriers to entry. Some of the more immediately apparent issues are lack of familiarity with electronics, difficulty rehearsing, notational issues, lack of physicality in the electronics, monitoring issues, and the visual dissonance between sound and performance. It is not the goal of this section or thesis to address all of these issues in great detail. However, I believe that becoming aware of them as performers, composers and RIMs is a first step in finding solutions.

7.4 Synchronization for Musicians

We have explored six issues for performers within mixed music, often touching on issues related to synchronization in performance. Chapter II explored the definition and classification of synchronization strategies and performance techniques by looking at some of the positives and negatives for each possibility. Chapters IV, V and VI, explored specific compositional examples. This section explores synchronization from the perspective of performers and conductors. By having seen these concepts through the eyes of both poiesis and aesthesis, I believe this can give us a more balanced view.

7.4.1 Fixed Media

Tape has left a profound mark on the history of mixed music. Expressions such as "the tyranny of tape" (Bahn et al., 2001) are common, suggesting a sense of loss of freedom from fixed media. Although one might believe from such a quote that most performers are hostile to fixed media, that is far from the truth. Enns (2017) reveals that tape permits her to play more naturally. Playing with pre-recorded fixed media parts may feel closer to playing in an ensemble "in which most parameters, including tempo and pitch, are dictated by the conductor or fellow musicians" (Enns, 2007, p. 18). Ding (2006) is also positive towards fixed media, despite explaining that fixed media's rhythmic and temporal rigidities often go against his instincts as a solo piano performer of the traditional repertoire. He further explains how the tape "provides a lot of information on style, which helps the player to interpret the work (…)." (Ding, 2006, p. 270). These clues for the performer can be beneficial and help counter the unfamiliarity. Marco Stroppa is mainly known as a composer, but his experience as a performer influenced his perception that if a piece is well written, it will not be limited by the use of fixed media even if it is fixed from the start to the end, such as Stockhausen's *Kontakte* (1958-60) (Stroppa, 1999). He promotes the idea that fixed media can be effective for the performer if well used. Pestova (2008) asserts that fixed media is particularly useful when there is a relatively steady pulse.

It seems to be a recurring theme for many that tape can help their performance because of the temporal limits. A piece with fixed media can afford them more space to focus on the performance of their instrument because the electronics are less intrusive. There is also no doubt that the simplicity of rehearsals, as mentioned in Ding (2006), Enns (2017), and Pestova (2008), is not to be underestimated either. I would also think that the more straightforward concert setup, which typically requires less technical assistance, might be positive.

On the other hand, many performers have described how they dislike playing with fixed media, sometimes for the same reasons. McNutt (2003) describes tape as the worst chamber accompanist possible, as it does not listen and respond in the way that another musician would. Kimura (1995) and Errante (1985) also have similar opinions. For them, the fact that tape is fixed is a problem as it does not let them perform within the familiar confines of classical performance.

Boulez has also commented on this in his function as a conductor. It can be challenging for a conductor because synchronization between the conductor and tape can become a primary focus, leaving little to no room for interpretation, balance, and other issues (Häusler et al., 1985). He comments:

> *The time of a tape recording is not psychological time but rather chronological time; by comparison, the time of a performer — a conductor or an instrumentalist — is psychological, and it is really almost impossible to interconnect the two (Häusler et al., 1985, quoted in Bates, 2009 p. 161).*

Roxburgh (2014) rightly notes that in many pieces of the early repertoire, the tape part does not play simultaneously as the ensemble/orchestra. It becomes possible to synchronize the ensemble once again by giving gestural cues at these moments, making it easier for musicians' entries. Essentially, each entry of the ensemble or orchestra is a pivot point.

A potential compromise between the temporal rigidity of fixed media and the flexibility of live performance is triggering the fixed media part in smaller sections using pivot points, essentially dividing it into cues, thereby combining synchronization strategies. Although many performers compare the repertoire of mixed music to playing chamber music because of its cooperation (Féron & Boutard, 2018), one can wonder if it might not be more productive to view it as entirely different, emancipating it from stylistic and genre-defined boundaries.

7.4.2 Cues

From a performer's perspective, triggering cues through foot pedals or other controllers generally offers much more temporal freedom, though it has some potential drawbacks as well.

There is a critical gestural component involved in using a MIDI pedal (as with most other kinds of controllers used for triggering), especially within ensemble or chamber music playing. Biasutti et al. (2016) and Davidson & Good (2002) have shown that musicians depend on non-verbal communication to coordinate a performance, including visual coordination. In large acoustic ensembles, the conductor is responsible for this coordination. However, for smaller groups without a conductor, these cues can serve as a significant gestural and musical clue to orient themselves within the score. Being so dependent on the gestures of a musician can also have some issues. Kimura (2003) points out that it can ruin the element of surprise for the audience as the physical gesture of pressing the pedal is often very conspicuous, setting up expectations that something is bound to happen with each pedal hit. Cues can also sometimes be a natural starting point for rehearsing a piece of music, especially if they coincide with pivot points. This can make rehearsals more efficient, allowing the performers to work with the electronics section-by-section with ease.

As mentioned in the previous section, the lack of haptic feedback from many hardware possibilities for cues is still something serious to consider. The RIM's presence gives an active safety net for the performer, which gives extra security and a sparring partner to understand the piece and electronics. As Féron & Boutard (2018) found out in their questionnaire and interviews, performers are often interested in this back and forth with the RIM.

7.4.3 Following

Most of the performance literature about following focuses on pitch tracking because of its long history. There are, however, some inherent problems with various types of following. Most following strategies also require a more complex technological setup making it less realistic for a performer to rehearse it alone.

When McNutt (2003) details the situation of having many cables and devices around her flute, she may well be describing a piece using following, such as Manoury's *Jupiter* (1987), as these works often require elaborate technical setups in order to successfully 'listen' to the musician's signal. McNutt further mentions that the consequences of score following malfunctioning can be dire. Having a RIM shadowing the performer can help lessen any errors.

Several performers mention other specific following possibilities especially involving live processing. Kimura (2008) suggests the augmented violin (technically an augmented bow) creates a possibility for interactive relationships with a broader expressive palette for the performer. We have seen some possibilities of the augmented bow earlier in the thesis with the music of Baschet and Manoury.

As mentioned with *Zellen-Linien* (2007), using an envelope follower to synchronize attacks can be an effective strategy and performance technique. Pestova (2008) explains that this has caused her to modify some of her dynamic range in passages of the piece. Tremblay (2017) also says that the use of envelope followers can reduce the problems associated with the gesture of pressing a MIDI pedal.

In my own experience, the performers I have worked with were often skeptical about following, but they have typically agreed that it was a positive experience. I believe this is because following potentially gives them the means to concentrate on their playing and interpretation instead of the electronics. I do not believe that all issues disappear, but for many performers having the electronics 'out of sight and out of mind' offers them the potential comfort to render their interpretation more natural. However, following often requires more technology and specialized knowledge, which makes rehearsing at home quite challenging or impossible for the performer.

7.4.4 Click Tracks

In my experience, classical musicians dislike click tracks. While they have become increasingly ubiquitous in studio and performance contexts in many kinds of music, it seems that they feel like an impediment to classical musicians' interpretation. However, Ding (2006) reveals that click tracks let him think less about his tempo, allowing him to focus on other aspects of the music. Stroppa (1999) says we should not insult musicians by assuming that they cannot interpret music with a click and that interpretation is not solely based on rhythmic aspects. While playing the music of Alexander Schubert, I felt that the click track was helpful to help bring everyone together and that despite the strict tempo, the ensemble could find many ways to make their interpretation lively and unique. However, this music deviates considerably from the classical idiom in many ways, as discussed in Chapter VIII.

Kimura (1995) and McNutt (2003) emphasize that click tracks make musicians listen less to their surroundings, creating a disconnect between them. A click track "emphasizes the reactive, rather than interactive" (McNutt, 2003, p. 300). If the performers are not accustomed to playing with a click track, they will listen less to their environment, often at the expense of ensemble playing.

In ensembles playing with a conductor, it is common that only the conductor hears the click track, such as in Romitelli's *An Index of Metals* (2003) and Jodlowski's *Respire* (2008). In these cases, the other musicians are allowed to focus their attention on ensemble playing, and only the conductor needs to pay attention to the synchronization with the click. Roxburgh (2014) does not seem to view this situation as problematic. Thomas Adès, on the other hand, feels that it can be too constricting. While conducting his piece *In Seven Days* (2008) – in which a click track is used to synchronize the ensemble to a video – he felt the click was restrictive and problematic (Bell, 2016). In my own experience as a RIM, these situations can be challenging if the conductor deviates from the click track, and there are often not the means to resynchronize during performance.

The click track's amplitude is often too loud or too soft for many musicians and conductors, depending on the current section's dynamics, which in this genre of music usually varies considerably over the course of a piece. In the worst cases, there may even be bleed from the headphones, rendering the click audible to the audience. Although a monitoring solution such as those in studios might be helpful for them to control the amplitude of the click, it is often not feasible in a performance context.

7.4.5 The Flow of Musical Time

The flow of time is an essential aspect of music, both in composition and performance. When learning an instrument, it is customary to take a long time to understand how voices move in music and that their flow might differ. Playing music with multiple layers of changing temporality is a challenging skill to master. Although the flow of traditional forms like fugues are relatively regular and stable, this is not the case in many contemporary pieces. With the addition of electronics, the change in the flow of time is more apparent. The use of time-based effects can have a profound consequence on the performer as well. This section will look at three aspects of time for the performer:

- The use of musical foreshadowing and sampling
- The use of different time scales between the acoustic and electronic sound worlds

- Sound processing and time

7.4.5.1 Processing & Time

Live processing gives an almost limitless toolbox to the composer. Several of these effects can profoundly impact the performer, primarily because of time. Time-based effects are commonly used in mixed music. Some of these effects modulate the sound in a recognizable form, such as reverb and delay, which have a large variety of uses. Reverb can be used to place the musician in a specific space and extend a sound's length. Adding a five-second reverb to a solo violin line has a considerable effect on the listener, the performer and the tempo the performer tends to choose (Meyer, 2009). Delay can be used for canons or to thicken the instrument's timbre. A multiplication of voices, time scales and lengths makes the concept of time exciting and complex. The use of delays explicitly extends the past into the present musically and aurally. On the other hand, reverb might be seen as slightly stretching the present but still within the limits of realism.

Many other effects mangle the original sound source in ways that one might not recognize. Granular synthesis is a relevant example. As an effect, it can completely change the timbre and pitch of the sound source. In several granular synthesis algorithms, it is possible to jump at several places from the past to the present simultaneously by varying the delay time, grain rate and the modulation of the grain rate and length. Granular synthesis opens up various ways to view temporality and performance between musician and electronics. Relationships can be developed aesthetically and compositionally between time scales without necessarily being perceived as such.

7.4.5.2 Musical Foreshadowing & Sampling

Musical foreshadowing as a concept is not new. In the traditional repertoire, the foreshadowing of later developed themes is typical and a primary aspect of art music's development, as are direct repetitions in imitative counterpoint, most evidently in canons (Rosen, 1998). An early and familiar example of these ideas in electronic music is in real-time implementation of tape delays, popularized by composers like Terry Riley in the late 1960s and recording artists like Brian Eno and Robert Fripp.[61] By the 1980s, the appearance of

[61] Much of the evolution of live electronics develops in parallel between art and popular music. Figures like Terry Riley are important within art music, but he has also inspired countless popular artists such as Eno, Fripp, and many more. Eno in particular had a large hand in popularizing the idea of the studio is an instrument and laboratory.

machines such as the 4X made this practice more manageable and a trend (Akkermann, 2016). With today's technology, the possibilities for live sampling and canons of all kinds are technically effortless.

Real-time sampling can present challenges to performers as well. Assuming that the musician knows they will be sampled between specific measures, the technique can add some uncertainty to their performance. The musician may wonder: did the trigger start the sampling at the proper place? Did the sampling end at the proper place? Is the tempo correct for when it will repeat later on? These possibilities also inherently affect the flow of time as it may interrupt the agency and causality of the here and now as one hears something from several minutes ago, as discussed in Chapter V with Manoury's *Jupiter* (1987). This effect can create a temporal destabilization for the musician as they realize that what is being played at one point will be re-used later. Psychoacoustic play an important part in fusion and fission, or ability to connect elements together has a finite length as discussed in Chapter I.

These complex temporal relationships are interesting from a poietical point of view for the performer and the audience. Gingras et al. (2016) show that performers' interpretative choices are highly influenced by the formal structure of the piece they play. Therefore, awareness and understanding of these different temporalities will likely dramatically affect the musician's interpretation of the piece.

7.4.5.3 Simultaneous Time Scales

Listening and playing music with simultaneous time scales can be a challenge for both the performers and the audience. The use of live granular synthesis is an example of simultaneous time scales. An event might be happening at the sample-per-sample scale in the electronics, but the performer is playing in the meso scale. The use of grain sizes and other parameters of synthesis can create quick-shifting time scales. In the first example, two time scales happen simultaneously, but the listener may perceive these as being linked.

The difficulty of simultaneous time scales for the musician also reflects that it might not be apparent to them how the temporality may be affected by their actions. In one of my early pieces, *Studie I: Dissolving Time* (2014), the primary compositional gesture is the expansion of the piano's timbre through time stretching. In rehearsals it took one of the pianists a long time to understand that what was coming out of the speakers was a time-stretched version of her performance. Because of the extreme use of time stretch, the sound was abstracted enough from the original gestures that the relationship between the two was not clear. Another pianist understood the electronics, but he felt it was not intuitive to understand how his actions will affect the resultant manipulated signal. This temporal dissonance can be uncomfortable for the performer because the causality of a sound might not be clear.

7.4.6 Closing Words

Temporal development is an integral part of contemporary music. The "now" of the performance may shift to a "then" and can be used musically. The past, present and future can collide together and fuse into the performance on the stage, whether it is just one performer or an ensemble with a conductor. These temporal shifts can be among the significant sources of discomfort for many performers, destabilizing them from their embodied and tacit knowledge.

7.5 Musical Perception

Perception is important for performers and audiences alike. The act of listening is critical for a performer to learn how to play, to make adjustments to their performance in the musical and acoustic context, and to project properly into space. It is the basis for musical activity. In mixed music, the subject of blending between acoustic and electronic sound sources can vary from composer to composer and aesthetic to aesthetic. By blending, I mean how the electronic and acoustic sources sound related to each other. By default, a classical musician will probably try to blend their sound with an emphasis on the acoustic properties. However, as we have discussed above, monitoring does make this difficult. The presence of electronic sound sources and amplification can present significant challenges to the performer's listening.

In mixed music, the performer often has less possibility of influencing the general sonic result, especially if they cannot adequately hear how their playing will sound to the audience. For example, in a piece using ambisonics to change acoustic environments, a venue's diffuseness might help blend both sound worlds for the listener in the hall, but not necessarily for the performer on stage (Bates, 2009). There is no doubt that the musicians will adapt to the acoustics as it is part of their training, but since they cannot hear what is happening in the room, it is difficult for them to make a significant difference. McNutt (2003) mentions her preference for amplification in mixed music as it increases her feeling of blending. On the other side, several composers and RIMs have mentioned how this can also compromise the blend in some cases (Manoury, 2012; Tremblay & McLaughlin, 2009).

Electronics that involve the musician's instrument directly may help repair this disconnect. With a piano, one can easily hide piezo elements or small speakers on the soundboard. With these possibilities, the musician can directly hear the effect as if it was an acoustic instrument. However, one must still remember that this may disturb the musician's inner ear as it has affected the instrument.

For some musicians, especially while playing in an ensemble, monitoring their sound might not be so important. In a survey, Thordarson (2019) found that many musicians openly admitted to not listening or paying attention to the electronics. This lack of attention is perhaps to be expected for many professional musicians in classical music. Their job is to play their instrument, not the electronics. Specialized musicians like Berweck, Enns, Kimura and McNutt are the exception rather than the rule. In other cases, division of labour between the musicians and the technologists may produce more successful results, so that each actor may focus on their own specialties. In these cases, however, awareness of each other's roles and their musical consequences by each party can only aid the process of performing mixed music.

7.6 Conclusion

Although this thesis is written by someone who is mainly a composer and RIM, including the musicians' aesthetic aspect is crucial to our understanding of mixed music. Their perspective on composition and synchronization is essential to understand the effects of such a radical shift in playing technique, and it is essential for their composer and RIM collaborators to have an understanding of these effects.

The chapter reviewed some of the most prominent literature written by performers of mixed music to assess what they view as problematic. From there, I identified six main issues that come up through many of these texts: unfamiliarity with electronics, rehearsal time and space, notational problems, lack of haptic sensation, monitoring and visual dissonance. These issues are often interrelated in a complex web that can contribute to the difficulty of musicians approaching performing with electronics.

The chapter also explored the various performance techniques and synchronization strategies from Chapter II within the performer's context. Using real examples from the literature, it becomes clearer that each technique and strategy has its own challenges that influence the compositional process and the performance process of musicians.

Afterwards, we reflected on how temporality and how electronics change the flow of time can affect musicians while performing. There has been little literature to date focusing on this area, but I believe it is an important concept to grasp for all actors involved in the production of mixed music.

Finally, we finished the chapter with a short discussion on how the perception of electronics and instrumental sound may influence the performers and audience. Blending the sound sources is often a compositional parameter, but it is also vital for the performers to reflect on its consequence and understand their role.

I encourage composers of mixed music to consider the various issues explored throughout this chapter. While conductors such as Thomas Moore express the view that it is not the composer's job to adapt for the musician,[62] I see it as problematic when a composer uses synchronization strategies and performance techniques without reflecting on how it will affect the musician. Reflection on the performative aspects is necessarily part of a composer's work, with regard to instrumental performance (as in the use of extended techniques, registers and so on), and I believe it should be natural to consider electronics in mixed music as a part of these concerns. It boils down to a philosophical debate on the role and responsibilities of the composer and performer.

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[62] Personal conversation at the International Conference of Live Interfaces 2020 in Trondheim, Norway on the 11th of March 2020.

Chapter VIII: The RIM: At the Crossroads Between Composition & Performance

From the outside it might appear to be an awkward and uneven relationship. I don't believe this is the case, at least not during the work. I do see how the relationship changes once this creative period is over and we return to our respective spaces and social/professional "norms" take over.

-Carl Faia (2014, p. 35)

8.1 Introduction

Mixed music is often performed with a RIM, which is a role that has received little attention in the literature until recent years. Most aspects of the practice are taught via mentoring between RIMs or learned through practice, rather than in formalized settings (Zattra & Donin, 2016). Although there has been a new focus on the role, it remains largely undocumented. This chapter focuses on the RIM by first looking at the existing literature on the performance practice of the role. It goes beyond the scope of this thesis to attempt to establish a definitive outline of the RIM's standard practice (it remains a diverse and relatively young concept), but it is relevant to examine the influence of the role on the integration of synchronization strategies in the performance of mixed music. The RIM's role is often integral to synchronization and understanding how technology and music interact together. Additionally, this role directly influences all of the recordings one can hear of mixed music, which has often been the primary analysis method in the literature. The chapter explores the RIM through the available literature and draws from my own experiences as a RIM. As I have already discussed the role of the RIM during the compositional process in Chapters IV and V, this chapter focuses primarily on the role of the RIM during musical performance. Studying and developing the RIM's role is a natural extension of the performer and allows us to see how synchronization strategies and performance techniques work within a composition's actualization.

8.2 The RIM as Performer

The literature on the RIM has so far concentrated mainly on their role in the compositional process. Performance is often mentioned in passing but rarely discussed further. In essence, within both spheres of work, the RIM assumes a subservient role that is rarely documented. The complex ecosystem of mixed music with its institutional, social, musical and economic issues often make it difficult to document the whole process and result. Here we will have a brief discussion about performance for the RIM.

Although the idea of historical performance practice for the then-young forms of electroacoustic and mixed music was rarely considered in the 1980s, it has since become an area of serious debate (Benedictis, 2018). Constructivist views for the analysis of composition and performance have become common. By constructivism in this context, I mean attention to the equipment and the time in which a piece of music was made or performed, as these aspects may have a considerable musical influence (Battier, 2003). Benedictis (2018) uses an example of how performance practice has often been documented and learned through watching and hearing previous performances of a specific work. A lack of documentation on performance practice has long been an issue, even for large institutions such as IRCAM and SWR Experimentalstudio, though important strides are being made.

Because of Moore's Law and the abandonment of earlier hardware and software, updating a piece's electronics becomes an everyday act for many RIMs (Faia, 2014; Zattra & Donin, 2016). IRCAM's increasing role in documenting and updating its repertoire has often been touted as one of its strength, and for composers it is considered one of the essential privileges of working with the institution. Faia's work list includes many ports, and a flux of articles about porting works have been published recently, such as Akkermann (2016), Boutard (2016) and Coccioli & Bullock (2005), among others.

Chapter III explored some issues of authorship because of the RIM's presence in the compositional process, but the question arises again under a different guise for performance: is it always possible to know what the composer wants? Zattra & Donin (2016) quote a RIM explaining that it is often impossible to do so, especially with older works where the composer may no longer be familiar with present-day technologies, or even still living! In some cases, a piece of equipment may no longer be available, representing significant challenges toward re-creating its functions and the sounds it affords. "Errors" often become part of the aesthetics of a piece, and newer equipment or software may not be able to replicate these errors in the same way. In many cases it becomes ambiguous whether or not the RIM should fix these errors, or preserve them as an element that has become ingrained within a piece's practice (intended by the composer or not). And so, interpretation is an essential aspect of the RIM's work before a concert, but it can be a difficult task where little information or documentation is available.

The RIM has a considerable influence on the result of the concert. They often have considerable control over essential aspects of the performance: sonically, dynamically, temporally, and beyond. If we look back at the actor-network discussed in Chapter II, we can see that the RIM is a central role. Many IRCAM-produced concerts will have two people devoted to the same task, one operating as a backup in case of errors. This is indicative of how vital the RIM is for the successful realization of the piece. Outside of the large institutions, often only one RIM is present for this task due to financial limitations. In my own experiences, I am usually the only RIM involved on a project, often with a sound engineer functioning as the in-house technician, but in many cases this role is also folded into the work of a single RIM.

Additionally, interactions between the RIM and the performers are essential and can significantly influence the performance. Most performers know little about electronics, as discussed in the previous chapter, and therefore the RIM plays an important role in communicating the technical aspects of the work, addressing any questions the players may have. Although the influence of these interactions might be minimal in well-known pieces, it can be profound on pieces the performer is not well acquainted with, and indispensible for the creation of new works. Tremblay (2012) refers to the RIM as a type of mentor for the instrumentalist. It is not uncommon for musicians to be confronted with the electronics only at the dress rehearsal, effectively meaning that the RIM has little room for error (Furniss & Dudas, 2014). A single error can sometimes completely derail the performance for all musicians involved, which many RIMs (myself included) learn the hard way.

The RIM's role may also include technical tasks for a concert if a sound technician is not present. If a sound technician is hired, then their tasks are mainly related to being the intermediary between technical and musical aspects. Common questions a RIM may need to address include: "How does the tape work? What equipment is needed to run the electronics? How do the Max/MSP patches work in relation to the musicians?" and "How do we keep time and synchronize?" It is an invisible role for many musicians, composers and audience members. Questionnaires sent to many RIMs show that it is still far from unusual to be omitted in the program notes, although that has been quickly changing (Zattra & Donin, 2016). In my experience, the invisibility of the RIM can result in them being considered an after-thought, which in the worst cases can involve challenging situations, such as being called at the last minute to assist with concert productions with little to no pay. Often, the organizers have little understanding about the electronics, what equipment is needed, and how much time is needed.

The RIM is also an important figure for the documentation of composition and performance. Inherently, this means that they have a significant influence on the dissemination and availability of the music. In some cases, the RIM does not provide any documentation on the electronics. This can lead to signficant difficulties in performing the music, and in these cases there can be considerable variations between performances of the same work. Even frequently-performed works in the repertoire, such as those by Luigi Nono, often lack this documentation (Boutard, 2019). Because of the lack of standardization and formalization of the role, informal training and mentoring is essential for the life of this music. There is no doubt that figures such as Miller Puckette, Andrew Gerszo, Gilbert Nouno, among many others, have been central to spreading knowledge on technical, compositional and artistic practices. As Boutard (2019) suggests, it is not easy to be a good RIM if you are not a good musician. This does not mean that one must be a virtuoso player on a given instrument, but understanding the music and playing with it is essential to the task. This role is essentially precisely where musicality and technicality cross into each other.

8.3 Practice-Based Research as a RIM

This thesis draws extensively upon my own experience as a RIM. Having a different role than a performer and composer has helped assess what works, why and how when it comes to synchronization strategies. These experiences have been invaluable in comparing my artistic production as a composer to others' and understanding the significant effects of synchronization strategies. This chapter explores eight of the compositions I have performed as a RIM. These performances have generally come through my work as a freelance musician or in pedagogical contexts such as Manifeste Academy at IRCAM in 2019. As a freelance RIM, I have not been involved in the programming of works, and so have not had exhaustive experience in each synchronization strategy. Further, the expectations on freelance RIMs are often different from those working in institutional contexts, where resources often afford much greater preparation. In my case, I usually receive the performance materials in as few as one or two weeks, or sometimes even only days in advance, offering little time to ensure that everything is ready for rehearsals. Several additional concerts for some of these compositions and new pieces were planned but cancelled due to covid, including six concerts with Schubert's music. Other pieces by the likes of Jodlowski, Harvey and Ferneyhough had also been planned.

The pieces to be explored in this chapter are:

- Romitelli – *An Index of Metals* (2003) with Trondheim Sinfonietta
- Schubert – *Hello* (2014) with Trondheim Sinfonietta
- Schubert – *Star Me Kitten* (2015) with Trondheim Sinfonietta
- Schubert – *Sensate Focus* (2014) with Trondheim Sinfonietta

- Tzortzis – *Incompatible(s) IV* (2010) at Manifeste 2019
- Saariaho – *Laconisme de l'aile* (1982) with Trine Knutsen
- Jodlowski – *60 Loops* (2006) with freelance musicians
- Kanding – *Obscure Transparence I* (2013) with Trondheim Sinfonietta

For each composition, we will explore the conception of the piece, which issues came up during rehearsals and discuss the possibility and effects of changing synchronization strategies and/or performance technique. This was not possible to do for each piece due to budgetary and time concerts, but it is a valuable exercise to analyze the links between the performance for various actors and the compositional elements of synchronization.

8.3.1 Romitelli's An Index of Metals (2003)

Fausto Romitelli (1963-2004) was an Italian composer who tragically died of cancer. He studied with and absorbed the styles of Hugues Dufourt and Gérard Grisey. His style is often described as post-spectral. His music is also deeply influenced by several popular music streams, mostly psychedelic and progressive rock. This poly-stylistic music is often wild and unpredictable, combining spectralism with psychedelic rock's energy in an idiosyncratic manner. His style is an important stepping stone for what has become known as saturationism, with composers of the style like Bedrossian, Cendo and Robin mentioning him as an important figure (Rigaudière, 2014). An *Index of Metals* (2003) is an opera for twelve amplified musicians with electronics and video. The piece is about 45 minutes long.

This challenging and intricate opera was the biggest project the Trondheim Sinfonietta produced in its 2019 season. It was played once at Dokkhuset on the 1st of March 2019, conducted by Christian Eggen.

8.3.1.1 Conception of the piece

An Index of Metals (2003) is Romitelli's last large piece. He wrote the music while the artists Paolo Pachini and Leonardo Romoli created the video. The sections of the work are interleaved with "techno intermissions"[63]contributed by the Finnish electronica group Pan Sonic, Francesco Giomi worked as the RIM, and the text is by Kenka Lèkovich. The score features a slightly unusual chamber ensemble of flute, oboe, clarinet, trumpet, trombone,

[63] This is how they are described by the ensemble that premiered the piece, Ictus. Their recording (2005) is the only version of this opera commercially available for both CD and DVD..

electric guitar, piano (as well as MIDI keyboard for some electronic sounds), violin, viola, cello, electric bass and a soprano as soloist. Both the guitar and bass are distorted, and this is an essential aspect of their timbre. There is no specific indication of which type of distortion should be used or any pedal recommendation.

In his program notes for the premiere, Romitelli (2005) mentions that this piece extends the psychedelic themes from his earlier work *Professor Bad Trip* (1998). His opera endeavours to create a secular ritual combining aspects of the modern rave party, light shows from the sixties, and opera. Romitelli explicitly explained that this is not meant as a renewal of the genre of opera, but rather a full multimedia experience. He stated: "An *Index of Metals* will be this abstract violent narration, distilled from all the artifice of opera, an initiation rite of immersion, a trance of light and sound" (Romitelli 2005, p. 140).[64]

The video is projected on to three separate screens. The video part is somewhat abstract, derived from extreme close-ups of various materials. The electronics consist of fixed media and amplification. There is a ten-speaker sound system around the audience. However, only the fixed media is sent to this system. The amplification is in stereo, and the score notes specifically mention how the sound engineer can be somewhat creative with effects on the instruments. The original Max/MSP patches from 2003 were included with the performance materials, but I could not open them when using Max/MSP 5 to 8. A more recent version of the electronics realized in QLab (which streamlines the cueing system)) was also included, created by the Ictus percussionist Gerrit Nulens, and this is the patch we used for this performance. The main issue we encountered with QLab has been timing, as there is a varying amount of delay when trying to trigger files. I often had to trigger events quite a bit before the beat in order to synchronize with the ensemble.

8.3.1.2 Rehearsal Notes & Concert

This piece required much preparation, such as reading through all of the documentation, learning the piece by heart, and editing the QLab files. There is a version of the score annotated for cue-following, but it is missing significant details from the full score, which sometimes makes it difficult to follow. I did not receive any example files of how the piece should sound, and the score itself is not always clear. Therefore, I quickly ordered the commercially-available recording from Ictus and watched all versions available on YouTube

[64] *An Index of Metals sera cette narration abstraite et violente, épurée de tous les artifices de l'opéra, un rite initiatique d'immersion, une transe lumino-sonore.*

as preparation (Ictus, 2006; Unknown, 2015; Sistema Michoacano de Radio y Television, 2015; Stipek, 2014).

The piece is challenging because it varies between multiple synchronization strategies and performance techniques, including the use of a click track, human following, and triggering events following chronometric time. I created a new document with information about each cue, which allowed me to answer any technical or synchronization questions from the conductor and/or musicians during rehearsals.

While rehearsing alone, it was clear that the most challenging cues to synchronize with the ensemble were 11 to 24. The final cadenza was also not possible to rehearse alone, and the cue-annotated score gave no information about it. In total, the piece has 56 cues.

Like all projects with the Sinfonietta, we had three rehearsals and then the dress rehearsal. The first rehearsal was acoustic, but I still attended it to meet the conductor and ensure mutual understanding. The two first rehearsals were done in the chamber music hall at the Norwegian University of Science and Technology (NTNU), which meant everything had to be in stereo and that the rigging was done quickly by another musician and myself. We only had the third rehearsal at the concert location – without being allowed to use the sound system. It was not until the dress rehearsal that we had had a sound technician and full sound system.

During the first rehearsal, we had to come up with a solution to where I as the RIM should be positioned in the hall. The conductor wanted me to sit in with the ensemble so I could follow him, but I was able to convince him that it is more important for me to be at the FOH position to be able to communicate with the sound technician and to be able to hear and see (as I was also responsible for the video part) everything that is happening. The original documentation for the piece mentions using a camera and analogue monitor for the cue operator. However, because of budgetary and logistic issues, the sinfonietta did not choose this option. This meant that I had to learn the piece thoroughly by heart, in order to read and often anticipate Eggen's movements from behind. Although this represented a significant challenge, with only one RIM present, it was the only feasible solution.

The second rehearsal included the electronics as well as artistic discussions related to synchronization. For example, at cue ten (22:07-22:27 in the full production), we decided that the phrasing was not working, which made us add a single beat at the end of the cue. It was also a significant challenge to negotiate between the musical tempi the chronometric sections, and the click track. The conductor may not have always been able to adequately hear the click track, and so with the limited time we had in rehearsals I found it was much more efficient for me to adapt to the conductor's tempo rather than troubleshooting any synchronization problems. For example, during the third rehearsal, it became clear to me that often I could give or take up to five seconds in the tenth cue to adjust everything to the conductor's tempi, which helped with the phrasing. It was easier for me to adapt myself without affecting the synchronization too much. I wonder if this deviation tolerance was intended or a consequence of choices of the production team when Romitelli wrote the piece. I tend to believe the latter.

The soundcheck and dress rehearsal revealed further issues. The first we encountered was that, without warning, the surround sound had to be reduced from ten to six channels due to equipment limitations at the venue. This left me no time to reconfigure the files. Our sound technician was also mainly from a rock and pop background, meaning he was less experienced in the particular needs of this kind of music. This meant that I often had to check my levels throughout the concert and often lower the gain on all channels in order to achieve the correct balance, which I could not have done sitting with the ensemble. This kind of last-minute problem solving has been a fixture of my experiences in mixed music concerts. In these challenging conditions, a RIM has to rapidly adapt to changing situations, often sacrificing features necessary to an ideal presentation of the work.

8.3.1.3 Shifting Synchronization Strategies

The piece mainly uses cues to trigger fixed media. A click track, chronometer and human following are used as performance synchronization techniques. In Table 17, I have presented the performance techniques as four categories. The hybrid category is a mix of one or several of these performance strategies. "Loose" means human following, but it might be written in the score as following the conductor and shows deviation tolerance. Figure 59 presents the synchronization's layers and hierarchy. It is of note that I have written that the conductor influences the RIM and not the other way around, reflecting the conductor's traditional role as the artistic director of the piece.

Table 17. Synchronization in An Index of Metals (2003)

Event	Performance Technique
1	Conductor
2	Chronometric
3	Loose
4	Chronometric
5	Chronometric
6	Conductor
7	Hybrid
8	Chronometric
9	Chronometric
10	Hybrid
11	Conductor
12	Loose
13	Loose
14	Loose
15	Loose
16	Loose

17	Loose
18	Loose
19	Loose
20	Loose
21	Loose
22	Loose
23	Loose
24	Loose
25	Loose
26	Loose
27	Conductor
28	Loose
29	Click
30	Click

31	Click
32	Click
33	Click
34	Click
35	Click
36	Click
37	Click
38	Click
39	Loose
40	Loose
41	Loose
42	Loose
43	Loose
44	Loose

45	Loose
46	Loose
47	Loose
48	Loose
49	Loose
50	Loose
51	Click
52	Click
53	Conductor
54	Conductor
55	Conductor
56	Conductor

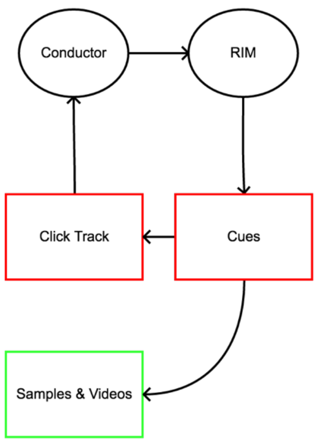

Figure 59. Synchronization layers in An Index of Metals (2003)

We will now look at the possibility of shifting synchronization strategies and performance techniques and how they would influence the performance. Because of the length of the piece, I will only draw attention to a few cues that exemplify the synchronization challenges in the composition. For reference, I will refer to timestamps from the recording by Ictus Ensemble (2006), which as of writing remains the only commercially-available recording of the work. The example files are drawn from the concert with Trondheim Sinfonietta, mixed by myself.

I will not be discussing the use of sensors or camera possibilities for any of these cues. Because of the ensemble's size and scenic elements with the videos, these possibilities represent significant expense and risk, in my opinion. Table 18 gives detailed information about each cue for the following sections.

Table 18. Cue comparison with synchronization in An Index of Metals (2003)

Cue #	**Measure**	**Ictus Time**
2	51	Track 2, final seconds Track 3, from 00:00
10	451	Track 5 from 06:02
27	641	Track 8 from 00:00
39	695	Track 10 from 00:24

8.3.1.3.1 Cue Two (04:53-05:13)

Cue number two arrives at a crucial point in the composition. In the most recent revision of the piece, one should trigger cue two after 05:12 from the beginning of the piece, then after three and a half beats, trigger the third cue, which is only affects the video part. Chronometric time is also used to indicate the timing of cues four (audio) and five (video). However, within the score, the next cues are based on the time of other overlapping sound files. The second cue triggers a file that is 07:32 long, which ends around the beginning of cue four. The sound example starts about 5 seconds before cue two is launched and gives an idea of the musical context surrounding the onset of the cue. The scoring here is sparse. The foregrounded musical aspect is the soloist singing the word "shining," which begins five measures after the start of the cue, as shown in Figure 60. The piece's current use of the chronometer has some advantages in this section. It affords precise timing of the cue, allowing the RIM to trigger at the correct moment with ease.

The electronics here consist of subtle harmonies with slow glissandi in the background. The chronometer is used to synchronize the long glissando with the guitar, bass, and piano harmonies. Separating this file into shorter files to trigger them at different points would not offer much further flexibility to the piece: the sound is continuous and does not lend itself well to being separated. If the conductor would cue this section, there could be an offset, and so the use of the chronometer allows the RIM to ensure accurate timing independently. A score follower's use to trigger the second cue is also not practical as no instruments are playing where it should be triggered.

Figure 60. Measure 56 of An Index of Metals (2003)

One feasible alternative solution could be integrating the electronics as part of the keyboard part. It would eliminate issues of synchronization as the tape follows the keyboard voice closely. The sound in the fixed media would be easy to reproduce live as samples triggered from the MIDI keyboard. The score itself does not have much information on the keyboard's sound, offering significant room to for interpretation. This solution would free up the RIM to focus on other important aspects of their task during this section, such as controlling the levels and spatialization. While this solution puts a bit more responsibility on the keyboard player, their existing part is almost identical to the electronics, allowing them to be integrated easily into their notated part with few modifications.

Another possible solution could be to use pitch following on the vocalist. Each time the appropriate section is triggered, a MIDI file could then be sent to a live synthesis engine as if the keyboardist was playing. This idea presents the risk that the RIM may be required to shadow all of the parts of the glissando in case of any errors, but it could still work musically.

8.3.1.3.2 Cue Ten (22:07-22:27)

Cue ten marks the beginning of a musical transition. This cue occurs in the middle of the piece's action. Figure 61 shows the measures leading up to cue ten in Figure 62. The cue is again synchronized with the use of the chronometer. The electronics only play a short sound file in channels nine and ten of the surround array.

What are some of the alternative possibilities to synchronize this section? The conductor could have a MIDI pedal that cues the file. However, the piece is already challenging to conduct, and not every conductor is comfortable with a MIDI pedal. Score following could also work in this section by following certain instruments. The flute, clarinet, keyboard, cello or bass are all playing materials that could be used as input for following. The current solution may indeed offer the best possibility. It is also possible for the RIM to follow the music and trigger the cue by following the conductor. I have highlighted the most salient musical features of the section which I used to synchronize the electronics. In our performance of the work, I found that this solution was much simpler than attempting to coordinate to absolute time. This is because the electronics are not too rhythmic, which means the deviation tolerance is higher.

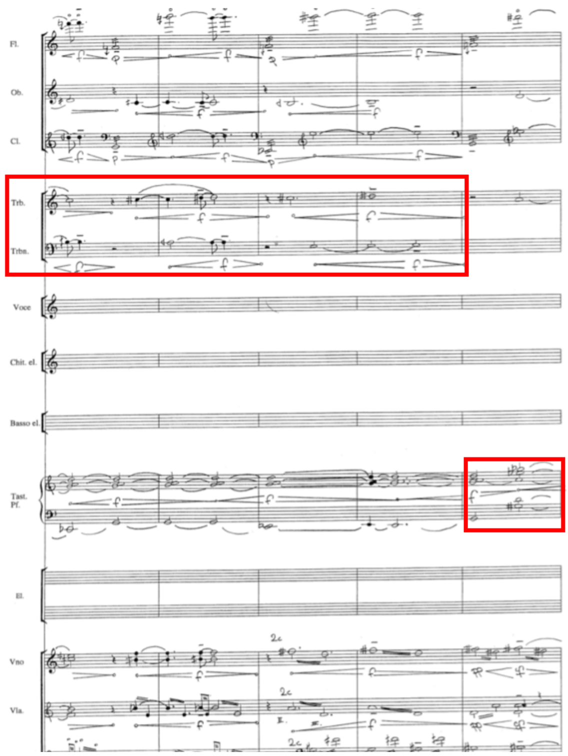

Figure 61. Mm. 446-550 leading up to cue 10 in An Index of Metals (2003)

Figure 62. Cue 10 in An Index of Metals (2003)

8.3.1.3.3 Cue 27 (32:03-32:35)

Cue 27 is straightforward since the conductor signals it. Right before the cue, the last gesture can be seen below in Figure 63. The cue is easy for the RIM because the timing is clear. The most salient features from right before the cue and on the cue are highlighted.
In this section, the fixed media file is a series of swells with a high deviation tolerance. Additionally, the RIM will trigger several "stingers" in the following cues (such as at 33:18), which are bubble-like sounds with glissandi. A possible alternative again would be to let the conductor trigger this cue through a MIDI pedal. However, since the fixed media is not heard at once, these kinds of cues present greater risk of double-pedals, as the conductor would not be able to immediately hear whether or not the trigger was successful. The conductor could similarly trigger the next few cues, but in any case, this strategy retains the challenge that the conductor's task in this piece is already quite ample.

Score following would be difficult to implement in this section. Several of the instruments are playing long swells or repeated notes, both of which are difficult to use as distinctive 'signposts' for software to accurately detect. The exception is the piano, which plays chords that fall on the first beat. As with the previous example, this would still require shadowing from the RIM. Therefore, I do think that having the RIM follow the conductor and trigger these cues independently is the most effective solution.

Figure 63. Last page before cue 27 in An Index of Metals (2003)

Figure 64. Cue 27 in An Index of Metals (2003)

8.3.1.3.4 Cue 39 (37:08-38:17)

Cue 39 marks the beginning of the opera's climax. The fixed media file is a spatialized guitar chord that sustains longer than the actual guitarist's corresponding chord, extending this sonority. The following cues function similarly and in the same musical context. The primary musical cue in this section comes from the soloist, which is clear and cuts through the thick instrumental gesture.

Since the guitar player is playing the same chord as the electronics, another possible solution for this cue could be extra live processing on the guitar. A similar sound, timbre and profile would not be challenging to re-create with digital or analogue equipment. There are several other options. The soloist could use a MIDI pedal as she sings the word "are" in the same measure. The guitar player themself would also be a natural choice to trigger a pedal here, as electric guitarists are often accustomed to performing with effects pedals. Score following would also be feasible to implement in these sections. The voice and piano especially have musical materials that would not present any issues with pitch detection. It would also be possible with the guitar and bass, especially if using envelope detection as well.

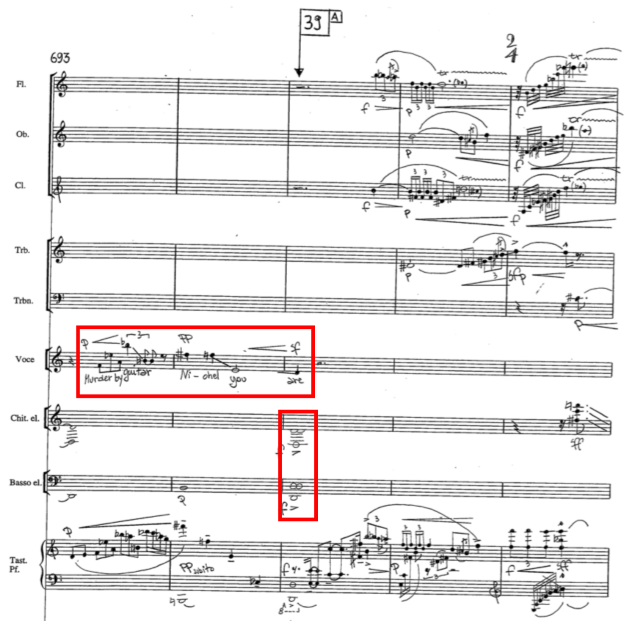

Figure 65. Cue 39 in An Index of Metals (2003)

8.3.1.4 Conclusion

In discussions with the conductor Christian Eggen, we concluded that the electronics often felt rushed and not always well adapted to the musical context. The various synchronization performance techniques represented significant challenges in certain sections of the piece. The synchronization often feels rigid, which seems to contradict the overall *écriture* of the piece. This may be a consequence of the electronics being made by Pan Sonic separately from the composer. The electronics often serve to expand the existing instrumental sound world by doubling the material the ensemble performs, especially the electric guitar and bass. In many cases, a similar result could be achieved through the use of effects pedals on those two instruments alone. The score offers no specific information on pedals or other manipulations of those instruments' signals, and so as the RIM it was important for me to coordinate with both musicians to ensure an appropriate sound in the context of the electronics.

The use of chronometric time in many of the cues is interesting. As I see it, it makes the piece easier to perform without the specialized training of a RIM. It makes the job more manageable, allowing one to concentrate more on balancing issues and creative use of effects as the composer asks for. However, some of the cues are also quite constricting for the conductor, and in this sense, Romitelli's opera presents an interesting case study in trying to manage issues of how challenging cues can be between the RIM and conductor. Having a second RIM could mitigate some of these challenges considerably, but this is of course not always feasible.

This piece is an excellent example of how logistics, pragmaticism and artistic vision interact and sometimes compete in mixed music. These elements are challenging considerations for a composer, and in this case alternate strategies at the compositional level may have mitigated the challenges in performing the work. I hope to be able to perform this piece again and compare both experiences. Although the electronics are often written as if everything should be rhythmically rigorous, this is far from being the case.

8.3.2 Schubert's Hello (2014), Sensate Focus (2014) & Star Me Kitten (2015)

Alexander Schubert is a German composer born in 1979. Unlike many composers with a more traditional background, he started his career by studying bioinformatics and media composition. Despite his young age, he has already won many awards and been granted several prestigious commissions by the likes of IRCAM, SWR, ZKM and many more. Walshe (2016) considers him part of what she has termed the "New Discipline" movement, although Schubert himself does not agree or understand this classification (Kanga & Schubert, 2016). Schubert's music has overt influence and referentiality to popular music and culture. Many of his pieces include video and the use of sensors. In recent years his music has started to garner discussion in academic circles by authors such as Ciciliani & Mojzysz (2014), Moore (2020) and through his own writings (Schubert, 2019; 2021).

On March 28th, 2019, Trondheim Sinfonietta played a portrait concert of Schubert's music. In February 2021, we reprised one of these works, *Sensate Focus* (2014), twice at an art opening. Further concerts had been planned for 2020 but had to be cancelled due to the COVID-19 pandemic. This section details our experience performing three of Schubert's pieces : *Hello* (2014), *Sensate Focus* (2014) and *Star Me Kitten* (2015). Because of the concert location— a tiny theatre (5m x 7m) — it was necessary for me to position myself within the ensemble of musicians, presenting certain challenges. However, in this case we had a FOH engineer who was well-situated to the performance of this kind of music, and so I was able to focus on the performative aspects of my role and delegate concerns of balance and sound reinforcement to him. Although these are three completely separate pieces, the strategies for synchronization are similar for our intents and purposes, and they are therefore combined into one section.

8.3.2.1 Conception of the Pieces

8.3.2.1.1 Hello (2014)

Hello (2014) is an audio-visual piece that needs at least four musicians, including percussion and guitar or piano. It is a playful composition with an overt influence from techno and hardcore punk. The hybrid score features 42 symbols that give the musicians information about their performance gestures and the electronics. Several of these gestures are completely open to the ensemble to define both visually and musically, offering significant freedom to the performers in determining not only the instrumentation, but also the overall musical and visual result,

The electronics are made in Ableton Live and there are three versions of the piece. The various versions are musically identical, but one includes a remade video of higher quality, while the third project includes a new video with Evy Schubert, which dramatically changes the narrative of the work. The Ableton project files make the electronics relatively accessible since they have no third-party VSTs.

There are two audio effects in the piece: a reverb and a delay. Additionally, there are several sections in which the ensemble is recorded in real-time. These buffers are then looped, stretched, pitch-shifted and panned. The fixed media consists of mainly percussive sounds.

The video matches most of the musicians' gestures, which creates a "precise mapping between visual gestures and sound" (Kanga & Schubert, 2016, p. 550). The video has a narrative of its own, but it also comments on what the ensemble plays in an absurd, surrealistic and often humoristic manner.

8.3.2.1.2 Sensate Focus (2014)

Sensate Focus (2014) is scored for electric guitar, bass clarinet, violin, percussion, live electronics, and lights.[65] Schubert (Kanga & Schubert, 2016) explains that the point of the lighting in the piece is to "create the illusion that the ensemble on stage is a digital projection" (p. 535). The score specifies that the musicians must perform in as machine-like a manner as possible. All physical and musical gestures are highly exaggerated.

Once again, Ableton Live is used to operate the electronics. There is little in the project except for MIDI information, which is then translated into a DMX signal to control the spotlights. There are also two fixed media files: a "violin tape & tape" file and a rendered version of the instruments' processing. A Max/MSP patch helps connect Ableton Live to the DMX signal and gives a GUI to test if everything is correct. To connect the computer to the lights, one needs a USB-to-DMX switch.

The notation of the piece is similar to *Hello* (2014). This time the symbols already have various associations, and some pitches are written. Much of the notation details how the musicians should move and react along to the fixed media. The focus on gestures and light brings the piece closer to multimedia performance art than classical music performance. It is not physically possible for the musicians to play along at several points in the piece, invoking a surrealistic and exaggerated aesthetic. An example is measures 421 to 503 (12:12-12:52), where the tempo goes from 65 to 999 bpm. This 'impossible' section highlights the aesthetic of error for humans while the machine plays it perfectly. It also presents an interesting challenge in negotiating between having low deviation tolerance and deviation becoming the goal of a gesture.

8.3.2.1.3 Star Me Kitten (2015)

Star Me Kitten (2015) is a piece for a variable ensemble with a singer/speaker. The piece begins as though the singer is about to do a PowerPoint presentation, but chaos ensues.

[65] The Trondheim Sinfonietta transposed the violin voice to the cello.

Like much of Schubert's work, the piece is playful and features a strong connection between sound and visuals.

Ableton Live is used again. Each ensemble that plays the work is asked to edit the video to include a few pictures or videos from the performers themselves. For example, the ensemble must include a clip of the singer on vacation, sleeping and rehearsing the piece. There are two slots for including commercials of eight and three seconds, respectively. There are two input channels for processing: the voice and the sum of the ensemble. Much like *Hello* (2014), the live processing consists of reverb and delays, which are automated. There is also a fixed media part.

The score once again features heavy use of symbols representing various aspects of gestures, playing and organization. Organization means groupings within the ensemble, which will play different musical cues. Musically there are more references to contemporary music here than in the two previously described pieces. *Star Me Kitten* (2015) plagiarises (to use Schubert's own words) the music of Romitelli and the free jazz band The Thing. Additionally, and there are references to metal, drone, and the music of Helmut Lachenmann. The piece actively involves the RIM in the theatricality of the work. In section E (04:24), the RIM needs to act as though the computer is crashing. The piece's unique narrative scenario creates a self-referential blurring between an academic-like presentation of the piece, a description of how it will be played, and what might be called "the piece itself."

8.3.2.1.4 General Conception & Aesthetics

All three pieces have high energy and are loud. They employ humour, social commentary and sometimes even social taboos. An essential aspect of Schubert's work is also breaking the fourth wall, especially in the narratives of *Star Me Kitten* (2015) and *Hello* (2014). The relationship between human and machine is often set in focus, as is the concept of error (Schubert, 2019). Theatricality is vital in these pieces, and they thread the limit in a playful manner between performance art, theatre, mixed music and popular music.

From a more musical perspective, the structures and harmonies are straightforward and simple. There are no complex harmonies, gestures or extended techniques. His sense of rhythm is often four on the floor, playing around that as a clear reference to electronic dance music. These pieces may seem slap-stick at first to certain listeners, but gestures, sound, human/machine relations, and synchronization are at the forefront in every one of them.

8.3.2.2 Rehearsal Notes & Concert

As with most Trondheim Sinfonietta projects, we had three rehearsals and a dress rehearsal before the actual concert. From a technological perspective, these three pieces were straightforward. The only problem we had was with the USB-to-DMX adapter, which did not work correctly. I later learned that this particular adapter seems to have known issues. For the concert in 2021, we had bought another adapter which worked without issue.

For the first two rehearsals, we rehearsed only with the click and tape. In general, the musical difficulties arose mainly in understanding what to do and getting accustomed to playing with the click. The musicians seemed to have fewer issues in understanding and familiarizing themselves with the electronics. The videos and fixed media files show a direct and easy-to-understand relationship between the musicians, the score and the electronics.

During the concert, the main issue was the venue's size which forced me to sit at the musicians' side, making monitoring challenging. However, this placement for the electronics felt appropriate to the more theatrical aspect of Schubert's music. At certain points, I found myself acting out my role in an exaggerated, theatrical manner for the sake of each piece's hyper-stylized performative narrative.

8.3.2.3 Synchronization Strategies

All three pieces use both fixed media as a synchronization strategy with the help of the click track performance technique. Two of the pieces use fixed media as their primary strategy, while the third uses cues. Schubert describes this setup as straightforward and easy for synchronization (Kanga & Schubert, 2016). Although the presence of video likely influenced this strategy, the rhythmic drive of Schubert's music is also at the heart of this choice.

The dependence on the click track might lead to a lack of embodiment for some of the musicians. Schubert notes that his use of sensors in other pieces can afford a more embodied performance (Moore, 2020). However, there is no doubt that the use of sensors presents more technical complications and requires more rehearsal time. Could other synchronization strategies and performance techniques work for these three pieces?

In *Sensate Focus* (2014), there would not be any significant issues in separating the piece into sections triggered either by one of the musicians or the RIM. This could make the piece less physical to a certain extent, but it would be completely feasible. It would give slightly more freedom to the musicians to catch their breath. However, in the grand scheme of things, I would not consider it appropriate to the piece. It is also possible that most musicians would find it too difficult to use a MIDI pedal in combination with the piece's demanding physicality.

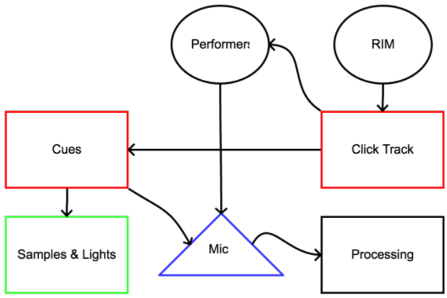

Figure 66. Synchronization layers in Sensate Focus (2014)

In *Hello* (2014) and *Star Me Kitten* (2015), there are a few technical issues to consider. If one wanted to create cues for the work, one would need to separate the piece into sections, including the video. Already here, one runs into the problem that Ableton Live does not allow video clips to be initiated from the session view, which would be necessary to operate the work in its current software configuration. However, it is possible to find a solution by using Max for Live to trigger the video clips. There is the further issue that one would need to modify or somehow extend the video clips, or else leave the screen blank during moments where the triggering of the cues does not align exactly with the video as it exists in its fixed form. This subtle change between the video's main cues could dramatically lessen the narrative's effect in both pieces. One could use cues with a click track making every clip/section start on the beat. However, if the musicians do not listen to the click track, they would still go off tempo. The only advantage is if the musicians wanted to be more self-sufficient. In *Star Me Kitten* (2015), the RIM's role is needed for the piece's theatrical aspects, and so a 'self-sufficient' alternative for the electronics would lose this aspect of the work.

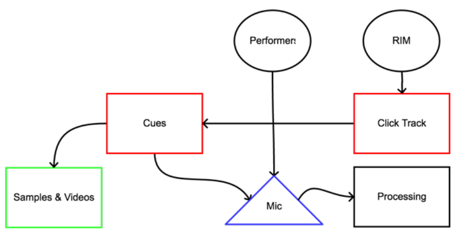

Figure 67. Synchronization layers for Hello (2014) & Star Me Kitten (2015)

Anything based on pitch tracking would be pointless because Schubert's music is often not pitch-based, or else the pitches are improvised. Many of the notated physical gestures produce little to no sound. At best, such an approach would be unstable. An envelope follower would encounter similar problems. Additionally, the pieces are loud and active, increasing the potential of false triggering.

Gesture tracking could be a better idea, but camera-based tracking systems would not be possible for *Sensate Focus* (2014) due to the flashing lights. The two other pieces might also be challenging because of the changing light from the video part. Another possibility is various types of sensors, such as gestural controllers like the Wiimote. However, because of the quickly shifting emphasis on pitch, gestures, and acting, it could be challenging to create a robust system to support all three pieces. In this case, gesture-based tracking would need to be supplemented with a backup plan because of how rhythmically precise the music is. Each time a cue is late or early by a few milliseconds, it could severely disrupt the use of video in particular.

There is little doubt that using the click track with fixed media is the most straightforward way, and the most appropriate to the aesthetic of Schubert's music. It forces the performers to be more "on the edge of their seats" which seems to be a desirable performance energy for the works. Additionally, because of the mechanical feeling of the music, it makes sense for the musicians to react to and attempt to emulate the electronics, rather than the contrary.

8.3.2.4 Conclusion

Schubert's three pieces employ similar synchronization strategies. Much like Jodlowski and Romitelli, Schubert is influenced by popular culture, but this influence is often more overt in his works. His use of video and theatricality greatly influences his aesthetics. Schubert's use of technology is not meant to blend into the classical tradition, unlike many previously mentioned pieces, but rather to create new work that plays with the classical frame. For example, *Star Me Kitten* (2015) actively pokes fun at the idea of what contemporary music can be. Is the piece a presentation? Is it theatre? The delineation between human and machine is actively problematized in his music. Computers actively crash "on purpose" and make human errors, while humans act robotically. He calls upon the musicians to perform like actors, often notating theatrical performance gestures more than sounds. Schubert explores what he can deconstruct through his music. His use of technology is not a mere addition to his musical aesthetics: they are one and the same. Although his use of electronics might seem simple at first glance, they are meticulously planned and created with the total conception of the work as multi-media performance in mind. His work brings the idea of the *gesamtkunstwerk* into the 21st century while poking fun at the 20th century's attempts.

8.3.3 Tzortzis' Incompatible(s) IV (2010)

Nicolas Tzortzis (b. 1978) is a Greek composer that is currently established in France. He has a Ph.D. from the Université de Montréal, Canada, which he completed in 2012 with Philippe Leroux and Denis Gougeon, and completed the then two-year Cursus program at IRCAM. There is no scholarly study of Tzortzis' pieces to date. The Incompatible(s) series spans ten pieces for varying instrumentation. For Tzortzis, this series focuses on how to use heterogeneous material. He believes that the acoustic writing and the electronics come from two dissimilar sources that it is his task to blend (Merlin, 2019).

8.3.3.1 Conception of the Piece

Incompatible(s) IV (2010) is a piece for bass clarinet and electronics. It was written when Tzortzis was studying at IRCAM. The music is physically demanding on the performer. It features extended techniques on the instrument ranging from bisbigliando to multiphonics to buzz tones, among many others.

The composition is based around several gestures that relentlessly lead into each other. Although the piece does not problematize or make this aspect theatrical, it is an integral part of its aesthetics. The electronics only reinforce the piece's brutality. There are a myriad of processing techniques in the piece, as shown below.

- Three filters, each with two frequency responses and interpolations
- Two harmonizers. One works similarly to the one in *Laconisme de l'aile* (1982), while the other has pre-determined lists of how the signal is transposed
- A randomized pitch shifter.
- Granular synthesis
- Cross-synthesis
- Two spectral delays which interpolate between two presets
- Convolution
- Freeze function (frequency)

- Traditional overdrive
- Single tap delay with feedback
- Time-stretch
- Reverb
- Spatialization on eight discrete channels
- Fixed media files. Most of these are closely related to the sounds the clarinettist makes. Most files are short, but several are around one minute or more.

8.3.3.2 Rehearsal Notes & Concert

I was assigned this piece as part of the Manifeste Academy 2019 in Paris, France with the bass clarinet player Ambroise Daulhac. The class was part of a collaborative project where musicians from the Conservatoire de musique supérieur de Paris are associated with RIMs from the academy to play a piece in concert. I had two 45 minute sessions before a dress rehearsal. Each pair were assigned two rehearsal sessions two days before the concert. These rehearsals were mostly devoted to the musician's interpretation rather than on the electronics. This often left little time to ensure mutual understanding between the performers and RIMs regarding their pieces. Due to administrative errors, no full files to test the electronics were given either until two days before the concert.

In these sub-optimal situations, the rehearsals were rather tense affairs. I had created a new version of the Max/MSP patch which had a few sonic variations from the original, but with little time to test and troubleshoot the new patch, we ultimately reverted to the older patch. I had recreated the patch from scratch as the class's initial brief was to recreate the electronics and fix problems. Little did I know before meeting the composers that some of these "errors" were completely intentional! [66] This is an important aspect to remember when working from a distance. Since there was no contact between myself and the composer until the final rehearsal, it was impossible to know with no referential recordings and no information in the score.

The rehearsals were also difficult for the bass clarinettist because it is a demanding piece. The music flows by with little respite except for measures 108-116. Additionally, the performer must press the MIDI pedal to trigger cues and presets among the various effects. There are 54 cues in the ten-minute piece. The performer had clearly rehearsed an incredible

[66] This was mentioned by Simone Conforti that had performed this piece as well. Private conversation June 2019.

amount, but several cues were too awkward and difficult for him to play balance-wise, which led me to have to take over several cues.

8.3.3.3 Synchronization Strategies

The primary synchronization strategy used in *Incompatible(s) IV* (2010) is cues triggered by a MIDI pedal. Although most of the electronics involve live processing of the instrumental sound coming into the Max/MSP Patch, there are also thirty-three fixed media files and several buffers recorded and processed throughout the piece. The layers are shown in Figure 68.

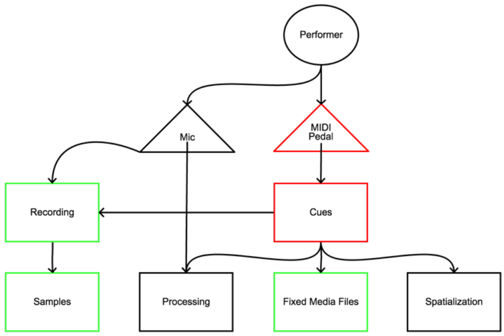

Figure 68. Synchronization layers in Tzortzis' Incompatible(s) IV (2010)

What would happen if the primary synchronization strategy changed to fixed media? The piece is physical, and the brutal aesthetic fits with the use of fixed media. Additionally, setting the various sections' tempo could help establish a more precise performance practice. A single long file for the whole piece is possible, but it would be demanding for the musician. Having several files could help the musician rehearse at home, leave more performance flexibility, and be less risky in concert. An example of possible files is shown in Table 19. Although one would lose some flexibility, I do not think it would be problematic. While the amplification of the performer is a necessary part of the aesthetic, the risk of feedback would be dramatically reduced without the extreme live processing. Since many electronic effects are noisy and distorted, slight temporal shifts between the musician and tape would not be too noticeable. The possibility for the musician to rehearse from home and be more self-sufficient seems useful for this piece.

Table 19. Proposition of fixed media files in Incompatible(s) IV (2010)

File #	Measures
1	1 to 8
2	9 to 28
3	29 to 50
4	51 to 72
5	73 to 108
6	109 to 116
7	117 to 140
8	141 to 172
9	173 to 195
10	196 to end

Another possibility is a kind of hybrid-approach, reducing the number of cues and live processing module by amalgamating fixes media cues and puting more of the sounds achieved through processing in the fixed media. This idea can take away some of the ‘liveness’, but it could also allow the composer to construct his distorted sounds specifically as he wants them to be. It similarly would eliminate some of the risks with feedback. A few challenging cues in particular, such as cues 33 to 40, could be amalgamated to reduce the demand on the performer.

Following could also be an interesting strategy for this piece in thatit would relieve the musician from pressing the MIDI pedal. Partly because of the instrument's nature and the music, I doubt camera or gesture-based following could be useful or stable. The bass clarinettist’s movements are likely not differentiated enough to detect, and asking for extra movements or exaggerated gestures to trigger cues would certainly not help in reducing the demand on the performer.

Audio descriptors other than pitch could work because of the extended techniques’ salient features. One of the issues of this technique is that it would likely need calibrating for each performer. This might be difficult in the often rushed production context of mixed music, but it could, however, be a helpful approach in the case of a touring musician.

Score following often struggles with the extensive use of extended techniques. However, in this piece, there are often musical gestures that are easy to follow. Most of the cues happen at the end of such gestures, which would not be a problem for score following to trigger at the right time. This strategy would also offer as much temporal freedom to the performer as they do using the MIDI pedal, but without the additional physical demand. It would still require the RIM to shadow the musician, but this is no different from the case of using the MIDI pedal. Additionally, it could give the RIM more time to overlook the electronics to ensure that everything is working. Although rehearsing at home would still be too difficult for most musicians, this strategy offers several advantages.

An additional aspect that could be added is to have more internal processes checking how the patch is functioning. These could give the system more stability to have a more homogenous and stable sound for each performance. As it is now, the composer wants a rather brutal sound and aesthetic[67], but communicating how to best achieve this to the performer and the RIM could be aided with explanatory notes in the score and the electronics documentation.

Several synchronization strategies and performance techniques could work in realizing this piece. Each one would have a slightly different colour, but each could function without sacrificing the composition's aesthetics and goal. A large part of the decision of synchronization strategy is to consider how it will influence the performer. Each of these possibilities has different affordances. From a concert performance perspective, I would think that score following would be the ideal solution for this work. However, the difficulties in rehearsing make me consider that fixed media files could also be a valid way of moving forward. In this sense, knowing who the performer will be, both currently and in the future, could be a useful way to gauge which strategy to use.

8.3.3.4 Conclusion

Incompatible(s) IV (2010) is an example of a composition where changing synchronization strategies could make a considerable difference in the performance. The use of score following could make the piece more comfortable for the performer and allow the RIM to concentrate more on the mass of sound during the concert. Therefore, this piece is a good case study on exploring issues of pragmatism for the performer's physicality. There is no right or wrong answer, just a question of aesthetics.

8.3.4 Saariaho's Laconisme de l'aile (1982)

Kaija Saariaho (b. 1952) is a Finnish composer that is often associated with mixed music. She studied with Brian Ferneyhough and Klaus Huber before moving to Paris to study and work at IRCAM in 1982 (Moisala, 2009). She quickly became one of the most well-

[67] Personal communication with Nicolas Tzortzis on the 27th of June, 2019.

known composers of the post-spectralists. She is also one of the most performed contemporary composers (Bachtrack, 2019). Born (1995) presents her as a talented young composer that the management at IRCAM largely ignored, and notes theridicule they faced for it when she won a prize at Darmstadt.[68]

Saariaho has often written about how the texture of painting influences her compositional thought (Saariaho, 1987; 2013). Although she describes herself as not fanatical of technology (Cohen-Levinas, 1999), her music is often named as an example of the elegant and integrated use of electronics in articles by the likes of Battier & Nouno (2003), Lorieux (2004), O'Callaghan & Eigenfeldt (2010), Riikonen (2003) and Young (2016) among others.

I played this piece with Trine Knutsen in a studio in December 2019 and then in concert in February 2020 at Dokkhuset as a presentation of her research as an associate professor at the Norwegian University of Science and Technology (NTNU). The timing references in the text come from this performance.

8.3.4.1 Conception of the Piece

Laconisme de l'aile (1982) is an early piece for solo flute with optional electronics. It can be seen as a predecessor to *NoaNoa* (1992), which is more frequently performed and arguably presents a more mature style. Saariaho has described the goal of the piece as examining "[t]he possibility to move from secret whispers into clear, beautiful and 'abstract' sound" (Saariaho, quoted in Hoitenga, 2011). Like much of her music, Saariaho moves from timbre to pitch and everything in between by using extended techniques. In this piece, she uses microtones as a way of colouring harmonies.

The electronics have three elements: amplification, reverberation and harmonization. The amplification is not meant to change the timbre and focus of the instrument. Saariaho suggests in the program notes that the amplified sound should also be relatively loud, although not dominating. The reverberation is used mainly to extend the flute's sound, help blend the sound sources, and often accents important climaxes.

The harmonizer is an interesting aspect of the piece. Firstly, it is technically not a harmonizer but a series of short delays with transposed feedback, which creates a glissando-like texture. There are two transpositions: +45 and -50 cents. The harmonizer is often used in sections where the flute plays noisier textures, especially those based on breath.

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[68] Although Born (1995) has anonymized the names she discusses, it is often easy to guess who is behind each name.

The piece has several gestures that come back throughout, such as the transition from text to texture, quick variations from pitched tones to noise and back, and a twisting melodic figure. The electronics reinforce these gestures by accenting and amplifying them. The gestures often include the electronics, which shows they are thought of as part of the composition. This is clear at the end of the piece, as shown in Figure 69, at which point the reverberation lengthens the microtonal scales and accents their dissonances and consonances (starts around 07:34).

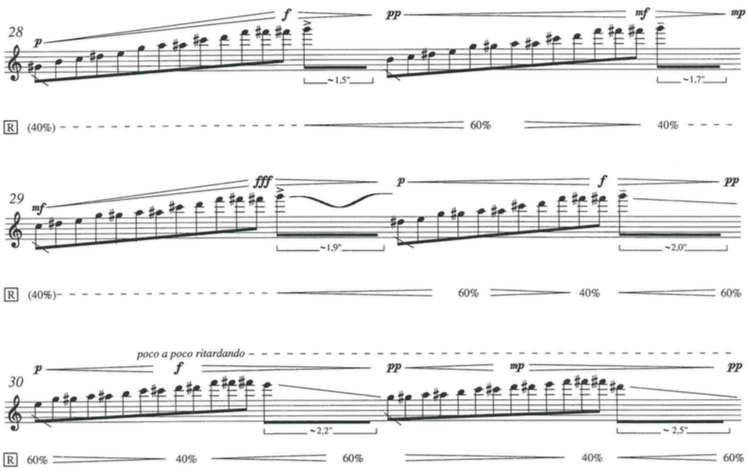

Figure 69. A clear gesture between acoustic and electronic sounds in Laconisme de l'aile (1982)

Although it is possible to play the piece acoustically, its full poetic meaning is only attained with the electronics. The flutist I had the pleasure to work with, Trine Knutsen, had played this piece in concert at least twenty times but only acoustically. After working together, she remarked that the piece feels fuller and makes more sense compositionally with the electronics. This piece was written in 1982 when Saariaho was still early in her career. Marking the electronics as optional likely allowed the work to be performed much more frequently, as the analogue technology needed at the time was still prohibitively expensive. The piece was eventually updated to allow the electronics to be performed with a Max/MSP patch, which I have used. I have also included Knutsen playing the piece without electronics from the same concert to illustrate her interpretative variations.

8.3.4.2 Rehearsal Notes & Concert

This piece was rehearsed in two contexts. The first round was in December 2019, intending to do a few studio sessions. This was part of a discussion Trine Knutsen and myself had about a year earlier in which she wanted to get more used to playing electronics and explore its possibilities. The second round was for a research concert organized by the Norwegian University of Science and Technology (NTNU) in February 2020.

The studio sessions meant having no prior rehearsals due to the lack of time and having booked the studio to explore the piece together. The rehearsals' goal was for Trine Knutsen to get comfortable with the electronics, as she was already very familiar with the flute part itself. One of the main differences with the electronic version as a performer is that she does not have to project as much. There were sections where we had to discuss interpretation. An example of this is the transition in System Eight seen above in Figure 70 (01:54-2:10). For us, the tremolo on E5 needed to have little to no harmonizer, and the D#5 is completely clean. Some of these very subtle elements became essential aspects of our interpretation. Several interpretations of this section can be seen in the video example.

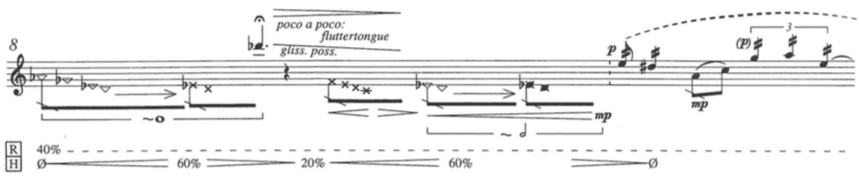

Figure 70. System 8 in Laconisme de l'aile (1982)

One of the reasons for the ease of rehearsing this piece is the flexibility of the electronics. Firstly, the composer writes that the electronics are optional. This may help the performer feel more secure, as this piece is valid without the electronics. Secondly, there are no demands on the performer to control or react to electronics. The performer is free to concentrate on interpreting the piece, just as if it was another traditional recital piece, though of course most performers will naturally change their interpretation due to the electronics. Thirdly, the electronics are operated in real-time by the RIM. Although many of these gestures could have been automated, the RIM needs to control the reverb and harmonizer by following the score, and so the RIM has a rather performative role, giving the piece the feeling of chamber music. We are two musicians playing together.

8.3.4.3 Synchronization

This piece is only synchronized by human following. Everything is done manually by the RIM, as shown in Figure 71. Take note that the score is in blue as the RIM functions as a human score follower. What would happen if we changed the synchronization strategy or performance techniques?

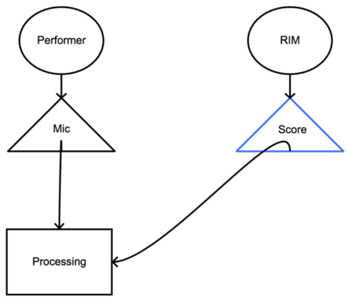

Figure 71. Synchronization layers in Laconisme de l'aile (1982)

Using fixed media for this piece could be problematic. The piece offers much interpretative freedom. Comparing various recordings of the piece, such as Trine Knutsen’s, professional recordings, and other recitals, shows a variation of tempi that results in up to three minutes discrepancy in the total duration of the work. Additionally, the electronics are entirely comprised of live processing the performer. Using fixed media would require tight synchronization that possibly only a click track could give, robbing the music of its most critical performative aspects. It would also be difficult for the musician to rehearse with fixed media as there would be few recognizable pivot points. These issues would not be resolved by using smaller files for each system either.

One can shift to using cues, which Saariaho tends to do for most other pieces by giving the performer a MIDI pedal. It would change the amplitude of the effects as there are no presets because the effects' settings remain stable throughout the composition. Although individual sections could be challenging for the performer, it would also be possible to use a timer in chronometric time between cues.

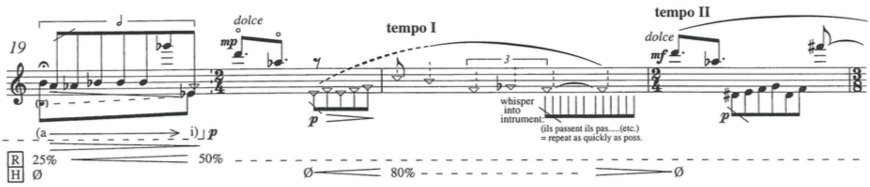

Figure 72. System 19 in Saariaho's Laconisme de l'aile (1982)

We can use System 19 (05:11-05:33), as shown in Figure 72, as an example. There are three tempi in this system and three events for the electronics. The first possibility would be to let the performer press the MIDI pedal at the beginning of each cue. This solution might seem comfortable, but it can affect the performer’s timing, as discussed in Chapter VII. Additionally, one would need to program how long these crescendi and decrescendi are, limiting the performer’s interpretation. However, it is possible to change these timings during the rehearsal period. The use of a tap tempo function is not appropriate here as the tempi shift quickly, and it could severely offset the musician’s balance. Therefore, I believe it would be better to edit the different cue times for the musician to feel comfortable.

A final possibility would be the following strategy. Score following, such as Antescofo, could work well in this context. In the sections where extended techniques are used, it would be possible to write that the section should take X beats and then resume with the attack on Y note. The crescendi and decrescendi could be based on how the performer plays by using real-time calculations, which could be complemented with cues embedded in the software in a hybrid approach. However, the calculations would not be as precise, hence riskier. In the case of score following, it would be relatively easy to use. It is also easy for a RIM to step in and manually set levels or trigger cues in the case of errors. The main question here is one of time investment. Although making this piece with score follower would not be too difficult, it still represents a significant amount of time and work compared to programming it with MIDI cues, or operating it as it currently is.

Following using other audio descriptors would be a challenging endeavour. Since the piece does not actively use other salient parameters, there is little reason to include them. Likewise, it would be theoretically possible to do something with sensors or a camera, but it would take much time. There would also be more risk involved in those possibilities. Following as the highest layer of synchronization, with some cues embedded within Antescofo, seems to be a good solution. If a performer wants to be completely self-sufficient, this could also be the way to go, supplemented with a MIDI pedal as a safeguard.

8.3.4.4 Conclusion

Laconisme de l'aile (1982) is an interesting piece to look at in terms of the electronics, the RIM's role, the interpretation, and from a historical perspective. The piece is a preview into many aspects that would become codified, perhaps even stereotypical, in mixed music by the late 1980s.

From a performance perspective, this is an ideal piece to introduce a flutist to mixed music. Although *NoaNoa* (1992) is more well-known and more frequently performed, I think this piece might offer a more accessible introduction. The clear delegation of roles between performer and RIM, and human following as a synchronization strategy, might help build a rapport between both actors, imitating the relationships between musicians in chamber music. Due to how precise the notation is and how clear all of the gestures are acoustically, a performer with little experience with electronics may find it easy to integrate within familiar rehearsal structures.

The synchronization also suits the piece. Saariaho's aesthetics needs high deviation tolerance and the time to breathe. Therefore, the musical solutions are different from that of the rhythmically precise music of Jodlowski and Schubert. Although following could be even better for the musician, it could also weaken the collaborative aspect that I have found to be an excellent introduction to mixed music for this piece.

8.3.5 Jodlowski's 60 Loops (2006)

Pierre Jodlowski (b. 1971) is a French-Polish composer that explores intricate ways to blend electronics and acoustic sound sources. His musical universe is inspired by contemporary and popular music. He sees amplification as liberalization of instrumental sounds, which he compares to Lachenmann's idea of *musique concrète instrumentale*. He often wants his pieces to explore the density and materiality of sound (Jodlowski, 2012).

Playing *60 Loops* (2006) was meant to be the first piece of the string quartet project for this thesis. However, the string quartet never came to fruition. We did have the chance to rehearse twice. I used much time to think about the possibilities of changing the piece's synchronization strategies. This section is an extrapolation of the programming work done during our rehearsals and discussions before the quartet dissolved.

8.3.5.1 Conception of the Piece

The piece is written for string quartet and pre-recorded electronics in 2006 as a commission for Myriam Naisy l'Hélice. This is, to date, the only string quartet the composer has written. *60 Loops* (2006) is, conceptually speaking, a straightforward piece of music. Its principal idea is that the string quartet plays a segment, and it is looped in the electronics.

The piece is separated into two sections, each with its climax. The main difference between the sections is their rhythmical feel as the first section is in 7/8, while the second is in 5/8. Both sections have their groove, and I use that word explicitly. It is an essential aspect of the piece to understand its foundations, which are influenced by rock music, and especially progressive rock. The music's groove makes it easier to follow intuitively instead of counting with the metronome. Rhythm is also important to think of as one of the dominant musical ideas in this piece. Jodlowski describes the piece as:

> *The opportunity to approach the music world of Steve Reich and give to musical time a funny and relentless meaning. From Steve Reich, I borrowed the principle of repetition, but it is compounded by a stacking principle up to 40 quartets that play simultaneously* (Jodlowski, N.D.).

The loops' accumulation creates a dramatic crescendo that serves as the central dramaturgy. It is simple yet effective, presenting with clarity how the piece functions and is structured. This is a vital factor in considering changing synchronization strategies, as discussed in the next section. In essence, *60 Loops* (2006) is almost like a process piece except that there are two instances of this process, and they do not reach a logical contrarily to Reich's definition (2004).

8.3.5.2 Reprogramming the Synchronization

Before we discuss the possibilities of reprogramming, it is crucial to explore how fixed media is used; its advantages and disadvantages. Afterwards, we will look at changing synchronization strategies and performance techniques. The synchronization strategies and layers as the piece was written are shown in Figure 73.

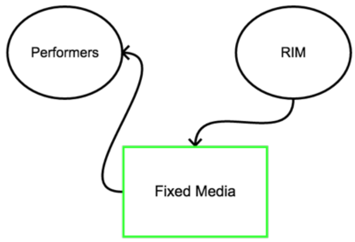

Figure 73. Synchronization layers in 60 Loops (2006)

The tape part of the piece is separated into three files. The first file is just an introduction, while the second and third files are for the full 7/8 and 5/8 sections, respectively. This three-part separation has a few advantages. Firstly, an introduction file lets the quartet prepare. Separating the introduction and the first loop lets the sound engineer ensure that the file starts at the correct position. Secondly, this makes the electronic parts relatively comfortable to handle for all actors. There are only three files, meaning it is easier for the quartet to rehearse at home. Thirdly, it means that the engineer does not necessarily need to be able to read a score, making the work more accessible in contexts where it is difficult to find technicians with this specialization. And finally, the separation of one process per file makes the piece easy to understand and synchronize. Staying perfectly in time with a tape/click can challenge some classical musicians as it might not feel natural. Therefore, separating it into two main sections that start a process permits everything to restart from scratch in terms of synchronization. The fixed media files are presented in Table 20.

Table 20. Information on tape parts in 60 Loops (2006)

	Length in tape files	**Measures**
File 1	00:17	1-10
File 2	06:32	11-151
File 3	02:33	152-239

An alternative idea would be to let one of the musicians trigger the fixed media using a MIDI pedal as a performance technique. This shifts the responsibility of the electronics from the engineer to the quartet. The main positive of this approach is that the quartet can become more self-sufficient, effectively cutting out one actor from the piece. The negative side is that this offers less of a safety net to the performers, who may prefer not to be responsible for everything. To practice this performance technique, I made a Max/MSP patch which could shift between various synchronization strategies and performance techniques. It included a click track for the musicians to practice at home, but we were unfortunately not able to rehearse with this patch.

The next logical strategy to consider was to separate the tape files into smaller cues, and specifically into each loop. This idea has severe drawbacks, however, as it introduces too many possibilities for error, whether it is the quartet or the engineer triggering the loops. In total, this would make sixty possibilities for the piece to go wrong (one for each of the eponymous sixty loops). The deviation tolerance of such an idea is low because of the accumulation of loops. The advantage to the approach would give more control to the quartet. However, the price to pay and the margin of error make this idea too risky.

Another way to offer more control to the quartet would be to do live looping of the ensemble, which I discussed with the composer.[69] We shared similar reservations. It would be difficult rhythmically for the ensemble because of the low deviation tolerance. The second challenge would be that the microphones may pick up too much ambient and room sound, which would then be amplified cumulatively throughout the loops.

The technical rider included with the score explains that the microphones should be on stands, which typically means using good condenser microphones perhaps 1-2 meters away to balance the acoustic and electronic sound. I would argue that clip-on microphones would help with reducing the potential of feedback and improving the signal-to-noise ratio while maintaining the piece's aesthetics. If ambient noise is still a problem, a gate with a low threshold could perhaps help. Such processing would generally be anathema in the world of classical music recording. However, this aesthetic would suit Jodlowski's music. If the sound of a more distant condenser mic is needed (which would likely be especially desirable if the concert is being recorded), then an extra pair dedicated to the whole quartet could be used to supplement the clip-on microphones, which is a conventional practice.

The main advantage of live looping is that everything occurs in real-time, and the looped string quartet sound will always match that of the live players. It should be reinforced that this is only an advantage if it is an essential concept for the composer, technician and/or string quartet. However, liveness offers no inherent advantage, as we have explored throughout this thesis. A proposition of how these loops could be separated is shown in Table 21.

[69] Personal communication on the 5th of February 2018.

Table 21. Proposition of Loop Numbers for 60 Loops (2006)

Loop #	**Starts at m. #**	**File #**
1	11	2
2	15	2
3	19	2
4	21	2
5	27	2
6	31	2
7	33	2
8	36	2
9	38	2
10	43	2
11	45	2
12	48	2
13	52	2
14	57	2
15	61	2
16	66	2
17	69	2
18	74	2
19	78	2
20	81	2
21	88	2
22	90	2
23	93	2
24	99	2
25	104	2
26	108	2
27	112	2
28	114	2
29	117	2
30	122	2
31	124	2
32	126	2
33	128	2
34	130	2
35	132	2
36	137	2
37	139	2
38	141	2
39	143	2
40	152	3
41	155	3
42	159	3
43	164	3
44	168	3
45	176	3
46	182	3
47	190	3
48	196	3
49	203	3
50	207	3
51	212	3
52	215	3
53	219	3
54	227	3
55	229	3
56	231	3
57	233	3
58	235	3

The next idea I considered was the possibility of a score follower. I refer here directly to a score follower instead of following because the music is too repetitive and mechanic to use audio descriptors, sensors or cameras. The musical information would be too difficult to parse effectively. Repetitive patterns and repetitions of the same note are generally the Achilles' heel of score following, making the strategy impractical and risky. The engineer would again still have to shadow the score follower, which would give few advantages.

The last idea I thought of for *60 Loops* (2006) was to create the loops live by using generative methods with physical modelling. This means that a score follower would still be used but primarily for its extended functions that permit complex processes with flexible tempi. It would be possible to shift the electronics' tempo in real-time actively. In essence, the electronics could correct the tempo mistakes that would crop up. However, this idea does have some severe drawbacks.

Firstly, physical modelling takes up a substantial amount of CPU, and even though modern computers are powerful, having up to 40 loops at once, which requires 160 instances (4 x 40) open simultaneously, would likely not be feasible with today's technology. Using sample libraries would not allow as much flexibility in timing and playing techniques. This makes the idea slightly far-fetched, but it would still be possible by separating the CPU load among several computers, for the sake of argument. Secondly, the amount of time needed to code something of this complexity is perhaps more than the potential rewards. Therefore, this might not be the most pragmatic solution. Thirdly, although this idea is exciting technologically and compositionally, it is far-removed from the performativity of the live string quartet. Generative techniques also make it more difficult for musicians to rehearse the piece at home because of the lack of equipment and software at their disposal.

My final thoughts on the subject are that the synchronization strategies, performance techniques and ideas used to implement electronics should function with the piece's aesthetic. Whether it is "live" or "fixed" plays a minor role in the performance quality, and most of the audience will not perceive the difference. When considering Jodlowski's conceptualization of *60 Loops* (2006) and his general aesthetics, I have no doubt that using the fixed media is not only the most practical option, but the one that best fits the idea of the piece.

8.3.5.3 Conclusion

Jodlowski's style presents an interesting case study in trying to change synchronization strategies. Although I did not get the chance to realize a concert with this piece, the process of preparing the work was useful in my research. By programming prototype incarnations of each of the strategies and techniques detailed above, I learned valuable tricks and concepts that I have since used extensively in my own compositions. Jodlowski proves that a simple conception of a piece and its pragmatic execution can often yield outstanding results. This is an incredibly valuable lesson to learn as throughout the history of mixed music, much of the literature is solely concentrated on innovation.

8.3.6 Ejnar Kanding's Obscure Transparence I (2013)

Ejnar Kanding (b. 1965) is a Danish composer associated with the Danish Royal Conservatory since 1989. His education is from Denmark, France and Israel. He has specialized in mixed music since 1996, with over seventy compositions in his worklist. As far as I am aware, his music has not been the subject of scholarly research until now. He is the composer that has written the most pieces for string quartet and electronics (see Lacroix, 2021), having written seven and counting between 2004 and 2021.

Since starting this thesis, which initially was about the mixed string quartet repertoire, I have been interested in Kanding's music. Except for a few specialized ensembles such as TANA, Diotima, Arditti, and the JACK quartet, few string quartets approach this repertoire. Therefore, as part of the Meta.Morf opening, I thought it would be interesting to include a string quartet. Further plans to play one or two concerts with only string quartets in Trondheim Kunsthall had to be cancelled due to the covid crisis. This section will be looking at Kandig's Obscure Transparence 1 – Mosaico 2. The entire piece consists of three parts, but they may be played as independent pieces.

8.3.6.1 Conception of the Piece

The first part of the quartet, *Obscure Transparence 1* (2013), is minimal in style. In the program notes, Kanding describes it as textures with long extended lines and a multi-layered structure. The dynamics stay calm throughout the composition. However, the electronics can be loud, which creates a contrast that is not often heard in the repertoire. This piece shows that electronics can also take the lead even when not necessarily intended.

There are several recurrent gestures within the piece. The first is a slow glissando, accompanied by a loud cluster glissando in the electronics (01:26-01:44). This gesture can be seen in measures 50 to 54, as shown in Figure 74. The electronic glissando is made by four sinusoids, which, in the parts shown below, start from C#7-D7-D#7-E7, moving towards F7. Simultaneously, a rhythmic bass sinusoid around a C0 (32.85 Hz) begins. Another gesture consists of noise spatialized around with subtractive synthesis. A third and final main gesture is a tremolo figure — as shown in Figure 75 — whose pitch and rhythm develop further throughout the piece (starts around 04:53).

Figure 74. One of the main figures in Obscure Transparence 1 (2013-2017)

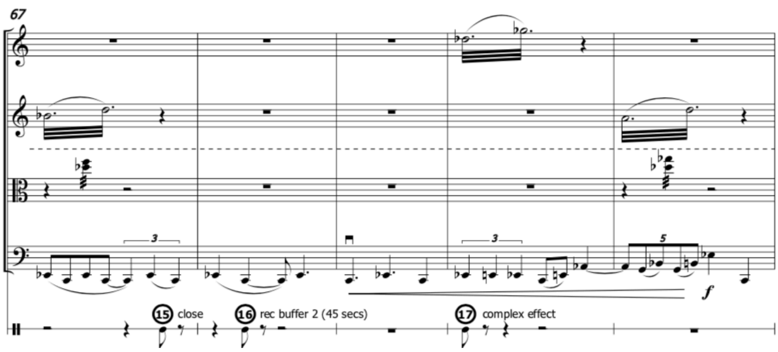

Figure 75. The tremolo gesture in Obscure Transparence 1 (2013-2017)

Kanding records the quartet at several points throughout the piece. These samples are then played back, transposed a tritone by changing the speed of the recordings. There is some live processing used in the piece as well. The gliss cannon (as Kanding calls it) at event eight is a variable delay that changes in real-time, creating a series of glissandi in the background (03:48 is event eight). In the score, he describes a "complex effect" such as in measure 70, which is a delay with an additional flanger effect. The delay times used are rhythmical, with the composer playing around with triplets, dotted notes, and other rhythmical values. The effect is similar to Harvey's blurring ideas in Chapter V. Additionally, there is an eight-tap delay without feedback, which is mainly timed rhythmically with the music. Some of these taps are slightly irregular. Furthermore, the patch also has a standard reverb used to extend certain gestures/pitches, especially at the end of the piece. The reverb is used with the first and second violin in front of the audience. The viola and cello are sent behind the audience. The electronics are relatively simple and play an essential role throughout the piece. There is little direct agency between the electronics and the quartet on stage. Many of the sounds are not related or do not sound as if they are related. However, they often start with the same gesture, which creates a sense of theatricality in the piece. The other more sinusoidal-based sounds are so inherently dissimilar from the musicians that a blend of the two is not entirely possible.

The electronics do have a few issues, such as bugs primarily affecting rehearsals as one needs to restart the patch, but there are no error warnings. An issue for rehearsals is that the click track only starts from the first cue, and it is not possible to skip forwards or backwards. This patch would be challenging for a string quartet to use without having much experience with electronics.

These problems might sound minor, but when combined in rehearsals where one might not have that much time per piece, they become problematic. At worst, it can make musicians wary of playing with live electronics. When playing the piece, I made my own version of the patch with these issues and others corrected.

8.3.6.2 Rehearsal Notes & Concert

Playing the piece was not too problematic, and the musicians understood the electronics intuitively. The main problem was that the use of the click track felt musically restrictive, perhaps without being necessary. One of the musicians described it as being much too ‘square’. The solution we found was for the cellist to lead the ensemble, rather than use the click. She looked at me at the start of the piece to synchronize together with a visual metronome. The visual metronome let her check her tempo throughout the piece without having to worry about discrepancies. Despite the electronics recording samples, the musicians and I found that the rhythmical discrepancies were not musically problematic. We found that this compromise was needed to let the music breathe.

There are several reasons for this. Firstly, the processing effects are used to blur and accentuate gestures. Although some effects are rhythmically tuned, we did not feel that they had an essential musical role. Secondly, the principle is much the same for the buffers. The performance did gain more musicality and nuance (both in tempo and dynamics) from the players when they did not feel tied down by the click track. To me, this was not a very difficult decision. It would not have been possible to do so if the electronics' rhythmical aspects had more importance within the *écriture*. Therefore, the deviation tolerance is high despite not being planned as such originally by the composer.

With the new version of the patch, the rehearsals did not have any significant issues or difficulties. This is the only example in which I have changed so radically a performance technique in this thesis. I was surprised at how much better the performance was as a result.

8.3.6.3 Synchronization

Kanding's piece uses cues as its primary synchronization strategy. These cues are triggered by the person operating the electronics, alongside a click track as a performance technique. The hierarchy is shown in Figure 76. The click track is not outlined in red to symbolize a performance technique related to cues (as I have done in previous cases) because Kanding separates his cues and click track completely. The question remains, would differences in the synchronization strategies make the piece easier to perform?

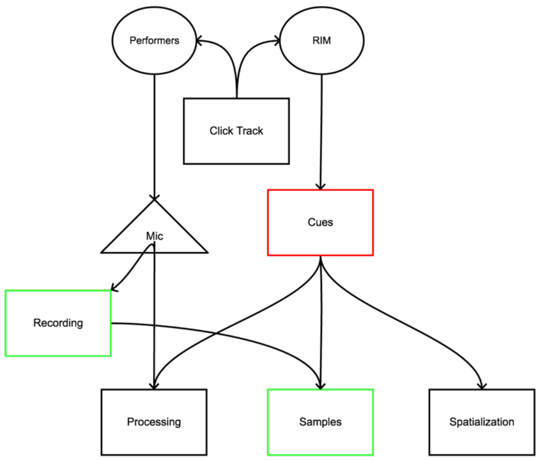

Figure 76. Synchronization layers in Obscure Transparence I (2013)

The piece could work with a fixed media approach from start to finish. Since the music already uses a click track, tape would be easy to implement. The piece's interactive aspect is not crucial to the piece's drama, therefore making the samples beforehand would not disturb its aesthetics. By using fixed media, it would be easy to rehearse without a technician. Splitting the fixed media into several sections would also not be problematic. I feel that agency and liveness are not the main parameter of the music; therefore, this could work but it is not ideal.

I do not see a reason to give a MIDI pedal to the performers. There is some shadowing needed, and the piece requires a sound technician to balance the sound in any case. Except perhaps for more self-sufficiency, this performance technique would not alter much about the work or its ease of performance. What could be useful within the cue synchronization strategy is a tap tempo function. One could get rid of the click track and have the electronics in time without any issues. All of the delays' values could be changed in real-time with relative ease. It would also be possible to implement relative tempo curves if needed. One could also use the tap tempo to influence the fixed media files' reading speed and align them with the quartet giving a maximum of flexibility.

Score following could also be a feasible strategy for this work. The repetitiveness of the piece's music and relative stillness might require an additional envelope follower to synchronize events, such as in *Zellen-Linien* (2007) (discussed in Chapter VI). The downside to the use of score following would be making the piece more difficult to rehearse at home for the musicians when the music's complexity does not require it. The use of gesture following or audio descriptors would not allow anything that could not be attained with music more straightforward strategies and techniques in the programming and its live implementation.

I would argue that for self-sufficiency, the use of fixed media with a click track would be ideal. If the musicians want to have live electronics, then using a tap tempo function to remove the dependency on a click track would potentially afford the musicians greater musicality in their performance. I feel that the composer's synchronization strategies and performance techniques do not precisely suit his compositional wants and needs.

8.3.6.4 Conclusion

Kanding’s *Obscure Transparence 1* (2013) is part of an under-performed repertoire, and it is historically significant since he is the composer that has written the most string quartets with electronics. In this piece, Kanding does not attempt to blend the electroacoustic sounds completely with the quartet. The piece’s theatricality is an element that is not present in many of the other pieces analyzed throughout the thesis, except for Schubert. It is also an interesting case study as it is one of the few pieces where I actively changed (or wanted to change) a synchronization strategy or performance technique.

8.4 Conclusion

This chapter explored various aspects of the RIM, a role which has been crucial to the discussion throughout this thesis, and looked at how this role has been described within the literature. This field of research is relatively new, despite mixed music's now-substantial history. Afterwards, we looked at eight case studies of performances of compositions from various styles. We looked at the electronics' role and how they function in a performance situation for each of these compositions. Synchronization strategies and performance techniques were then discussed within each piece's context before discussing how shifting strategies and performance techniques could change the performance. For some of these compositions, the synchronization strategy(ies) and performance technique(s) chosen by the composer (and/or RIM) feels perfectly appropriate to the work and its effective performance.

In some cases, switching strategies could make some aspects of the composition more comfortable or feasible to perform. These examples show the wide-ranging affordances of synchronization. If these do not align with compositional goals, it might cause significant challenges for the performers (or the RIM).

Issues such as pragmatism, suitability of synchronization strategies, differences between conception and performance, style, and difficulty were addressed through these pieces. Each case study presented these issues in varied ways. The chapter shows how there are no one-size-fits-all solutions for synchronizing mixed music. Various compositional problems and styles have their own varied solutions. Each solution has advantages and disadvantages. One has to find the solution that suits the music and its intentions as best as possible, and this may of course vary from performer-to-performer or from context-to-context.

Chapter IX: Practice-Based Compositional Examples

S'orienter est impossible et le naufrage est obligé

-Arbo, 2003, p. 19

9.1 Introduction

In the introduction of this thesis, I outlined the paradigm of *recherche-création*, which holds the act of artistic creation and artistic practice as essential to establish general theory and knowledge. The previous chapter developed this from the artistic practice of a RIM. This practice allowed me to analyze how synchronization strategies and performance techniques work in reality, not just in theory, which, in turn, has had a profound influence on how I analyze theoretically.

This chapter explores how synchronization strategies are related to compositional processes but from the perspective of artistic creation. I intend to relate the discussion on compositional processes in Chapter III with my own practice, with this perspective in mind. This portfolio alone is not intended to "legitimize" the theoretical frame put forward by this thesis, but rather detail its application through real-world examples and serve as a starting point for further research into the compositional process and synchronization strategies of mixed music. Working as a composer, programmer, and scholar provide different perspectives on the same motif. Each of these roles feed into and inform one other. This chapter will explore my compositional process in the following compositions:

- *Quasar* (2020) for sinfonietta & electronics
- *North Star* (2018) for solo flute & electronics
- *Stadig Fjernare, Bort. Stadig Fjernare, Stadig Nærmere* (2020) for solo horn & electronics

For each piece, I will give an explanation of the general conception of the piece, detail information about the electronics, and offer a discussion on the synchronization strategies I employed. I will also discuss salient information about the rehearsals and concerts where appropriate. Recordings of each of these pieces are included with the thesis.

This practice-based section also provides examples of how outside influences such as time, economics, and logistics profoundly influence electronics in their elaboration and performance feasibility. Much of the literature on mixed music focuses on works and productions that may be unrealistic to realize for people outside of academia or large institutions. Outside of such contexts, pragmatic considerations often render potential technological or artistic goals infeasible. In my discussion of these works, I intend to be transparent about the challenges faced throughout the creative process (as with the case studies of my work as a RIM), and it I hope that through such a discussion, I can provide a useful case study of mixed music production in a diverse set of contexts with limited resources. Through this discussion, I intend to put forward the notion that academic and artistic research should consider the time and resources for both activities, and how these interrelated activities can reinforce each other.

By working on these compositions (and others), I have learned much about synchronization. At the start of this project, I had assumed that the following strategy is almost always an ideal solution for mixed music. However, through my practice, I have developed a more nuanced view. Through my work as a composer and RIM, I have understood how a piece's aesthetics and synchronization are deeply intertwined. These experiences have allowed me to think of synchronization more abstractly, and apply this thinking to my own artistic practice. I also believe that my practice as a RIM has a profound influence on my composing, especially in thinking pragmatically and developing my understanding of the bounds of what is possible. Concerns such as performance, CPU use, the time required to program various kinds of patches, and many other elements of the RIM's traditional territory are often central to my compositional thinking.

A complete list of compositions written during this period is included in appendix A, and a complete list of the files included with this thesis can be found in appendix B. The three compositions I will discuss in detail demonstrate a variety of synchronization strategies and performance techniques, and the practical concerns involved in each. The accompanying sound examples I have provided serve only as documentation, and are typically unmixed. For each piece, the mixed and mastered performance recordings are labelled as appropriate. In the text, relevant timings are given for the listener to identify the examples discussed. I encourage the reader to listen to each piece before reading its corresponding discussion. If desired, scores can be acquired from my publisher, National Library of Norway Publishing (NB Noter).[70]

9.2 *Quasar* (2020)

The Trondheim Sinfonietta commissioned *Quasar* (2020) with support from the Norwegian Composer's Fund. The premiere was opened the 2020 Meta.Morf Festival, along

[70] It is also possible to peruse the notation online at: https://www.nb.no/noter/

with compositions by Natasha Barrett, Ejnar Kanding and Lasse Marhaug. As part of the festival opening, I wrote a text on some of my thoughts and ideas for mixed music and technology, which is included in Appendix C.

Figure 77. Official Meta.Morf poster for the concert with Quasar

9.2.1 Compositional Process & Ideas

The original idea for *Quasar* (2020) came from an audio-visual image of a contrabass player holding a tone as it resonates around the audience like a ring. That visual image conjured in my mind the idea of the accretion disk of a black hole or quasar, reinforced by my interest in science fiction and astronomy, especially through the writings of Luminet (2008). To realize this idea, I considered a large ensemble and the possibility of spatialization essential. I wanted to write a piece in which the movement between the ensemble and electronics feels fluid instead of constricted. With this in mind, I anticipated employing various compositional strategies, and that a conductor would be necessary.

These ideas propose a few interesting challenges in the context of this thesis:

- How does the presence of a conductor influence the choice of synchronization strategies?
- Ensemble writing often takes up more spectral space. How does this affect compositional decisions when there is the potential for full-spectrum sound in both the acoustic and electronic elements, and how might this effect their temporal relationships?

- With a large ensemble, what affordances arise from the different possible synchronization strategies and performance techniques?

I viewed it as essential to relate the electronics directly to the musicians' gestures, offering space for interpretation while maintaining a cohesive sound. This led me to mix from among the three synchronization strategies as part of my compositional ideas. The concept was that the strategies' affordances together could offer more musical flexibility, despite requiring more technological work in order to make them function together. Additionally, writing for a larger ensemble permitted me to reflect on how the number of musicians may influence a composer's approach to electronics more generally, as discussed in Chapter IV.

During most of the writing, I worked on both the electronics and acoustic elements in parallel. However, I mainly concentrated on the score in order to have it sent to the musicians in time by the end of autumn. Moving between concretization and formalization happened throughout, but stress-testing the electronics for potential errors occurred toward the end of the process. Deadlines affected my process, especially in my decisions regarding when and how I moved between concretization and formalization.

Sketches of a section were often a mix of graphic notation, ideas for how the harmony would develop, and so on. The compositional process of harmony and other formalized elements played an essential role in shaping the electronics. There are three main pitch sets in the piece: [0, 2, 3, 7], [0, 3, 6, 7] and [0, 4, 8] (see Carter, Link & Hopkins, 2002). The electronics often expand or transpose these pitch sets both in space and time. For example, they are used to create interpolations between these harmonic areas. It was an important compositional goal that harmonies develop in various manners between the acoustic and electronic *écriture*.

Compositionally, I often wrote with more focus on timbre and sparse textures than I would in works for smaller forces, so that the electronics would have enough space within the ensemble's significant scale. The number of musicians made me reticent to compose sections where the electronics lead as they play. Although there are two electroacoustic interludes, when the ensemble is playing the electronics are often either directly embedded within the instrumental writing or are otherwise subdued; they never occupy the foreground. The electronics' role within the ensemble is generally responsorial, environmental, or instrumental in character. The role of the ensemble also varies, and this movement between the paradigms was an aspect I wanted to explore.

In hindsight, having the electronics lead may have offered practical and compositional decisions I had not considered. I found that even during the electroacoustic interludes, the ensemble occupied much more ‘weight’ than the electronics moving around the audience. This may have been inevitable, due to the visual weight of thirteen people on the stage. Including parts where the electronics lead could have offered more musical variety, but it also could have been difficult for the conductor. More active electronics may have required other synchronization strategies such as following to attain the rhythmical flexibility used in the rest of the work. Considering rehearsal time was already limited, this might have been a real problem. For clarity throughout the text, Table 22 shows the timings for the various sections of the piece.

Table 22. Detailed structure & notes for Quasar (2020)

Rehearsal Mark	**Measures**	**Timing**
A	1-35	00:00
B	36	04:28
C	37-50	06:36
D	51-69	08:12
E	70-85	08:52
F	86-90	10:00
G	91-96	10:23
H	97-104	10:50
I	105-111	11:23
J	112-114	11:55
K	115-118	12:06
L	119-124	12:20
M	125-136	12:48
N	137-149	13:41
O	150-169	14:20
P	170-173	15:29
Q	174-180	15:58
R	181-185	16:27
S	186-191	17:04
T	192-196	17:36
U	197-208	17:59
V	209-212	18:46
W	213-216	19:10
X	217-220	19:26
Y	221-224	19:44
Z	225-232	20:04
AA	233-238	20:38
BB	239-243	21:02
CC	244-246	21:26
DD	247-249	21:42
EE	250-End	22:42

9.2.2 Electronics

The electronics include fixed media and live processing, as shown in the signal chain of Figure 78. The processing includes physical modelling, a ring modulator, a granulator, a freeze-like effect, a spectral delay, a traditional delay, live sample recording, and reverb/spatialization. Additionally, several audio descriptors control various effects based on input from the musicians’ performance. I was familiar with these effects from their application in other pieces, and so I knew how they would respond to various types of input.

This made it easier to orchestrate the electronics within the score, plan how the effects could be triggered, and react in a live situation. The effects are used in parallel, although there is the possibility to send one effect into another. Chain processing is used primarily to accent sounds, such as sending granular synthesis into a spectral delay or vice-versa, which adds an otherworldly extended grainy tail. Additionally, the piece uses ambisonics around the audience (through eight loudspeakers for the premiere, with an additional five discrete speakers on the stage called avatars), as shown in Figure 79.

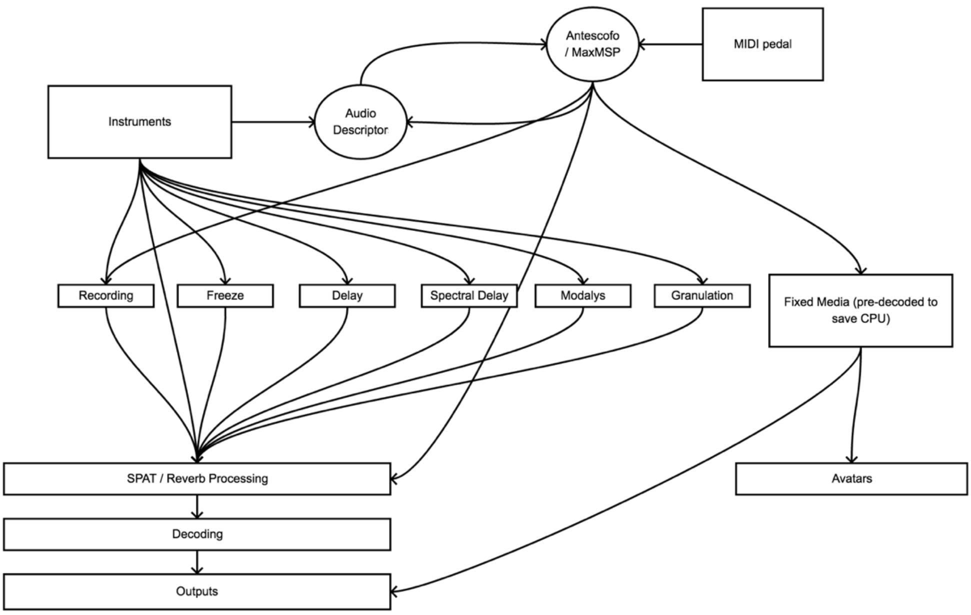

Figure 78. Simplified signal chain of Quasar (2020)

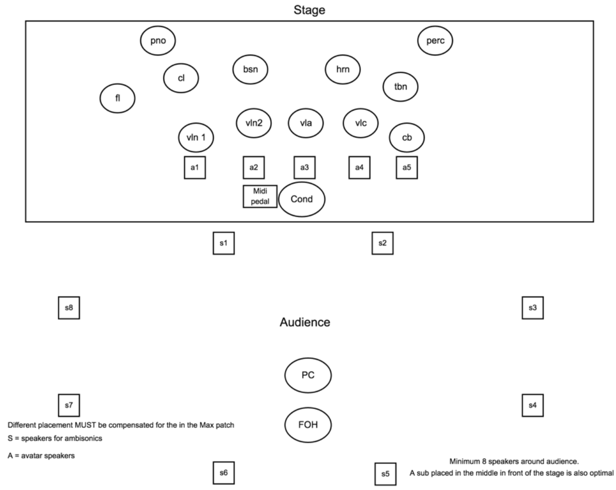

Figure 79. Stage plan for Quasar (2020)

Modalys, the physical modelling tool that I used in Max/MSP, presented challenges because it was not stable and would often crash. Troubleshooting required extensive trial-and-error, since there is little documentation. The initial role of this effect was more prominent within the piece but had to be scaled back because of these stability issues and to spare CPU. Initially, physical modelling as live processing was going to be a central aspect of the electronics. In the end, I used Modalys only to create a relatively simple bowed metal plate sound that adds resonances based on several audio descriptors.

Some of the effects were also mainly used as an extension of instrumental sounds and gestures. For example, I used ring modulation to create a slight saturation on the instruments before they are sent to other effects. I was less interested in creating a recognizable ring modulator effect, instead using it to add a subtle quasi-chromatic and microtonal flavour to the piece. The ring modulation allowed me to create thicker structures in an ensemble without doubling instruments (except violins), especially in lower dynamic registers and to vary the ensemble's texture. One can hear this at rehearsal marks J, K and L, among others.

One of the issues that quickly arose when testing the piece was the patch's CPU load. Initially, I wanted to use several ambisonics-based effects, such as real-time beamforming. However, adding ambisonics processing took up considerable CPU, rendering it unfeasible with the resources I had for the premiere. Additionally, I made compromises on my application of reverb, as my initial approach required an infeasible amount of encoding/decoding.[71] All effects were enclosed into poly~ objects allowing to turn them off when not active to save any bit of CPU and make the patch more stable.

The use of fixed media became more important than initially planned, in order to save CPU. Many of the effects heard in the tape parts could have been done live, but pragmatism was critical. In hindsight, this allowed to create more detailed fixed media parts, which heavily relied on spatialization around the audience. The fixed media files were often a more immediate way of working than programming in Max/MSP and Antescofo because they could be tested in the 16-channel room at NTNU, affording me immediate feedback and control over the sound without the extensive testing that would have been required in a real-time context. By working within a traditional DAW, I could think more like an acousmatic composer than I would while working in Max/MSP. Because I did not need to worry about CPU limits, I was able to apply more extensive processing. This allowed me to create rich tapestries of sound, which compensate for the less detailed live processing. It was especially relevant to work on the score and electronics simultaneously to plan risk mitigation and think about which sounds were more appropriate to realise in real-time or through fixed media.

The electronics and ensemble form a hybrid sound world, rather than one in which the electronics only serve to extend the instrumental sounds. I sought approaches in which both worlds can influence and sound like each other. Some solutions were relatively intuitive, such as using an EBow on the piano strings, producing an interaction that sounds neither fully electronic or acoustic. The bowing of cymbals is another similar sound used during the ending, recalling the beginning's timbres yet never repeating it. The acoustic instruments on stage mostly replace the starting sound files' role while the electronics add slight nuances. Extended techniques were used as a type of instrumental writing that can serve as an in-between, bridging more familiar instrumental sounds with the broader sound-world of the electronics. Due to these hybrid sounds, the composition can be thought of as a spectrum between instrumental and purely acousmatic sounds, as illustrated in Figure 80. Throughout the composition, the different areas of the spectrum are used with similar gestures to explore the various combinations. The spectrum of possible sounds demonstrates the importance of agency. The question, central to acousmatic music, "Do we want or need to know what causes the sound we hear?" (Emmerson, 2007, p. 5) becomes an exciting aspect of the piece's dramaturgy. Within the live processing, there is a spectrum related to how recognizable a

[71] Specifically, upmixing, encoding/decoding from VSTs to combine with SPAT uses too much CPU in Max/MSP. I am hoping eventually for more ambisonics possibilities with reverb in Max/MSP.

sound is, relative to how much the processing transforms the original signal. A delay, for example, is closer to being purely acoustic, while extreme granulation is closer to an acousmatic experience, because it is further divorced from its source sound.

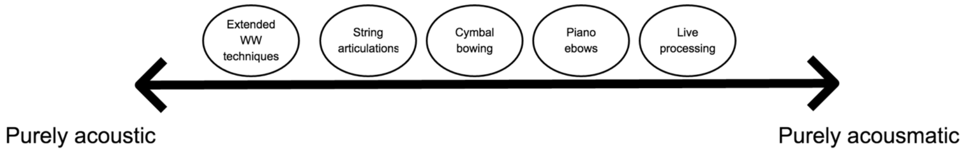

Figure 80. Agency spectrum as used in Quasar (2020)

For example, in sections AA to CC, this technique is used extensively. Samples move around the audience with shifts in the harmonies. The EBows in the piano resonate with the same harmonies. The writing in the strings (excluding the contrabass) moves between various states with varying amounts of vibrato. The wind instruments are mainly accenting with pianissimo tones and breathing in various rhythms. The contrabass plays a sort of solo, with Modalys acting as a resonant plate. The electronics accentuate and change the agency of the ensemble's playing. Effectively in these sections, one hears the whole spectrum blending together. The introduction of the piece similarly constantly moves between agencies. Without the corresponding visual of the movement of the musicians (which itself is often quite subtle, except for the soloistic role of the contrabass), it may be difficult to discern what is acoustic and what is electronic.

These ideas of a spectrum are used extensively not only with regard to agency but with concern to all of the *écriture* throughout the piece. The electronics and the acoustic writing present slowly changing parameters and states. This process of gradual transformation is used as a unifying factor between both sound worlds. Additionally, using fixed media files that are stable in terms of pitch, supporting the pitch-class sets used in the instrumental writing, allowed for expanded variance in timbre and movement in space, drawing these elements into focus.

Live processing in this piece was important. Firstly, it provided a stronger feeling of agency, connecting the ensemble to the electronics that the audience could hear. Secondly, using a combination of live processing and fixed media allowed me to explore various types of ensemble writing. Time-based effects especially made me consider how sparse textures could be in various sections. Time-based effects also often necessarily reinforce a more responsorial type of writing, while effects without delay (such as the ring modulation) reinforce the feeling of an augmented instrument. Time-based effects with grainy tails, frequently employed throughout piece, also have a higher deviation tolerance. This strategy had a pragmatic application as well, allowing room to smooth out any potential mistakes in synchronization between the electronics and ensemble.

9.2.3 Synchronization

The synchronization strategy hierarchies for *Quasar* (2020) can be seen in Figure 81. The piece uses all three strategies in various manners, with the cues being the most important strategy. A MIDI pedal was used to trigger various cues. This section explores how synchronization works in the piece and how it influenced the composition and performance.

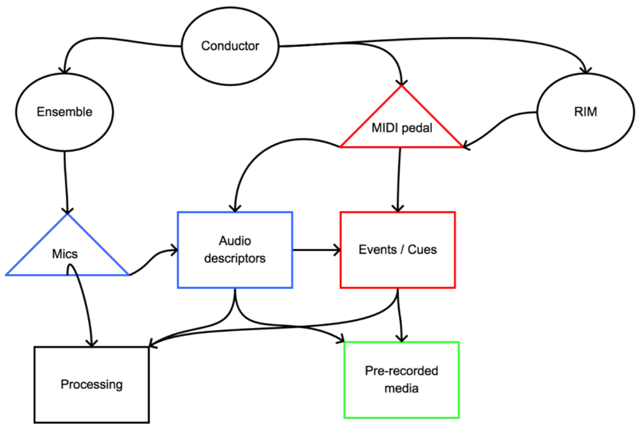

Figure 81. Synchronization hierarchy in Quasar (2020)

An essential aspect is that I wanted the conductor to be involved, without a click-track. It was important to me on a compositional and pragmatic level to let the conductor do what they do best without too many constraints. After all, the conductor synchronizes the musicians together, so it seems natural to involve the conductor within the synchronization strategies of the electronics as well, whenever possible. Therefore, I wanted to give the conductor a MIDI pedal so that they could control several aspects of the timing. Essentially, having cues as the highest hierarchical synchronization strategy allows an easy, streamlined way to involve the conductor. It also allowed the electronics to wait in time and only start with the conductor.

Following and fixed media are challenging to use with a conductor as they both effectively take away control from them. Following, despite its name, will generally be hierarchically above the conductor, because the relationship is not direct but between an intermediary (the musicians who are conducted). Fixed media used as a synchronization strategy would also have imposed its own narrative (tempi, rubato, dynamics) on the conductor. A solution such as Thordarson's (2019) would have been a possibility. However, requiring the least amount of hardware to play a piece is a principle I try to uphold because it is already demanding enough with software, so I try to make things simple on the hardware front.

Following was used in two contexts. Firstly, the contrabass is processed by Modalys to create resonances at the beginning and the end of the piece. Descriptors (centroid, spread and skewness) change some physical modelling parameters, as shown in Figure 82.[72] In this example, the amplitude of the contrabass influences Modalys parameters. The amplitude influences the stiffness of the plate, the weight and speed of the bowing, and the output position, which causes subtle variations. The skewness influences the damping of the and its brightness. Although the details are subtle, they add a direct link between the live gestures of the performer and electronics. This type of following was also helpful in making Modalys sound less static despite lowering the settings to save CPU. The audio descriptors only influence a part of the values, which served as a form of risk mitigation. If a value is based solely on a descriptor, there are more possibilities for problems, bugs and erratic behaviour.

```
whenever ($cb_amp > 0.3 && $moda_descr == 1) {
  $stiff := 80 * $cb_amp + 30
  $p_weight := (0.0001 + $cb_amp) / 2.
  $p_speed := 30 * $cb_amp + 5
  $p_bpos1 := ((50 * $cb_amp) / 1.5) + 10
  $p_bpos2 := ((70 * $cb_amp) / 1.5) + 10
}

whenever ($skewness > 3. && $moda_descr == 1 && $cb_amp > 0.3) {
  $p_damp := 30 + ($skewness / 1.5)
  $p_bright := 85 + ($skewness / 2)
}

whenever ($stiff > 0) {
  p_stiff $stiff
}
```

Figure 82. Use of audio descriptors to change parameters of physical modelling

In this context, the following is a minor synchronization strategy as it does not influence the temporality or narrative of the piece. It would have been almost impossible to create these subtle variations based on the contrabassist's playing with another strategy. The

[72] For audio descriptors in Max/MSP, I always use the Zsa externals which I then average out in time to have useable data.

closest possibility could perhaps have been a live side-chained fixed media track separate from the rest.

As I was composing the piece and creating the electronics, it became clear that the piece often requires a synchronized start of cues but that processes otherwise have high deviation tolerance. In the few sections where this is not the case, cues appear more frequently. It would have been possible to use score following throughout the piece. However, this would have required more programming while offering few benefits. The risk of error would also have been greater. Because the musical material already afforded high deviation tolerance throughout the piece, whatever increase in flexibility score following could have offered seemed unnecessary. Pivot points often naturally occur because of how the musical gestures develop, giving natural points for cues.

The fixed media files do not provide a synchronization strategy because they do not offer any points of synchronization. The cues essentially limit the duration of the fixed media files, which were composed with extended tails to accommodate variations in tempi. If a file has several harmonic changes, those changes typically evolve more slowly than the ensemble will. In some cases, the harmonies in the fixed media changer faster to act as a sort of premonition or anticipation of what will happen later. The most salient changes still occur in the acoustic ensemble, and so the audience may have the illusion of a tighter synchronization between the two. In any case, the desired synchronization of the fixed media elements in the piece is controlled by the cues, affording more liberty to the conductor.

The fixed media mainly fulfils two functions. Firstly, it fills a compositional need: because of the weight of the ensemble at the front of the stage, it sometimes feels too unnatural to spatialized processed electronics back the audience (in cases where the processed instrumental sounds are recognizable). If one sees a violinist play on stage but hears their sound coming from behind them, that cognitive dissonance can take the audience out of the piece. Therefore, spatialization is applied primarily tothe fixed media, as most of its constituent sounds are distant in character from the sounds on stage. This allowed me to both fill the room and create dense textures in my writing without too much cognitive dissonance. Occasionally, I applied spatialized live processing to small instrumental gestures, accentuating certain textures and integrating them into the surround-sound.

The fixed media also serves the more pragmatic purpose of risk mitigation. The sound files will always play “correctly” since they are fixed. The placement of the speakers and the room’s acoustic will of course affect how they sound, but fixed media offers a comparative point of stability and precision. Their use also allowed me to offset the CPU that would have been needed for extensive live processing while having access to the acousmatic style of *écriture*. Often, the sound sources heard within the fixed media are based on sound sources in the ensemble, but processed beyond recognition.

9.2.3.1 Section A

I would like to examine in detail how synchronization functions in the opening of the piece to provide a concrete example of how they interact. Already in this section, all three synchronization strategies are present in their described form. An annotated score excerpt for the third part of this section can be seen in Figure 83. An unedited file with only the fixed media in Section A is included with the thesis.

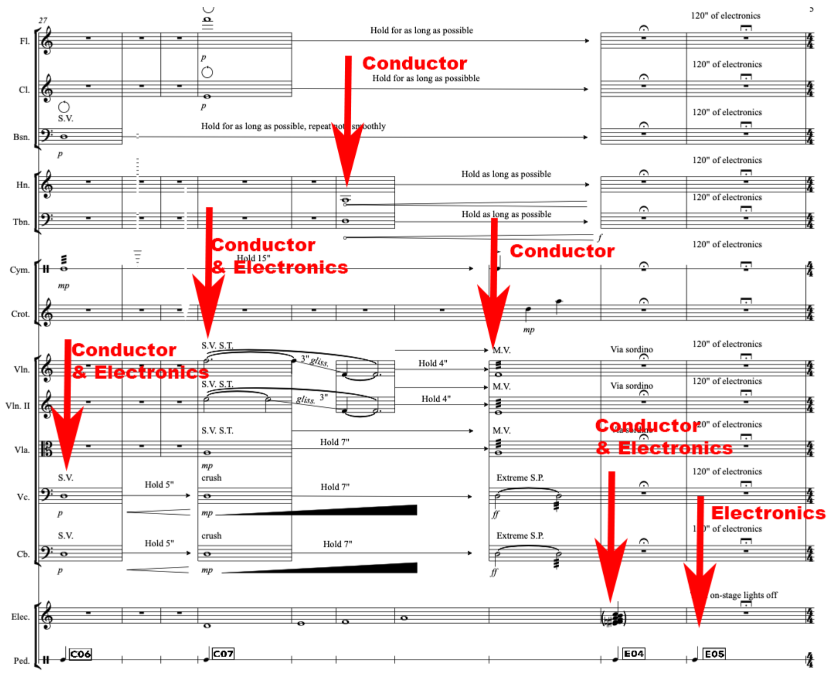

Figure 83. The end of section A in Quasar (2020)

The *écriture* here is in amorphous time, which greatly aids synchronization. The conductor naturally separated this part into four cues for the musicians. On the other hand, the electronics only have three cues and a final cue that starts the acousmatic section B. One can see how the conductor is cueing each of the various instrumental groups in the included video documentation of the premiere. Each of these conducting cues could essentially be pivot points. The function of each cue in the electronics can be seen in Table 23.

The first cue sets up the main features of the electronics in this section, launching a fixed media file and introducing the Modalys-driven resonance of the contrabass, which has an augmented tail from the granulation. The second cue continues the fade-in of electronic elements by sending signal to the avatar speakers on stage. There is a natural crescendo from the acoustic writing that is mirrored in the evolution of the electronics. The fixed media file takes a longer time to develop than the corresponding five-second period in the score. As mentioned earlier, the tape elements are intended to arrive be a bit behind the instruments, sounding almost as if it is processing the instruments. The live processing in the granular synthesis and Modalys may fuse perceptually with the fixed media, contributing to the impression that everything is happening in real-time. The diligently-applied automation in the fixed media file may contribute to this effect; nothing is ever entirely static for too long.

The synchronization here is rather loose. The use of cues allows me to pinpoint when an action starts in the acoustic or electronic writing, which offers significant freedom. Although determinate lengths of time are written in the score, these will seldom be perfect in practice. The conductor was utterly free to make these sections longer or shorter, depending on her interpretation of the music. The strategies actively used in this section are cues and following.

Table 23. Event list for the end of section A in Quasar (2020)

Event #	**Actions**
C06	• Spectral delay parameters are slowly changed towards a new preset, giving movement • Spectral delay starts moving around the speaker array • Granulation starts moving around the speaker array • Contrabass -> Modalys -20 dB over 6 beats • Modalys -> granular synthesis -20 dB over 6 beats • Modalys fades in over six beats • Modalys -> avatar speakers 1 & 5 -20 dB over 6 beats • Granulation -> avatar speakers 1 & 5 -24 dB over 6 beats • Shift the resonant frequency of the Modalys plate to the correct harmony • Start fixed media file “tape_a4” • Turn on audio descriptors for Modalys
C07	• Modalys -> avatar speakers 2 & 4 fade in to -44 dB in 6 beats • Granulation -> avatar speakers 2 & 4 fade in to -36 dB in 6 beats • Strings -> granulation -40 dB in 6 beats

E04	• Strings -> granulation fades out in 2 beats • Contrabass -> Modalys fades out in 2 beats • Volume of Modalys fades out in 16 beats • Fixed media volume fades out in 45 seconds • Close audio descriptors
E05	• Mute the live processing effects and make them ready for the next section • Mute granulation only after it has faded out • Play fixed media file "tape_sectionb" • Play fixed media file "avatar_sectionb" in the avatar speakers • Stop the movement in spectral delay and granulation • Reset all of the send matrices for the next section.

How would the section be if either following or fixed media was the primary synchronization strategy? Following would be rather challenging in all its forms as the music is relatively static. Score following tends to have trouble following sections with a high degree of similarity. Audio descriptors could similarly also have difficulty parsing useful information. An envelope follower that switches instruments could perhaps work. However, there is practically no transient between the two first cues due to the violins entering pianissimo. Microphone bleeding within the section could present significant challenges to this approach. Following would allow more deviation tolerance than in the currently implemented version, but it would be challenging to mitigate risks

Fixed media as a synchronization strategy would mean no triggers for the whole A section. In such a case, I would also have put all of the live electronics within the tape part. This strategy would also have some rather significant challenges. Firstly, most of the electronics have few rhythmical cues or clear audible pivot points, and so it would be incredibly difficult for the conductor to follow, and in my honest opinion, it would not be possible without a click track. Secondly, this would cause a loss of flexibility in the tempi of the piece, which is a musically important element. The textures and melodic gestures in *Quasar* (2020) often change in tempo. In this section specifically, this would mean having specific lengths of time for each cue. How long these cues are is a part of the interpretation, and should vary depending on the acoustic properties of the hall, as acoustic musicians regularly adjust their tempi according to acoustic.

There would probably have been less interaction between the score and electronics in a more traditional environment with a RIM. Because I have experience from both worlds, I feel like it informed my choices throughout the compositional process. Both aspects of the *écriture* could be changed or have a compromise simultaneously instead of only working on the electronics or score separately.

9.2.4 Testing with Samples

When writing for such a large ensemble, it is very rare to have the luxury of working together experimentally outside of the often-limited rehearsal schedules. Therefore, some solutions have to be found to be able to test the programming without their presence. One of the pitfalls of testing with samples is that they are relatively fixed and stable compared to the high variability of sound in live performance, potentially giving a false sense of security.

Another issue is that few sample libraries include extended techniques. Any gradual transition in the strings is awkward at best, for example. Some sonorities are then impossible to test. In my opinion, in these cases, an experienced musician's inner ear remains the best method for understanding how things will sound, which of course takes time and experience.

Testing with samples does offer some advantages. If I was uncertain about a signal chain for processing on an instrumental combination, working with samples could help test this. Combining the samples with my inner ear allowed me to find hybrid solutions for testing many sections, saving a lot of valuable rehearsal time.

9.2.5 Rehearsals & Concert

For the entire program, we had three rehearsals and a dress rehearsal right before the concert. These rehearsals lasted two hours each and included about fifty minutes of music, which meant that we had little time per composition. Additionally, two of the three rehearsals were held in the local symphony's lounge room, which meant we had no access to the speaker array to test anything in multichannel, to say nothing of the very different acoustic and performance conditions from the hall.

The first rehearsal was purely acoustic, which allowed the ensemble and the conductor to find any underlying musical difficulties they might have in the piece. Starting with the second rehearsal, the conductor was given a MIDI pedal to rehearse with the electronics. One of the issues we encountered was correctly cueing at first and knowing when to wait for the electronics. Another issue was that the EBows could not excite the lowest strings of the piano as much as anticipated. Therefore, we had to transpose or re-arrange a few sections for the piano in order to achieve the desired effect.

For the second rehearsal, I had set up a small stereo PA and amplified up the strings. The roof of the lounge room is low, which made feedback a problem for processing. Under these conditions it was not possible to make the electronics loud enough for the conductor to hear without feeding back. However, it was at least still possible to play with the fixed media parts, making the musicians more comfortable and helping them understand the piece's aesthetics.

The third and final rehearsal was planned to take place in the concert venue, which meant that we could have a sound technician and a full PA set-up. However, we had logistic issues with the concert venue, which meant that we had to rig everything down and up again the next day. The venue had misunderstood the number of outputs needed, which meant we had to get two extra stage boxes before starting the set-up. We could not have a soundcheck due to minimal time, which meant that we still had some feedback issues. These issues cost a lot of rehearsal time, making it difficult to test the electronics in full. Instead, most of the rehearsal was spent fixing technical issues within the venue. However, we could still get most of the acoustic sections played for all of the program's pieces. Considering that it was a technically demanding program, this was something of an achievement!

The conductor, Halldis Rønning, has a very physical style, and so, over the course of the rehearsals, though she had initially been operating the MIDI pedal, we decided that I would control all of the pedals so that she could focus on coordinating the ensemble. Although this removed some of her control over the synchronization with the electronics, we agreed that it was a necessary step to mitigate errors in the piece considering the tight rehearsal schedule.

9.3.6 Conclusion

Quasar (2020) is, as of writing, my longest and most ambitious piece of mixed music. It was important from a compositional perspective to try several synchronization strategies within one piece to see how they can affect my compositional process. When the writing of the electronics and the acoustic sound sources is so integrated, it becomes challenging to separate processes. To return to the questions I posed at the start of this section, having a conductor changed how I thought of synchronization. The conductor's job is technically synchronization (and interpretation), therefore delegating some of this control away from them felt artistically wrong for this piece. Working in a large ensemble context also changed how I viewed synchronization, as I found that the ensemble perceptually fuses into a kind of hybrid instrument, rather than retaining the distinct character of individual instruments. The conductor was the key to connect the electronics with this ‘meta-instrument’. In the end, Halldis did not use the pedal. I found that the synchronization of the piece following the conductor still afforded the flexibility needed for the piece’s artistic goals. Employing the Following strategy as the highest order of synchronization would have required too much programming and testing to be feasible in this context. It also would have been riskier without offering significant advantages in the musical context. On the other hand, relying completely on fixed media would have made the piece much less flexible in time and more challenging for the conductor.

When thinking back on the discussion on risk mitigation for larger ensembles in Chapter IV, I am unsure if my approach aided more than usual. In one sense, pivot points function in the same way that they did when the conductor was initially triggering the cues, except that in this cases, it is the conductor responding to them rather than the individual musicians. Pragmatism was necessary, but I do not feel that I took fewer risks with this piece compared to the other pieces on the program. I was careful to cover potential risks, but for the level of technical elaboration I sought in the electronics, risk is always a factor, and this is only magnified by situations with limited resources and rehearsal time.

The final question posed in this section’s introduction was: “How does writing for a larger ensemble influence my process when having access to instruments that can together cover the whole frequency spectrum?” I found this situation to be quite liberating. Especially in solo writing, in order to achieve the dense textures that I often seek in my music, I sometimes find it difficult with certain instruments not to have the electronics cover the instrument too much. While separation between instruments and electronics within the frequency spectrum is one way of avoiding this masking, it might not help with the integration of both sound worlds. With an ensemble spanning all registers, I felt freer because the various registers of the ensemble afforded a sort of acousmatic mode of writing, sculpting the sound and ensemble as I desired between acoustic and acousmatic writing. This liberty was simultaneously the main challenge of the composition.

To conclude, *Quasar* (2020) presented unique challenges for me as a composer. However, I realize that many of these challenges (compositional and technical) are typical of the repertoire. Although the literature has focused mainly on solo pieces, discussions with other composers have shown me that these issues are far from unique. After listening to the recording of the piece, I have identified a few sections where I would make changes to the proportions, dynamics and the like – especially within the acoustic writing. Several details will be adjusted in the score and the electronics before it is performed again. Working on this piece also taught me how flexible cues can be in the context of ensemble writing. The use of following as a lower form of synchronization may also have helped create more direct relationships between the ensemble and electronics. The illusion of synchronization I ultimately arrived at is a consequence of the complexity and density of much of the polyphonic material in the ensemble writing. In such cases, I do not suspect that it is not possible for the audience to hear if every single detail is strictly in sync with a specific instrument or not.

9.3.7 Technical Specifications

Fixed media: Zynaptiq Adaptiverb, Zynaptiq Wormhole, Pianoteq 6, SWAM Instruments, Omnisphere, Flux Audio Solera, Flux Audio Epure, Blue Ripple Audio OA3 Reverb, 2C Audio Aether

Live Processing: Munger~, IRCAM SPAT, Antescofo, zsa audio descriptors, Modalys, ej.line

Mixing / Mastering: Mathieu Lacroix
Live sound engineer: Terje Hallan
Live video engineer: Martin Kristoffersen
Stagehands: Sebastian Sandved, Joel Hynsjö
Mics: Most instruments have DPA4099s, the percussion has two overhead AKG C414s. Additionally, a pair of Oktava MODELS was used as the main stereo pair for the recording and backup.

9.3 North Star (2018)

North Star, for solo flute and electronics, was originally written as part of a call for works for a contemporary music festival in Italy. The work was then tested with Tonje Elisabeth Berg in 2019. Afterwards, Trine Knutsen and I did a studio session with this piece and Saariaho's *Laconisme de l'aile* (1982), discussed earlier in section 8.3.4. Both of these pieces were then played together as part of a concert in February 2020. Later in 2020, the piece won the Tacet(i) Ensemble call for works and was then played twice in Thailand in

August/September, and it received an additional performance in Trondheim in September with Tonje Elisabeth Berg.

9.3.1 Compositional Process & Ideas

There were two essential aspects of *North Star* (2018). The first was that I wanted to write something that could be approachable for performers who might not be familiar with electronics. The second was that I wanted to write a more vibrant and playful piece than usual. I wanted the piece to be lighter and have more supple, lyrical writing than I had previously explored. The first of these goals offered many affordances. It was important that the musician felt that they have control without any extra burden. Therefore, I wanted to avoid both triggering and fixed media. By avoiding triggering through a MIDI pedal or other means, I wanted to offer a situation where the musician could focus on the physicality of their instrumental performance undisturbed. My main goal was to give the musician the impression that playing with electronics is not difficult, and that they could focus on their part without thinking about the electronics during performance. This is perhaps an idealistic goal, but the main point was to make the musician comfortable and understand their agency over the electronics. I wanted to avoid fixed media so that the musician would retain significant agency. It was clear to me that the use of score following might be the most suited solution. This allowed the music to be as striated as I wanted, following the musician's tempi and affording rhythmical processes in time.

The music is inspired by the contemporary soloistic flute repertoire. An essential element of this repertoire is how fluid/rubato the playing often is. A strict tempo does not suit it; everything should flow and breathe. Some of the music's pauses are not in musical time, which presents a problem for click-tracks. A more fluid performance expectation allowed the musician to be comfortable and assume their traditional role, focusing on the strengths of their training. Trine Knutsen described playing the piece as like "playing chamber music, but with electronics" (Knutsen, 2020). She mentioned her discomfort with the idea of playing with electronics initially, but that working on this piece had been a positive experience, making her want to explore this repertoire more.

This piece is somewhat unique within the three presented in this chapter because there is a large gap between its composition (2018) and the first time it was played through in its entirety (first in a studio session at the end of 2019, with the premier ultimately occurring in 2020). Like all of my pieces, there was much going to and fro between formalization and concretization. However, the difference here is that the corrections and rehearsals occurred long after the initial compositional process. The corrections needed were aspects I did not expect (described later).

9.3.2 Electronics

The electronics have gone through three versions. The first was tested with Tonje Elisabeth Berg, the second in the studio version with Trine Knutsen, and then the third is a slightly edited version for the premiere. The signal chain and all of the ideas are the same, but small details have changed to make the electronics more stable. Additionally, because of the lack of fixed media files and the flexible programming achieved through following, it is possible to shift the tuning from, for example, A=440 to A=442 by changing a single variable, making the piece more flexible to be played in different areas of the world with different performance practices.

The electronics' main elements are adaptive FM synthesis, a harmonized delay (à la Brian Eno), granular synthesis, physical modelling of a flute, and harmonized overtones. The latter is a type of FM synthesis combined with convolution to create an exciting timbre used for the harmonic background throughout the piece. This effect is an elaboration of Chowning's principles (described in Dodge & Jerse, 1997) integrated with convolution from a field recording of waves on a beach in Nord-Trøndelag.

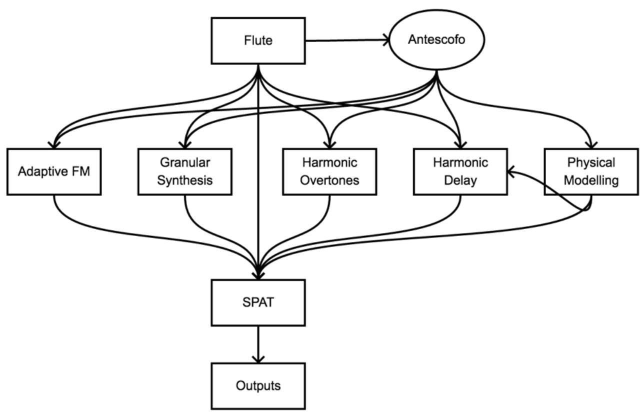

Figure 84. Simplified signal chain in North Star (2018)

The physical modelling of a flute was chosen to create striated time and polyphony between the performer and electronics. Using pre-recorded samples would potentially lock the musician into strict tempi, not afford the musical striation I sought. Initially, the plan was to create physical modelling with Csound, and although I was satisfied with the sounds I could achieve in the software, I found that it took too much time and programming resources to respond dynamically in a real-time context. Instead, using the robust SWAM software allowed me to work more on the music than spending time programming physical modelling. This was also my first piece in which I tried to have more reactive electronics with physical modelling. The compositional affordances and consequences of this will be discussed in the synchronization section.

The harmonic delay, adaptive FM and the overtones create a background of harmonies throughout the piece, occupying various spectral regions. Both feature constantly-changing parameters, creating a rich texture that is never stable. After testing with Tonje Elisabeth Berg, I added granular synthesis, as I felt that the electronics needed more 'grit' and roughness in their texture. It is the only effect that is not backgrounded by the flute within the production of the piece. It takes its space right in front, almost breaking the image of smoothness the rest of the electronics create. The effect also breaks the monotony of the relationship between the electronics and performer, which is otherwise relatively consistent throughout the piece. Though all of the electronics are generated through live processing of the flutist's signal, the radically different processing and its placement in the foreground creates the illusion of the electronics leading the musical discourse at certain moments during the piece. Despite this, and although several of the live processing techniques I used are time-based, the electronics are mainly responsorial, sometimes verging on acting as an augmented instrument. They create sheets of sound for the flutist to play over top of. The granular synthesis may sound like a type of distorted accompaniment, but it generally fades quickly in the background.

9.3.3 Synchronization

The piece's synchronization strategy is following, accomplished with Antescofo, as shown in Figure 85. This strategy allowed the musician to be freer and worry less about triggering events. The use of score following makes it essential that a RIM shadows the performer. However, since the score following has become so stable for this piece, the RIM's main task is live mixing. Score following combined with live processing, processes and physical modelling instead of samples (other than the poetry) allowed for fluid and flexible electronics.

This section will first look at several examples of the links between the compositional process and synchronization. Afterwards, it explores how these affected the performers before finally discussing the possibilities of other synchronization strategies.

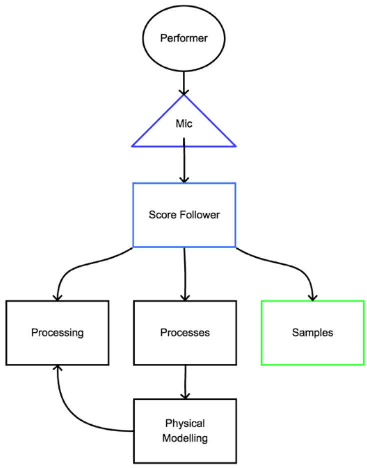

Figure 85. Synchronization strategies in North Star (2018)

An example of the affordances from the synchronization strategy is systems 3 and 4 (starts at 00:50), as seen in Figure 86. In the tremolo gesture, the electronics are programmed as an evolving ecosystem instead of a fixed narrative. The score following analyses the tempo and pitches of the performer. The physical modelling then accompanies this by continuing this gesture with the semitone structure on each detected tremolo [1, -1, 2, -2, 3, -3], which gives flexibility and accommodates the possibility of performance errors. If they plays the wrong note, the electronics will also play the “wrong” note, retaining their integration within the gesture (described further in Lacroix, 2020). The composition is full of these processes, in which the electronics expand a gesture from the performer. We will further discuss three aspects of such gestures: their influence on the compositional process, their link to synchronization strategies and their effects on the performer.

Figure 86. System 3 & 4 in North Star

While composing, one usually is in complete control over the flux of notes in time. For example, with live processing, one knows which notes the musician will play but not the exact consequence. However, one has a relatively good idea of the result since although severable variables are uncertain (exact dynamics, timing, timbre, and so on), but others are relatively certain (pitch and rhythm). In processes such as described above, more variables of uncertainty are added. The flute's pitches are as specifically notated, since the music is through-composed, but the reaction of the electronics is not as certain since it is based on the [1, -1, 2, -2, 3, -3] process before being sent to live processing.

It is difficult to imagine how a composition can sound when writing with such processes. However, it also unlocks many possibilities. This piece, for me, was an experiment in trying to think more abstractly about what electronics can do, and has influenced my thinking, both in other pieces in this chapter and further planned works.

Processes like this are also related to synchronization strategies. If one used fixed media instead, it would be possible to transpose the file by a fixed number. Combining several files for each note would allow more flexibility and introduce more possibilities for disjointedness and artifacts. Untreated fixed media files would dictate the rhythmical flow of the musician, which is contrary to the aesthetics and performance practice I desired for the piece. Cues could function by creating a live buffer that is then transposed, but that could also introduce artifacts. Both of these possibilities are also sensitive to timing, making deviation tolerance lower. The use of score following with physical modelling in such a process dramatically increases the deviation tolerance. There are fewer possibilities for a performance error (such as triggering cues or files), which makes more complex rhythms possible. Additionally, the use of score following in such a process opens up the composition to more complex possibilities that may evolve, which I had not yet explored in this piece.

The result might not sound striated in this piece, which is related to several aesthetic and technical aspects. Firstly, I did not want to create a piece that followed the conventional format of acoustic instrument with electronics accompaniment. Therefore, I chose that the flute sound in the electronics only comes in specific parts of the piece. The disadvantage of this is that these moments stand out more in the sound-world of the composition, due to the surrounding context of the *écriture*. In *Partita I* (2006) and *Tensio* (2010) by Manoury, physical modelling is often surrounded by chaotic *écriture*. In the musical context of *North Star* (2018), the physical modelling stands out in the texture significantly, but through the application of reverb and automation, I was able to control the foregrounding of the processing and create interesting interactive structures. I believe that the agency of these processes is quite evident in the result despite the lack of perceptual striation. I believe they are perceived as coming directly from the flute and flowing from the performer.

These processes also affected the performers. Trine Knutsen, for example, had expressed skepticism of electronics because of the challenge they often present to performers. Additional questions such as “When does one have to press the pedal?” or “How will the effect sound?” can put performers outside of their comfort zone. For this piece, I made it clear to her that the electronics will follow her and that she can therefore focus her attention on her own performance. This is, perhaps, an oversimplification, because of course, a performer naturally adapts their playing to what they hears, but this kind of attention draws upon the training that musicians have in acoustic performance contexts.[73] A video example systems three and four from several takes she did in the studio and finally at the concert. One can hear that she is adjusting herself as musicians naturally do while performing chamber music.

The synchronization strategy and performance techniques used in this piece are more subtle for traditional performers. They might not be aware of how the electronics are responding to them, but they operate in a way that intuitively models their traditional performance practice playing chamber music, as discussed in Chapter VII. When I first began working on this piece, such as in the initial sessions with Tonje Elisabeth Berg and other performers, I would take considerable time to explain the details of how the electronics function, but I realized that this information wasn’t necessary for them to perform well with them, and that in some cases, created potential confusion. By simply staying that the electronics will follow them, I believe this offers space for the performer to rely on their musical instincts and listen as they would within any chamber music.

[73] In such a context, I would also argue that the role of the composer and RIM becomes closer to that of the music producer. A part of the work is technical, but a large part of it is getting the best performances possible, which might include having to bend the truth for some musicians.

The electronics and synchronization throughout the composition are primarily written in this manner, which gives more flexibility with temporality, dynamics and pitch. It also afforded the possibility of errors from the performer in these parameters, as the electronics adapt to and match their playing. This makes the performance more human and makes less immediately audible any mistakes the performer might make, which can be an issue in some mixed pieces. The main downside to this approach is that it requires a substantial amount of coding and testing as part of the compositional and rehearsal process.

The use of physical modelling may present some challenges, since I used a commercial virtual instrument. When relying on such externals, one has to consider that they might not be available in the future, and that one has no control over updates to the software that could affect how it functions. However, it did allow me to save a lot of time programming. The program is also flexible and easily interfaces with Max/MSP and Antescofo through MIDI. Using Antescofo to create the MIDI data gave me a more macro-level control that was easy to implement with various algorithms. Despite the risks of the program not being available in the future, this is a perennial concern when working with technology not unique to this particular piece of software, and I am reasonably confident that the work will be adaptable to new solutions that may take its place.

9.3.4 Sessions with Trine Knutsen December 2019-February 2020

Trine Knutsen had communicated to me her desire to play more music with electronics, which led me to propose working on this piece with her. This evolved into a project for her to pair my work with one of her most frequently performed works in her repertoire, Saariaho's *Laconisme de l'aile* (1982).[74]

Changes had to be made to electronics to keep up with Trine. At several points in the composition, the score follower had difficulties following her, especially towards the end of the piece. Once these issues were addressed, it was clear that Trine was comfortable playing the piece. Trine did not always realize that the electronics had trouble following her, perhaps because of their relatively unobtrusive nature. In rare places where following errors occurred, they were relatively minor, and only arose during the last page of the music.

The main effect of these sessions was that Trine became comfortable playing the piece without second-guessing the electronics. During the rehearsals before the concert, she tried various interpretations of the piece, allowing her to understand the flexibility of the

[74] Which she had only performed acoustically as discussed in section 8.3.4.

electronics. During the concert performance at Dokkhuset in February, I could concentrate on getting the balance right and changing some of the dynamics in real-time to fit how Trine was playing, while she could focus on her instrumental performance. This approach offered us each a clear division of roles, allowing us to both focus on our respective expertise and perform together comfortably.

9.3.5 Further Concerts

In 2020, *North Star* (2018) won the Tacet(i) Ensemble Call for Scores and was performed at two concerts in Thailand in August and September 2020. Additionally, the piece was played at a concert in Trondheim in September at Kunsthallen. I was not present for these concerts, and the electronics were operated by someone else. The electronics were unaltered except for some cosmetic changes to make the Max/MSP patch easier to understand for another operator. I had also written a guide on how to perform the piece for the RIM, but in such cases, it can remain a challenge to understand the full role they have in the performance of the work.

Interestingly, all of these performances offered significantly varied interpretations, and in each case the electronics were able to follow along. These performances show that a well-thought-of synchronization strategy can make a piece comfortable to play despite varying interpretations. Within each interpretation, I cannot hear any direct errors from the score following. It is also surprisingly flexible in its interpretation in the sense that each performance sounds natural within the piece's *écriture*.

9.3.6 Conclusion

I am generally satisfied with *North Star* (2018), especially with how each performer felt comfortable with the electronics, no matter their level of familiarity with mixed music. The extensive use of the following synchronization strategy imposes fewer restrictions on their playing, and I believe it played a large role in offering this approachability. Making the player more comfortable can lead to a better musical result. Additionally, the use of score following in this piece gave many additional affordances. The temporal and musical flexibility means that the electronics can "interpret" the music, which feels especially relevant and vital in the context of a soloistic piece of mixed music.

An aspect I would like to expand upon from this piece is the use of striated rhythms reacting to the performer. Although the rhythms and SWAM engine worked well in this piece, I still feel that it may be too stiff for some types of *écriture*. And so, there is no one-size-fits-all solution: one music consider the appropriateness of synchronization strategy to the musical context of the work. I believe that some of the limits encountered so far have been related to how I have programmed the electronics. In the piece *Stadig Fjernare, Bort. Stadig Fjernare, Stadig Nærmere* (2020), I believe I might have found some solutions to this problem by creating moveable goalposts for electronic events, which I will discuss in the following section.

9.3.8 Technical Specifications

Max/MSP externals: Munger~, Csound~, IRCAM Spat, Antescofo
Extra software: SWAM Flute

Mixing & Mastering:
Recording, mixing and mastering: Mathieu Lacroix, Dokkhuset for the live recording
Video recording/editing: Mathieu Lacroix & Martin Kristoffersen
Players: Tonje Elisabeth Berg, Trine Knutsen, Tacet(i) Ensemble

9.4 Stadig Fjernare, Bort. Fjernare og Stadig Nærmere (2020)

Stadig Fjernare, Bort. Fjernare og Stadig Nærmere (2020) for horn and electronics was commissioned by Gabriel Trottier as part of his doctoral research at l'Université de Montréal in Canada. The piece's title comes from a Jon Fosse poem. Initially, Gabriel asked me to write something inspired by Norway and Norwegian music. He wanted the music to be inspired by metal music since that is one of Norway's most significant cultural exports. Metal music is something that has inspired me since my teenage years and made me want to become a musician in the first place.

The included recording of the piece is only a demo, since the premiere of the work has been postponed due to the COVID-19 pandemic. Additionally, due to a technical problem at the studio of L'université de Montréal, only two of the four microphone tracks were useable in the recording. It nonetheless offers a sufficient point of reference to discuss the the compositional and performance issues at hand. All timings in this section refer to the fourth take that is submitted with this thesis.

Table 24. Sections and timings in Stadig Fjernare, Bort. Fjernare og Stadig Nærmere (2020)

Section	Timing
A	00:00
B	01:49
C	05:03
D	06:55
E	08:51
F	10:57
G	11:20
H	13:42
I	14:52

9.4.1 Compositional Process

Gabriel was an active sparring partner many times throughout the compositional process. He also sent me a document he wrote, explaining many of the instrument's extended technique repertoire (Trottier, 2019). Additionally, I shared many sketches with him as I composed, and we discussed at length the role of the electronics in the work. Some discussions were about logistics due to distance and the ongoing pandemic.

The writing of the piece was done simultaneously as the programming to try out various possibilities and see how it could work. The composition is based on four gestures and pitch-class sets. The gestures are shapes and figures that apply to both the acoustic and electronic writing. This permitted me to develop formal parameters of the composition in both domains. Figures are often started by the horn and then reflected in the electronics or vice-versa. In the electroacoustic sections, the electronics often develop material that the acoustic writing elaborates upon later, creating a more solid and related structure.

An essential aspect was how to capture the idea of heaviness in the piece. I wanted to include the contrast between oppressive atmosphere and beauty often found in metal, such as in the music of Dornenreich, Agalloch, Paysage d'hiver, YOB and Neurosis. I did not want to refer to typical genre tropes such as double bass drumming, tremolo riffing, guttural, or shrieking vocal lines. Additionally, I did not want to include drumkit sounds because of how strictly the instrument imposes rhythmical aspects. Guitar, bass and Chapman stick were important sound sources, primarily because of the distorted sound they can create, and their ubiquity within the metal genre. The writing for the horn is often rapid and relentless. The additional textures try to recreate some of the oppressive atmosphere in the musical genre that inspired the piece.

Since the creation of this piece was also a part of Gabriel's doctoral research, technical aspects were brought up early on, and these discussions influenced the composition of the piece. The piece was initially conceived with ambisonics, although it was made into stereo for the version that will be performed to afford greater flexibility in situations where the logistics required for ambisonics are unavailable. In general, this piece presents the most extensive collaboration I have had so far in my career.

Every few weeks or sometimes months, depending on where we were in the process, I would send him a score and discuss ideas. This drastically affected the compositional process as feedback on the feasibility of passages was almost instantaneous. This meant many rewrites of sections. For example, the split-tone section shown in Figure 87 was rewritten several times. Originally the split tones I asked for in the horn part were different, but we quickly found out that they were too complicated to perform. Muting and flutter tonguing was also included, but Gabriel explained that muting was too difficult in the musical context and that flutter tonguing within a split-tone is not audible. Changes such as these were typical, and discussing the instrument's technical possibilities was important throughout the process. For example, I am aware that the split-tone section is probably impossible for most horn players, and so the work is fine-tuned for Gabriel's individual expertise. In the case of another player that could not physically play these, a compromise such a fixed media files or switching between both tones would be possible.

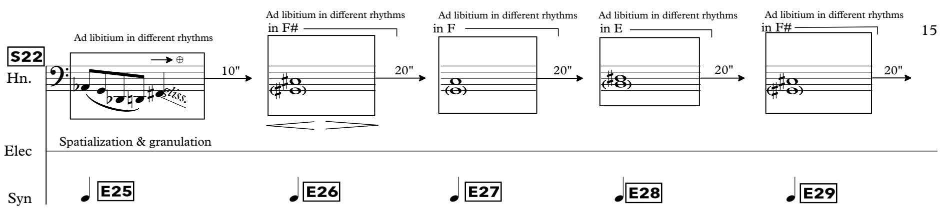

Figure 87. Split tones in system 22 – 09:20 – 10:36

This collaborative aspect is the main difference I encountered between the composition of *North Star* (2018) and this piece. As a result, *Stadig Fjernare, Bort. Fjernare og Stadig Nærmere* (2020) is a more demanding piece for the performer. Whereas with *North Star* (2018) I was interested in creating a work that would be approachable by many performers with various levels of experience, this work allowed me to create a piece honed to the specialized talents of an individual player. The many long discussions with Gabriel also allowed me to be more experimental with synchronization strategies, as discussed below.

9.4.2 Electronics & Programming

The piece's electronics are mainly based on live processing the horn, which was a request of Gabriel's. Some multichannel fixed media files are used as well, especially to create textures that a horn cannot achieve. There are four microphones on the instrument, which are muted and mixed throughout the piece to create different textures of amplification and processing. The first microphone is a traditional close mic. The second is positioned to capture piston and finger sounds. The third is closer to the performer's lips, while the final microphone is farther away, capturing more of the projection of the instrument's sound in the space. Each microphone is also heavily equalized. The idea here was to try to use various characteristics of microphones and distances artistically. Shifting between the microphones offers more animation to breath and piston sounds, and other delicate techniques that do not project as much acoustically. This gesture of shifting amplitudes of the microphones is made algorithmically, such as in systems 13 and 22.

The live processing comprises four main modules: granular synthesis, spectral delay, a conventional delay, and a frequency shifter, as shown in Figure 88. All of the effects are already in multichannel format, and the delay uses custom-built delay lines with circular buffers to avoid feedback. There is also the use of SPAT and its reverb. These modules have similar functions to the two previously mentioned pieces. They are often fed into each other to create longer tails.

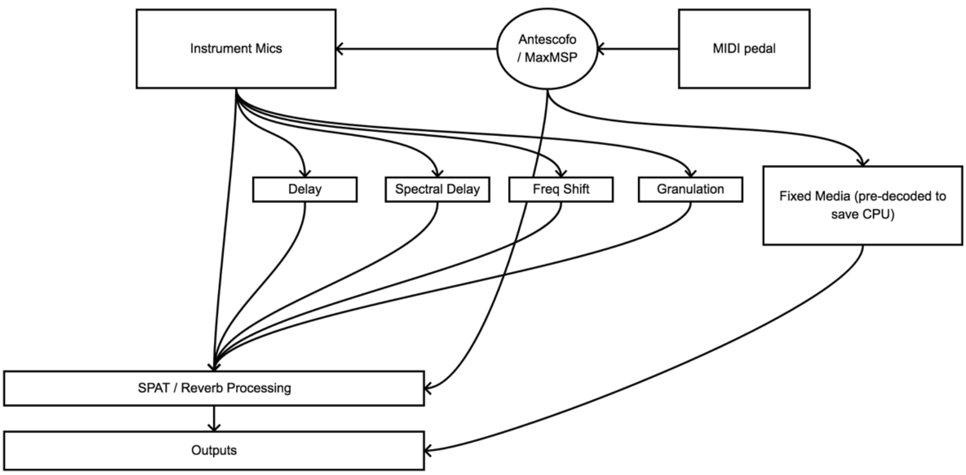

Figure 88. Signal chain in Stadig Fjernare, Bort. Fjernare og Stadig Nærmere (2020)

The main difference is the frequency shifter. I did not want to use physical modelling like in *North Star* (2018), and I did not want to use fixed media to create a call-and-response relationship in the piece. When experimenting, I found interesting results by using a delay with a frequency shifter tuned to glide between pitches. The result is something at the boundary between repetition and an effect. The implementation here is different from the flute piece, as errors from the performer are not considered. The main reason is that the critical aspect for me in this piece was not that the pitches created be perfectly correct, but rather that the shape of the processing is correct. While testing these movements, it became clear that they must be programmed within a single group instead of as reactions to each pitch played by the horn. This allowed for a more continuous movement, despite the loss in pitch precision.

The delays are specifically programmed to move around the audience in the ambisonics version. This is lost in the stereo version that Gabriel will premiere. Compositionally, the delay's role is to thicken the texture and make it more chaotic, rather than function contrapuntally. I also feel that having clear delays around the audience that do not fit in relative time helps diminish any form of cognitive dissonance between what is on stage and what one hears.

The granular synthesis adds grittiness to the sound of the horn, taking it closer to a more metal-influenced timbre. When combined with the fixed media and the spectral delay's tail, the granular synthesis is the main 'aggressive' sound processing in the piece. It helped create a bridge in both gesture and timbre between the heavily distorted samples and the instrumentalist. I hope that, especially within a live context, this will create a more visual referent to parse what is live and not, while helping to combine both sound worlds. Additionally, I find that there is less cognitive dissonance between a heavily distorted acoustic instrument and what the audience sees on stage, which permitted me to spatialize Gabriel's playing.

9.4.3 Synchronization

The piece uses several synchronization strategies in various sections of the piece, mainly cues and score following. A complete view of the synchronization layers of the piece can be seen in Figure 89. The two main strategies are used in different sections. The score following is used in sections of striated time in which there have to be quick musical changes that follow the performer in musical time. The cues are used in sections where the music is in amorphous time and in more open sections where the performer may decide on the length of various events. Having shifting strategies was something I wanted to explore at the start of the compositional process to see how it would influence my writing.

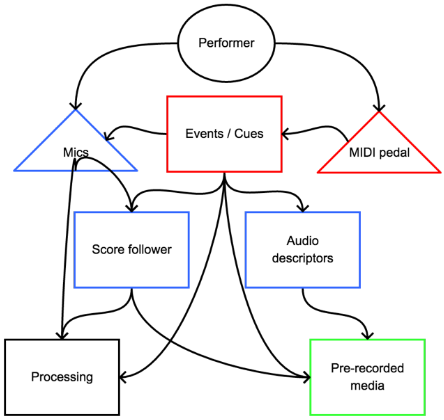

Figure 89. Synchronization hierarchy in Stadig Fjernare, Bort. Fjernare og Stadig Nærmere (2020)

Shifting strategies changed the compositional possibilities between sections, as well as the advantages and disadvantages each of them offered. It would be naïve to think that this combines only the strengths of each strategy, because shifting strategies also inherently affect the piece's structure. Additionally, issues of pragmatism can also affect which strategies to use, especially in the case of score following. There is no doubt that the whole composition could have been done with the score following. However, the risk mitigation would have been more challenging. It was easier and took less programming to shift from following to cues. Using cues for the whole piece would have been much more difficult due to the material often having little deviation tolerance, as we will see.

The main disadvantage I have found in shifting strategies is that I sometimes felt trapped by the type of musical material in each section. The indeterminate and more open sections are generally synchronized with cues, while the striated writing uses score following. At the same time, it felt natural to shift between various types of material because of this afforded freedom. I found myself rarely second-guessing which strategy would suit which material, but working with such combinations was relatively novel to me. Moreover, such a process invites the chicken and the egg question: are the strategies primarily influencing the *écriture* or the other way around?

In this case, I believe the material influenced which strategy to use more than the contrary. The composition's *écriture* is relatively straightforward, and it is clear to me what type of strategy it requires. Another possibility that I did not explore in this piece is having the strategies functioning in layers. The material did not need such multi-layered use of electronics, except for in section C (discussed below). This concept is something I would like to develop further in later pieces.

A final aspect to discuss is why I chose to use a combination of score following with fixed media. Much like in *Quasar* (2020), I used fixed media to use less CPU in live processing. Fixed media also permitted me to create textures with various sound sources, in this case, especially those related to the metal genre. One of the significant differences between this piece and *Quasar* (2020) is that in *Stadig Fjernare, Bort. Fjernare og Stadig Nærmere* (2020), the endpoints of the fixed media files are important in performance. The material is often rapid and aggressive, but the performer must wait (as they see fit) between musical gestures to let the electronics die. It would be possible to rapidly advance through the gestures in the piece, and it would still work musically. The fixed files here are much shorter and often reflect musical gestures, such as in systems 18-19. The longer sound files, such as those at events 13 and 24 take a more prominent musical role while the performer mainly uses cues and the sections are open.

This use of fixed media files also means that pivot points are sometimes more difficult to perform and that the fixed media sometimes becomes a synchronization strategy. Section C, which can be seen in Figure 90, uses only cues and fixed media. The hierarchy of synchronization strategies shifts radically as the following is not used, and the fixed media is only slightly lower than the cues. In the score, it is written that the whole section is about 75 seconds, and the fixed media file is 78 seconds long. In essence, the tape sets the approximate length of the section. However, the live processing is just as important, despite evolving independently from the fixed media. The cues can also shorten the fixed media file if needed, but the fixed media still sets the narrative. This section can be heard at 05:03 – 06:55.

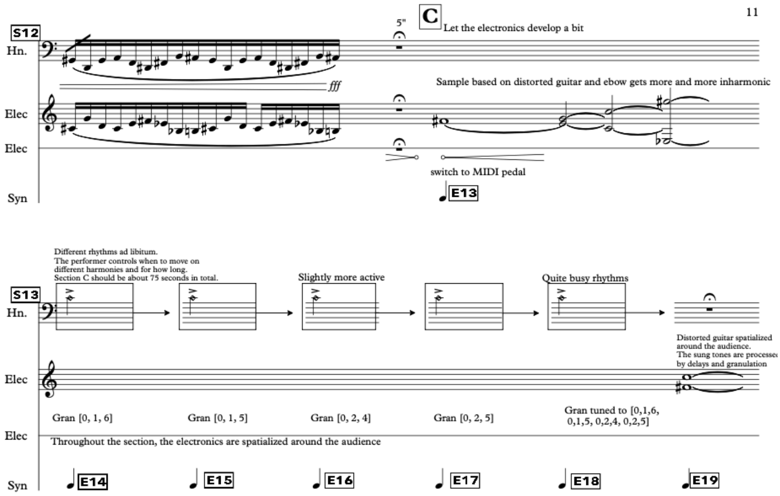

Figure 90. The use of cues and fixed media in section C

In this section, I would argue that the synchronization strategies heavily influence the compositional process. The first affordance is the narrative from the fixed media file. I need to decide the maximum length of the section, which is then related to the proportions of the macro-form of the piece. The second affordance is that the musical material must be relatively free from the narrative set by the fixed media. There are no direct cues in the fixed part, which in this section consists mostly of pitch sets varied through various types of distortion. This creates by default two musical layers. The second layer is mainly live processing sounds. Finally, the material also influenced the synchronization strategies because I wanted freer sections to reduce the aural onslaught and provide moments of repose. Pragmatically, these sections would also allow Gabriel to catch his breath. In such a free section, having a fixed media file is helpful to have a set narrative that guarantees a basic sonic result on which he can improvise within set boundaries. The live processing over the fixed media part offers a layer of freedom to the performer, but the most important musical functions are in the fixed media part and how the live processing adapts to the pitch sets.

9.4.5 Final Result & Rehearsals

The piece will be premiered in Autumn of 2021. As part of this thesis, I am submitting an early demo created with Gabriel and Marwan Laroussi as a RIM and engineer. This recording, and the version that will be premiered in concert are only in stereo, but the piece is designed to have eight speakers around the audience.

It is also worth mentioning that rehearsing and testing at a distance presents new challenges and advantages. The production side of the music becomes problematic. However, the deferred time can be an advantage, offering more time to change minor details. For us, Gabriel first recorded lo-fi demos system by system so that I could begin testing. While the recordings were not pristine, they were of sufficient quality to permit us to discuss aesthetic and performative issues within the piece early on. The main disadvantage has been, without a doubt, the lack of an intense pre-production period before a concert with three longer rehearsals. I find these intense periods valuable artistically and technically, to ensure that each party is on the same page. Without access to high-fidelity recordings from the musician, even hearing accurately how the piece is sounding can be challenging for the composer.

With the pandemic and everything associated with it, the project has developed on a much longer time scale than usual. Thinking about it now, the duration of the creative process is perhaps one of the more considerable challenges, as with the extra time, one can easily change their mind about various compositional and technical aspects, and this is not always an asset!

9.4.6 Conclusion

This piece is the first time I had the opportunity to cooperate with a musician so closely and over such a long time. Throughout the compositional process, I frequently delivered sketches of the score and the electronics to Gabriel for feedback and discussion. The experience permitted me to take more time to explore how the synchronization strategies and performance techniques would influence a specific performer to make the piece comfortable for them, while still providing an exciting challenge. Going back and forth between two people also positively influenced the compositional process between formalization and concretization. Often, Gabriel would not necessarily be aware that changing a small musical detail could change the electronics and synchronization, and these exchanges allowed for him to have a more nuanced understanding of the work as a performer.

On the compositional and synchronization side, this piece presents exciting possibilities that I have not had the chance to explore elsewhere in the thesis: multi-layered synchronization strategies. Composers such as Blondeau have taken this approach, but access to recordings and electronics has been difficult to get. It presents another way of working with synchronization strategies that will influence the compositional process differently from what has been discussed previously. This aspect is something I will explore further in upcoming commissions.

9.4.7 Technical Specifications

Fixed media: Zynaptiq Adaptiverb, Zynaptiq Wormhole, SWAM Instruments, Omnisphere, Flux Audio Solera, Flux Audio Epure, Blue Ripple Audio OA3 Reverb, Neural DSP Nolly, Neural DSP Darkglass, Neural DSP Parallax

Live Processing: Munger~, IRCAM SPAT, Antescofo, zsa audio descriptors

Mixing / Mastering: Mathieu Lacroix
Recording: Marwan Laroussi at L'université de Montréal

9.5 Conclusion

This final chapter should not be seen as only an artistic portfolio. The experiences from this chapter and the previous offer case studies of the relationship between synchronization strategies and the compositional process. Within the *recherche-création* paradigm adopted, this first-hand practice-based knowledge is used to posit new concepts, but it cannot be the only source of the formalized research. Art production is not equivalent to, but rather contributes to research and knowledge-making when developing theoretical frameworks such as the one that I have put forth. In other words, the findings described here are what led me to the results I have detailed in the previous chapters. These experiences have also shown how complex the relationships between synchronization and composition are. The relationships between the elements of the composition are like an ecosystem. It is also a challenging aspect to discuss when the act of composition and performance is so ephemeral. By describing my processes, I believe it can also help other researchers to start discussing similar issues.

Additionally, these three case studies have given the reader examples of the vocabulary developed throughout the thesis and how it may be used to discuss mixed music more generally. Each case explores issues of performativity and pragmaticism, which have been rarely discussed in the literature.

I have tried to purposefully write pieces of music in various styles when it comes to synchronization. Each piece is its own universe with its own rules as to which approach(es) may suit it. I have chosen these three pieces as they offer an account of deliberate synchronization and compositional aspects that have been difficult to pinpoint within the literature.

Quasar (2020) shows how fixed media and following can be used in conjunction to offer the electronics the flexibility of a large chamber ensemble. The piece also helped me reflect on risk in my discussion on writing for small or large ensembles in Chapter IV. Synchronization in such pieces might not necessarily be related to risk, but to pure pragmatism concerning which musician (or conductor) can lead the ensemble in order to make musical sense.

North Star (2018) showed how following affords the idea of processes within a piece. This reflects several of the thoughts described in Blondeau (2017), but also relates to the compositional difficulties of thinking in such an abstract manner. With this piece, I was able to offer performers a comfortable environment that allowed them to play in the same way that they would naturally in an acoustic chamber music setting. This made the musicians comfortable, which opened them to using their traditional skill from ensemble playing: listening, and apply it to the practice of mixed music. The several recordings with various performers also show how interpretation can change while maintaining the integrity of the piece. This is a sign of good handiwork in combining my skills both as a composer and a RIM.

Stadig Fjernare, Bort. Fjernare og Stadig Nærmere (2020) showed the possibility of changing synchronization strategy and hierarchies several times within the same piece. Sections alternate quickly between cues and following. Additionally, other sections have multiple layers of synchronization. Initially, my thought was that this would simply involve combining the strengths of each strategy, but as I worked on the piece, I found that the relationship between the composition and synchronization became even more complex, while compositional affordances became more evident. In this piece specifically, the section using cues often tended to be more amorphous, and the following sections tended to be striated. This was perhaps due to not having shifted strategies so radically in composition before. I am curious to develop my composing further within this new paradigm.

On a more general note, this chapter explored how synchronization is central to many of the core issues of mixed music, such as compositional process, structure, pragmatism and performance. It is difficult, if not impossible, to separate composition from synchronization. Even when discussing historical pieces, the affordances of tape are central to the discussion. Nevertheless, the literature rarely discusses the more significant ramifications of synchronization in contemporary mixed music. This chapter helps to establish and enlighten such a link in a situation without a RIM.

The chapter also highlights several aspects discussed in earlier chapters, such as risk mitigation, technological limits (CPU, for example), performance flexibility and the audience's perspective. The variation in instrumentation and size of the ensemble in my own works influenced the choice and affordances of synchronization strategies. It is easy to understand that more musicians may quickly mean more risk. The pragmaticism of the situation will often require other strategies that may be easier to handle. Findings in Chapter IV seem to support this conclusion as well, but it is essential not to forget that much of the literature is about pieces with institutional support, far from most composers' reality. Risk mitigation while working with an ensemble and electronics is primordial. If the experience is bad, a composer might not get a second chance. Even for composers with much support, such as Manoury and Harvey, most of their most experimental works are chamber music or soloistic pieces.

Technological limits and other mundane issues such as the amount of time allotted are also critical despite often not being mentioned or considered in the literature. If a composer has to write a work, program everything themselves for an orchestra in a short time frame, with little to no pay or testing time, it is clear that following might not be the wisest synchronization strategy. Technological progress has been an important aspect of the literature, such as in Chapter V, where many of the pieces initially tried to extend the possibilities of mixed music, but this is impossible for every composition. Original ideas must often also be changed to suit technological possibilities, such as those mentioned for *60 Loops* (2006) in Chapter VIII compared to what I have done with physical modelling in *North Star* (2018).

The flexibility of the performance is also important and at the heart of the classical recital. We must remember that mixed music is mainly connected to the live concert. Everything must work in the heat of the moment, and we want the performance to be unique and reflect the performer's personality. This is more difficult in an orchestral setting with over 75 people where homogeneity might be vital, but it is more important within chamber or soloistic pieces. Harvey did not use many of the possibilities afforded by Antescofo, and this is possibly one of the reasons. Manoury's works for larger forces (such as his operas) are arguably more conservative and less experimental in their use of electronics and synchronization. The freedom of expression afforded by soloistic music suits the experimental use of synchronization strategies and exploring their compositional ramifications.

I believe this is also influenced by the audience's perspective because there is more place for electronics in a sparse orchestration. A larger ensemble commands the audience's attention in another way than a single violinist. How the piece is composed and the role of the electronics will also highly influence the cognitive dissonance. In Murail's ensembles pieces from Chapter IV, the electronics are mainly adding colour and timbre. However, Manoury's *Partita I* (2006) has a more radical approach to the electronics, which might cause too much cognitive dissonance with a whole ensemble. These issues are related to the poetic nature of acoustic instruments and electroacoustic music. The way the music is written and how the various types of time interact both for the performer and electronics will also highly influence synchronization strategies.

In essence, the various topics broached within the thesis are a rhizome because the relationships are complex and intertwined. Each chapter and the issues brought up are connected to each other. This complexity makes mixed music a problematic type of music to research, but it is also part of the beauty of mixed music.

Conclusion

> *Musical thought, the technology and the practice of music including that of electroacoustic music are changing in too many fragmented directions to allow us enough distance to establish to what extent this will transform our current musical aims. It might be therefore wiser to explore this aesthetic threshold than to settle for immovable theoretical pillars.*
>
> -Javier Alvarez (1993, p. 150)

10.1 Goals and Results of the Research

In the thesis' introduction, I had defined my goals as:

- To explore the relationship between compositional procedures and synchronization strategies within mixed music, and
- To establish a vocabulary to discuss synchronization within mixed music,

with the following the sub-aims:

- To investigate the performative aspect of synchronization strategies.
- To analyze and understand the various technologies and strategies that allow composers and performers to use electronics in mixed music
- To further develop a theoretical and graphical framework that allows us to discuss and analyze mixed music.

To discuss composition and synchronization strategies, we first looked at the literature on the issues of time within music in the first chapter. I proposed a primary separation between score, performance, and perceptual time. Each of these illuminates various aspects of a musical piece that were important to my discussion of mixed music. Each type of time is examined within its contexts throughout the thesis, and they are tightly related to each other. The composer's conception the time of the piece might differ from its performance, and it could be perceived differently by the audience and the performers themselves. Drawing on concepts from psychoacoustics, the theories on aural fusion and fission also became relevant for my discussion of whether sounds are perceived as one hybrid instrument or two sound sources.

Chapter II introduced a theoretical framework to discuss synchronization. A synchronization strategy is any strategy used by the composer (or RIM) to regulate temporal relationships between the musicians and electronics to achieve a compositional goal. The three strategy families I presented are: fixed media, cues, and following; and they can be combined in various ways. These synchronization strategies can be used in different ways during a performance, which I have called performance techniques, such as using a MIDI pedal to trigger sound files, or a click track to follow a fixed media part. These strategies and performance techniques can be combined within a composition, leading us to think of layers of synchronization strategies. I introduced a graphical framework that includes the various ways acoustic sound signals and gestures can be connected to electronics. The framework is colour-coded to show clearly which strategies and performance techniques are present in each piece. Other concepts, such as deviation tolerance, meaning how much rhythmical deviation is tolerated in the electronics, were introduced to discuss compositional aspects of synchronization. Although several of these concepts may seem abstract at first, this allows them to be used and discussed in a broad range of pieces and aesthetics throughout the thesis.

Chapter III explored the compositional process and how it has been analyzed traditionally. The chapter showed how difficult it is to discuss the compositional process, reflecting the inherent challenge of capturing and examining a relatively solitary ephemeral process. There remain enormous gaps in the literature on the various aesthetics and subtleties of contemporary music. This chapter offered a new framework to discuss the compositional process specific to mixed music, inspired by software development feedback loops and the views of formalizing compositional ideas within contemporary music. The framework also showed how fluid the composition process can be and how different actors, such as RIMs, influence it. An essential aspect of the new framework is its non-linearity, which better-reflects the reality of most composers' process, as discussed in Donin (2019), Hervé (1999), as well as my own practice. Although it is impossible to survey every composer's compositional process thoroughly, this framework provided the necessary flexibility to discuss synchronization and its effects on compositions.

Chapter IV begins the discussion on relationships and affordances between synchronization and the compositional process. The chapter considered both poietic and aesthesic aspects varying between composition, intention and result. We looked at specific examples of how a piece's synchronization strategies and performance techniques influences its composition, and vice-versa. We also looked at several examples of technology in general influences composition before discussing how the electronics' role influences the synchronization strategies. We explored pragmatism from the composer's perspective regarding the compositional process and programming, affecting how much a piece gets performed. We explored the repertoire to see if there were discrepancies in synchronization strategies between solo pieces and ensemble pieces. The solo and small chamber repertoire seems often to allow the composer to take more risks than they are afforded with larger ensembles. Orchestral compositions were often safer in how they explored technology and its role within the composition. The solo repertoire especially offers opportunities for risk, which may reflect the one-to-one relationship in synchronization between a single performer and electronics. Rehearsal and testing time are also easier to arrange with only one musician (compared to over seventy in the case of large orchestras). This chapter explored how synchronization strategies are used in diverse aesthetic situations with various combinations. I reviewed historical debates regarding interactivity, as these were a central part of the discussion in the early development of mixed music. Although this debate has become less present with changing technology and attitudes, much of the mixed music literature remains permeated with pretenses toward the superiority of interactivity. When discussing and analyzing mixed music, we should be aware of these biases. Finally, I also explored the concept of mapping and how it may be used in conjunction with synchronization strategies, especially with following by using audio descriptors, and in adaptation of electronics to different venue sizes.

Chapter V explored the compositional process and synchronization strategies in several well-known pieces. I chose to look at more recent music as much of the literature focuses on the repertoire's classics. By addressing recent, but well-known pieces, I hope offer a more understandable and digestible discussion relevant to current practice. Through discussions of pieces such as *Tensio* (2010), *Speakings* (2008), *Behind the Light* (2011), among others, we looked at how the synchronization strategies in each piece are inherently linked with the compositional process in a complex manner. Electronics, scores and recordings were analyzed to show these links. While Chapter IV discussed mixed music in broader terms, this chapter's focus on specific pieces made it possible to see closer links between aesthetics, compositional processes and synchronization strategies. Manoury's aesthetics cause synchronization to affect his compositional process in radically different manners than Tutschku's, for example. The former sees real-time, uncertainty and electronics interpretation as significant elements of his style. This has often caused him to seek out new technology, which along with it often brings the pitfalls of technical problems, uncomfortable musicians, and the often short-lifespans of new devices and software. The latter emphasizes pragmaticism and prioritizing the means to let musicians practice at home, which limit Tutschku's use of technology. Their compositions have changed and adapted to function within these technological, economic, logistical, and artistic limitations in both cases.

Chapter VI looked at a practical example of how this theoretical framework for discussing mixed music developed in the previous chapters can result in a more holistic analysis of a piece. Tutschku's *Zellen-Linien* (2007) was chosen as it has already been widely performed and discussed in the literature. The framework permitted us to discuss both poiesis and aesthesis while still keeping in mind the performer's perspective, drawing from Pestova's (2008) and Berweck's (2012) artistic research. It also allowed us to discuss several aspects of how the compositional concerns of a piece and synchronization are intertwined. The chapter also allowed us to see how technology, composition and performance are often intertwined more broadly. By analyzing only one or two aspects, one loses the total meaning of the artistic product.

Chapter VII explored the potential challenges performing of mixed music from the perspective of various performers. The composition (including the score), performance, and electronics were analyzed as three interconnected pillars. I looked first at potential hurdles for performers of mixed music, such as unfamiliarity with electronics, lack of rehearsal time, notational problems, lack of haptic feedback, the challenges posed by monitoring, and visual dissonance. Afterwards, I revisited the various synchronization strategies and performance techniques from the eyes of performers. Finally, I looked at how time, as defined and explained in Chapters I and III, can influence a piece's musical performance. Moreover, this chapter showed how certain positive aspects of a synchronization strategy could also be quite difficult for a performer and vice-versa. The rigidity of fixed media is both a blessing and a curse for composers and performers.

Chapter VIII explored the RIM's role through practical work I have done for pieces by composers like Romitelli, Schubert, Tzortzis, Jodlowski, Saariaho, and Kanding. I analyzed the electronics' role and synchronization in the composition's performance. Afterwards, I shared personal impressions of the rehearsals and concert. Finally, we explored the possibilities of changing the used synchronization strategies and how they would influence the composition and performance. This permitted me to think simultaneously theoretically and practically about what each strategy could offer. The chapter demonstrated how inherently linked aesthetics and synchronization strategies are to one another. In some compositions, shifting a strategy might offer significant advantages, but it might not suit the piece at all, as in the case of *60 Loops* (2006). In my discussion of Kanding's *Obscure Transparence I* (2013), I put forward alternative synchronization strategies that I propose could assist the performability of the work. The chapter's case studies showed that sophisticated strategies might afford many possibilities, but they also take much time to create. Weighing the cost of time and the resources available against the benefits obtained is always a challenge in the production of mixed music.

In Chapter IX, I shared my experiences writing several compositions and how synchronization strategies were included in the compositional process, or influenced it, and vice-versa. These discussions reflect the application of theory to practice; detailing the way that the framework of synchronization strategies put forward in this thesis has influenced my compositional process. I discussed multiple facets of each work, showing how complex the affordances offered by different synchronization strategies are, and how they interact with the compositional process. We also explored several examples of discrepancies between conception and perception related to synchronization, as in the case of *North Star* (2018), where the following strategy is employed to follow and reply to striated passages, yet still sounds mostly as texture.

Throughout this thesis, the idea of an artistic product has been significant, as described in the introduction. The idea of *recherche-création* is that the art production is not a result in and of itself, but that it can support an argument. Chapters VIII and IX give specific case studies and examples of all the concepts discussed earlier in the thesis. These chapters use the same framework and support it holistically. Mixed music is a complicated and challenging field, and it is difficult to approach theoretically without also being a practitioner. This is not to say that non-practitioners cannot understand mixed music, but that the nuances of its production, such as the synchronization issues presented in this thesis, are inherently connected to composition and performance. To appreciate these details from the outside, the ephemerality of a concert performance may be insufficient. Hence the advancement of our field demands many more concerts, so that more and more practitioners can have the opportunity to discuss these issues together.

Additionally, this mediation between theory and practice included elements of aesthesis and poietics. Looking at the means of production and the sounding result offers a complete view of a composition as it involves the *écriture*, the performance, the electronics, and the resultant sound. Synchronization affects all of these areas in various manners, and although we have mainly focused on composition and synchronization, these other aspects have permeated my discussion and elaborated upon when necessary.

Throughout the thesis, it has become clear that there is a strong relationship between composition and synchronization in mixed music. This link was often mentioned in the literature, but it was never studied or developed further. In much of the literature, real-time is hailed as inherently better because it is in real-time. However, I would argue that the picture of synchronization is much more complicated than what many composers, performers, and researchers have written. Aesthetics become mixed with practicality, technical know-how, compositional needs and many other aspects to form a complete composition consisting of score/composition, electronics and performance. Alvarez (1993) points out how aesthetics and technological aspects can often be challenging to separate. By discussing compositions in terms of synchronization strategies, we are effectively not separating these issues but discussing their intrinsic links within a whole artistic production. It is not about how beautiful the lines of code are but how they are used within an artistic context. When divorced from their context, synchronization strategies on their own are neither novel, complex or exciting. A composition can be summarized as the composer's answer to an artistic dilemma. Various compositional dilemmas will require solutions that suit them. Throughout this thesis, we have been looking at these "answers" to further our understanding of mixed music composition. Artistic production and analysis of existing works allowed us to view these problems and answers in different guises and angles. Essentially, one can view the composition (and its performance) as an ecosystem. Synchronization strategies are what helps bind the electronics and composition together. Depending on the aesthetic goals of the piece, the importance of synchronization and its various affordances will vary. Each chapter and section of the thesis attempted to illuminate these aspects of the aesthetic ecosystem is various manners.

I hope that this research can then serve musicologists, composers, RIMs and performers alike. For the analyst, the presented frameworks try to effectively reunite technological and musicological discourse to view the gestalt of the music instead of examining the result, the technology, or the composition in isolation. Hopefully, this thesis offers to composers a useful account of how others have tackled problems of synchronization in their music, and some of the artistic possibilities that have arisen in these situations. For the RIM, the thesis serves as an important documentation and discussion of their work and role, which as of writing has rarely appeared in English. Additionally, I hope that my discussion on synchronization strategies and aesthetics may offer a useful resource to aid in determining how to best implement technology appropriate to different musical contexts. For performers, this thesis hopefully offers a similar occasion to better understand their role throughout different kinds of synchronization strategies, demonstrating some of the complexities and potential pitfalls, while hopefully demystifying mixed music for some. I also hope that this thesis can serve as the start of a meeting ground between research from performers and composers, leading to mutual understanding.

If anything, this thesis should show that not every problem can have only one solution. Many composers, RIM and performers struggle with the same aspects of mixed music. There is no be-all and end-all solution or answer, only different roads to explore. This research has ultimately left me with more questions than when I started, but has equipped me with many new tools (analytical, artistic and technological), that can only aid in future discussion, research, and music-making. The only certainty that I have gained is that synchronization strategies and composition are deeply related in a tight-knit and complex web of influence.

10.2 Issues & Weaknesses with the Research

The road has been far from linear or straightforward. Because of the impossibility of forming and maintaining a string quartet without support from my host university (the initial plan for the project), it became clear that I had to shift some of the thesis's themes and focus. The laboratory idea I had with the string quartet would not be possible, and thus the idea of working collaboratively with specific instrumentalists to explore a repertoire and then experiment with changing synchronization strategies no longer seemed viable. This meant having to work much more as a freelancer as no musicians were connected to this research through the host university, which, out of necessity, led to drastically different compositions with various instrumental combinations.

Without a dedicated group in a controlled setting, my research had to draw from the often-challenging context of real-world music production, which offers little time to experiment among any number of external pressures. While working freelance, actively shifting synchronization strategies during the production of a work is almost never a possibility. The principal loss of not having worked with a specific repertoire and quartet is that my experimental aim of shifting synchronization strategies became primarily theoretical. However, this perhaps allowed me to explore various aesthetics and musical contexts more than the original plan with a string quartet would have. Learning these pieces inside and out to perform at a high level forced me to analyze them in-depth. Playing music with varying instrumentation and ensemble-size has also become a strength of the thesis, as it now covers broader terrain than just the quartet repertoire and idiomatic writing. It permitted me to consider the role of the conductor, the affordances between solo, chamber, and large ensemble works, and providing case studies where practicality becomes an essential focus, providing real-world context for situations where making changes to pieces on the fly is necessary (as described in Chapter VIII).

In an ideal world, each piece I detail in my case studies, both as a RIM and composer, would have been performed several times to offer the chance to compare each performance. However, this was often logistically and economically impossible. I look forward to working towards new performances for my compositions to see if my reflection on the synchronization strategies will change with time.

Throughout the thesis, I have tried to address how much of the literature explores these concerns in institutional contexts, which represent a minority of performance conditions in our field. This is especially apparent in how much of the literature is centered around IRCAM. In my research, I have attempted to draw my research from literature and musical works from various backgrounds and contexts. However, this remains a difficult task, as there is little publicly available literature or information about composers working independently of well-known institutions. Countless e-mails were also sent to independent groups, smaller institutions and composers, but few answered or were willing to give information on their music. In institutional contexts, composers of mixed music are often far-removed from the consideration of synchronization strategies — these may be completely delegated to a RIM. Issues of authorship and genesis of ideas remain an element of uncertainty within analyses of such works.

Finally, the COVID-19 pandemic, still ongoing at the time of writing, has drastically affected my plans and most of the world's cultural activities. Many concerts, tours, commissions and collaborations have either been postponed or cancelled, which has affected the depth and breadth of my research. Much of my discussion had to remain theoretical without the ability to coordinate new productions in order to put some of these ideas into practice. With any luck, the coming year following the submission this thesis will offer the opportunity to realize aspects of this research that will advance it and my compositional practice further.

10.3 Relevance

Research in mixed music has often been based on the historical analysis of the genre. Many doctoral theses continue to look at works around which there is already significant discussion and documentation, such as Stockhausen and Varèse. The discussion of more contemporary pieces distinguishes this thesis and hopefully offers new insights into exciting current practices. The topic of synchronization has rarely been developed further in most of the literature that mentions it. No theoretical framework existed to discuss these issues, which I hope through this thesis to have shown are of central artistic concern, rather than a 'mere practicality.' Mixed music analysis is generally caught up in either electroacoustic, technological, or note-based analysis, but has rarely mixed these elements, which are all important aspects of this interdisciplinary field. Even within more recent studies such as Clarke, Dufeu & Manning (2020), at least one of these elements is always missing. Synchronization itself is implied in such analyses, but is similarly almost never discussed.

Due to lack of scope, and resources, it is often impossible to discuss composition, electronics, and performance issues in a single study. Therefore, many articles will only focus on one or two issues. This thesis has attempted to address all three issues in various ways, hopefully providing a more holistic view of the genre. This allows us to draw more parallels between various aspects of this music and relate wildly different literature sources together. As the quote at the start of the conclusion by Alvarez suggests, it is impossible to say how synchronization will affect art-making, and it seems futile to address only its theoretical aspects. However, by thinking of synchronization more abstractly and within a specific artistic practice, I believe this study shows how relevant synchronization is to mixed music and demonstrates its multifaceted importance.

10.4 Future Research & Art

There are several aspects related to this research that need to be developed further. In order to test some aspects of my theoretical framework and put it into practice, it would be useful to create an experiment on changing the synchronization strategies and performance techniques used in well-known pieces to see how it influences performance. Afterwards, a more general study based on these experiments could help us understand and generalize characteristics of synchronization strategies and compositional practices across the repertoire. Except for theses such as Tiffon (1994), few have tried to create a general overview of the repertoire, which I believe could be helpful for us historically, culturally, and artistically.

Another step that would aid this discussion is through further analyses of works of mixed music. Few works of the repertoire have significant discussion devoted to them. Multiple analyses of the same works, currently very rare, will permit us to discuss pieces much more in-depth, and compare notes and differing perspectives. Few scholars have written about the same pieces, leading to a multitude of analyses with vastly varying frameworks, fragmenting the field.

An in-depth history of mixed music is still yet to be written, offering little common ground for discussion. Although many authors have detailed aspects of the history of the genre, no one has attempted (as far as I am aware) to create a general history. While various scholarly articles permit us to create a patchwork, long-form research can offer us a comprehensive shared history, such as those established for electroacoustic and contemporary music. This would help establish mixed music as one of the important pillars of art music after World War II.

While these academic advancements would greatly serve the field, it is essential not to forget the art itself, and its direct connection with theory and frameworks of mixed music. Establishing and documenting practices of porting and changing synchronization strategies is important to the practice. Some articles on the subject exist, but I hope that this kind of documentation becomes a more established practice, and that further discussion of synchronization strategies helps to aid the production of this music.

Writings from the RIM's perspective and documentation of their practice are sorely missing from the current literature. As Zattra & Donin (2016) have detailed, most RIMs must learn their craft through trial and error and individual mentoring. By discussing the role more openly we can learn from each other, offer resources to aid in each other's work, and perhaps encourage a younger generation of RIMs to join and advance the practice.

Finally, my ongoing work as a composer represent a continuation of this artistic research. Through my work, I would like to continue to explore multi-layered synchronization strategies like the ones that I developed for *Stadig Fjernare, Bort. Fjernare og Stadig Nærmere* (2020). The possibilities are almost endless. There is little about multi-layered synchronization in the literature, and so as I experiment in my own compositions, I may need to change or elaborate upon my framework in the years to come. I am lucky enough to have been commissioned several solo instrumental works with electronics in 2021, and have recently applied to write an opera with a filmmaker as part of a multidisciplinary group. I have several already-composed works that remain unperformed due to the pandemic, which will hopefully have occasions for premiere in the coming years. From a research standpoint, it will be interesting to see if I change my reflections on the synchronization strategies used in my pieces. I may encounter various performance constraints that will require me to change strategies.

I am also working on using the lessons learned throughout this thesis within more improvised environments. I have been slowly working on playing solo Chapman stick with electronics. The convergence between performance as an instrumentalist and my role as a RIM is an exciting and fresh avenue for my practice and research.

The convergence between art and theory remains where my interest lies, and I believe that both have much to teach the other. My academic research feeds heavily into my compositional and artistic practice and vice-versa. Luckily, within academia, the door has been slowly opened to these discussions, and it is becoming more accepted to bring both of these avenues together, which I believe cannot be siloed from one another.

There is no end in sight for the work ahead.

"Art is longing. You never arrive, but you keep going in the hope that you will."
-Anselm Kiefer (Wroe, 2011)

Appendix A: Accomplishments

Since artistic practice was an essential part of developing my theories and thesis, I have included a list of the most relevant artistic activity throughout my Ph.D. period. Most of my compositions are mixed pieces, and although not all of them are relevant directly to the theme of this thesis, they have given me valuable insight into the artistic and practical aspects of my craft. Additionally, I have also become a member of Trondheim Sinfonietta during this period and became part of the artistic board in 2020. These types of activities are essential when working in a country with relatively little contemporary music. Additionally, as the *recherche-création* paradigm argues, these artistic products are not the research per se but support it.

A.I List of artistic endeavours

Several concerts and premieres have been delayed or cancelled because of the current pandemic.

Composition List:

In Memoriam (2017) – String Quartet & Electronics
Studie V – Aechernar (2017) – String Quartet & Electronics
Anomie (2018) – Solo Piano & Electronics
North Star (2018) – Solo Flute & Electronics
Threnody (2018) – For Bass Orchestra & Electronics
Degrade Me (2019) – For Quintet & Electronics
Life in The Anthropocene (2019) – Violin, Cello & Electronics
Facing Gaia (2019) – Solo Piano & Electronics
Quasar (2020) – For Sinfonietta & Electronics
Stadig Fjernare, Bort. Fjernare og Stadig Nærmere (2020) – Horn & Electronics
Fuck You, Capitalist Pig (2021) – Multichannel acousmatic

Other Artistic Endeavours:

2017 – Electronics and FOH for Terje Bjørklund's opera *Fra Kautokeino til Kalvskinnet*
2017 – Recording several pieces for the duo DonkeyJam
2018 – Reprogramming Pierre Jodlowski's *60 Loops*
2018 – Workshop about dance, music and interaction with STOCOS
2019 – Being granted a composer's stipend for *Quasar* by Det Norske Komponistfond

2019 – Doing the electronics & video of Fausto Romitelli's *An Index of Metals* with Trondheim Sinfonietta

2019 – Doing the electronics & video of Alexander Schubert's *Star Me Kitten*, *Sensate Focus* and *Hello*

2019 – Reprogramming all of the electronics for Nicolas Tzortzis' *Incompatible(s) IV*

2019 – Participation at Mixtur Composition festival in Barcelona Spain

2019 – Participation at Manifeste electroacoustic performance workshop

2019 – Concert doing the electronics of Tzortzis' *Incompatible(s) IV* at Centre George-Pompidou in June

2019 – Concert *Facing Gaia* while studying with Hans Tutschku & Jaime Reis

2019 – A new acousmatic version for 36-speaker dome of my piece *Solace* (2015) played three times and sold out each time

2019 – Converting several pieces by John Chowning from a quadrophonic set-up to a 36-speaker dome that respects his vision for the pieces.

2019 – Recording *Laconisme de l'aile* by Kaija Saariaho with Trine Knutsen

2020 – Concert with *Laconisme de l'aile* by Kaija Saariaho & *North Star* played by Trine Knutsen at Dokkhuset in Trondheim

2020 – Stipend by the Norwegian state for *Degrade Me*

2020 – Concert with *Quasar* by Trondheim Sinfonietta

2020 – Two concerts with *North Star* in Thailand

2020 – Winning Tacet(i) Ensemble Prize for *North Star*

2020 – Performance of *North Star* by Tonje Elisabeth Berg at Kunsthall in Trondheim.

2021 – Playing Schubert's Sensate Focus with Trondheim Sinfonietta twice for an art gallery opening

2021 – Norway tour for the piece *Fuck You, Capitalist Pig*

2021 – Concert with Bhakti by Jonathan Harvey with Trondheim Sinfonietta

2021 – Concert with Aorko by Annesley Black twice

2021 – Concert with Professor Bad Trip by Fausto Romitelli and Princess Nightmare Moon by Natacha Diels

2021 – Performance of Stadig in Montreal, Canada & online by Gabriel Trottier

2021 – Concert premier of *Degrade Me*

A.II List of Publications & Talks

2018 – Presentation of the project at EMS in Florence, Italy

2018 – Presentation at the first International Conference of Mixed Music Pedagogy in Montreal, Canada

2019 – Presentation about writing for performers and synchronization strategies in Trondheim, Norway

2020 – Presentation at the ICLI conference in Trondheim, Norway. Published article in proceedings.

2020 – Seminar on the compositional effects of score following by invitation from NOPA in Trondheim, Norway

2021 – Publication of an article on the string quartet with electronics repertoire in Studia Musicologica Norvegica

Appendix B: List of Files

B.1 Sound & Video Examples

All productions are given in both Wave and MP3 formats for space and listening environment considerations. Salient details about each production is given within the appropriate chapter. Timings may be different on video files due to the introduction. Pieces are mixed and mastered as documentation. All files are in stereo, multichannel files can be supplied if needed.

Chapter VIII:

Table 25. Sound & video examples in Chapter VIII

File Name	**Credits**	**Notes**
Kanding – Obscure Transparence	Recorded by Terje Hallan at Dokkhuset. Mix and mastering by myself	Performed by Trondheim Sinfonietta at the Meta.Morf opening in March 2020.
Laconisme – Studio – Take 7-8-9	Myself	Three takes to show the different interpretational possibilities of the piece. These are submitted as audio and video.
Laconisme – Dokkhuset	Recorded by Dokkhuset, filmed by Martin Kristoffersen, mixed and mastered by myself	Filmed and recorded at Trine's Forskningskonsert in February 2020.
Romitelli – An Index of Metals – Cues 2, 10, 27, 39	Recorded by Dokkhuset, mix and master by myself	These files are used for the examples in Chapter VIII. The timings of each cue is also given for the whole production
Romitelli – An Index of Metals	As above	Full production
Schubert – Hello	Direct from FOH by Andreas N. Haugen, mastering by myself	Performed by Trondheim Sinfonietta, March 2019 at Cinemateket.
Schubert – Sensate Focus	As above	As above
Schubert – Star Me Kitten	As above	As above
Tzortzis – Incompatibles IV - Daulhac	Recorded, mixed and mastering by IRCAM	Performed on 29th of June 2019 at Centre George-Pompidou by Ambroise Daulhac.

Chapter IX:

Table 26. Sound & video examples in Chapter IX

File Name	Credits	Notes
North Star – Dokkhuset Forskningskonsert	Recorded by Dokkhuset, filmed by Martin Kristoffersen, mixed and mastered by myself	From Trine Knutsen's Forskningskonsert in February 2020. Audio and video.
North Star – Taceti	Recorded by Tacet(i) Ensemble, mixed and mastered by myself	One of the two performances by the Tacet(i) Ensemble for winning the call for scores. Performed in August/September 2020. A video stream of the concert can also be seen at: https://www.youtube.com/watch?v=Q4QViKd5YBw
North Star – Tonje – Kunsthall Rehearsal	Recorded by the RIM Tale Vang Ellefsen. Mixed and mastered by myself	A rehearsal before a concert at Kunsthallen in Trondheim in September 2020. I was not present and the RIM for the occasion was Tale Vang Ellefsen. Flute played by Tonje Elisabeth Berg.
North Star – Trine – Studio Take 10-11-12	Recorded, filmed, mixed and mastered by myself	Three takes to show the various interpretations Trine Knutsen did. The electronics were still sometimes shaky at this point. December 2019. Video and audio.
North Star – Trine – Systems 3-4 Example	As above	Example file as discussed in Chapter IX. Video only.
Quasar	Recorded by Dokkhuset, filmed by Martin Kristoffersen, mixed and mastered by myself	Performed by Trondheim Sinfonietta from the Meta.Morf 2020 opening in March 2020. Video and audio.
Quasar – Section A – Fixed Media Only	-	Example file as discussed in Chapter IX.
Stadig – Studio Take 4	Recorded by Marwan Laroussi, mixed	This is a studio take of the piece played by Garbriel Trottier.

	and mastered by myself	

B.2 Max/MSP Patches

These patches may not run on your hardware due to the need for externals that I cannot share. However, the programming environment and logic is still there to be explored and understood.

Chapter VIII:

60 Loops – Rehearsal Patch

Chapter IX:

North Star – Main Concert Patch (Externals not included)

The other concert patches are not submitted as they are very large. They also re-use several of the same modules and systems as *North Star*. If the committee wants to see the patches, although it is not required to understand the thesis, these can be sent.

Appendix C: Meta.Morf Catalogue

DOKKHUSET / March 6, 2020 @ 20:30

PROGRAM: MATHIEU LACROIX – QUASAR, 2020 / NATASHA BARRETT – ISLANDS OF LOST PASSPORTS, 2017 / EJNAR KANDING – OBSCURE TRANSPARENCE 1 – MOSAICO 2, 2013

World premiere:
"QUASAR (2020)" **/** MATHIEU LACROIX **[ca]**
Trondheim Sinfonietta

Using the latest technology does not make music modern or even part of the digital wild. The problems we face today are not as much on the technological side, but about how we address aesthetic issues. How does the use of this technology change the poietic process? From there, we can also look at the aesthesis of the work of art created. With the speed at which technology has evolved – especially in the last few years – we seem to have a collective amnesia that many of these musical and artistic issues were already raised in the 1960's and 70's. The technology (and its speed) has changed, but the poietics and aesthetic questions have stayed the same. Perhaps it is time we try to answer them?

Another important aspect is humanity (and/ or transhumanity). What does humanity mean in music, and connected to this, what is contemporary? The Italian composer Fausto Romitelli wrote that a composer is modern when she is reflecting on language as a fundamental of her composing. Humanity is imperfection, small interpretational changes and that the music reflects on our nature and environments. Music (and art) cannot reflect upon the human condition if it is only beautiful, only ugly, only conceptual, only sensual, only composed, only improvised, etc.

The music you will hear, reflects on all these aspects and takes inspiration from several phenomena connected to black holes and quantum physics. It is not meant purely conceptually, nor is it program music. It sits somewhere in between, as our nature is never exactly here, or there. Some musical parameters are taken and mapped directly from astrophysics research, but they do not illustrate in any way how a quasar would sound or move.

The twelve musicians on stage give us the human aspect. They will (probably) make mistakes, their tempi will not be perfect but these are human elements which make it worth listening to. The electronics will be here and there. An array of speakers around the audience will let you travel into the murky and cold space of the digital wild.

Speakers on the stage will form the avatar of the instrumentalists in this brave new world. At the heart of this music lies the dichotomy of human and electronic possibilities, the heart of the digital wild and all its kinky possibilities. The musicians play mainly through-composed music, with a few exceptions of open sections. The processes used in the writing for acoustic instruments have then often been transferred to computer programs which will use these processes further in real- time to create the electronics based on how the musicians are playing and interpreting the music. The electronics do not truly come to life without the presence of the human in music.

These possibilities for hybrid ecologies between electroacoustic and acoustic have interested me for many years. I feel that they are of our times, showing both the real and unreal. It shows us a hybrid in the same way as transhumanism. In essence, it shows us the possibilities and limits of our future.

Mathieu Lacroix is a French-Canadian composer based in Norway. He has a master’s degree in music technology specializing in contemporary classical composition with electroacoustics. He has studied and/or participated in classes with composers like Natasha Barrett, Hans Tutschku, Jaime Reis, Tristan Murail, Michael Obst, Trond Engum and Ståle Kleiberg. He has studied at NTNU in Norway, IRCAM in France and Musiques & recherches in Belgium. He has been invited to festivals such as Mixtur in Spain and Manifeste in France. His music generally mixes acoustic instruments with electronic sound sources which can understand and interpret the music just as much as the musicians. He is currently a Ph.D candidate at NTNU in Norway analyzing the feedback loops between synchronization strategies and compositional processes in mixed music, using both academic and artistic research methods. Additionally, he also teaches in both music technology and classical music, and also worked as a sound engineer.

Trondheim Sinfonietta (TSi) is a gathering of professional musicians eager to explore new, fresh and challenging music. The last few years TSi increased the activity and the collaboration towards local composers. This has resulted in exciting projects influenced by jazz, nursery rhymes and Eastern and Scandinavian folk music. At the same time TSi has explored the works of international composers. The famous HK Gruber, Brett Dean and Steve Reich have all successfully conducted their compositions with TSi. They received a Norwegian Grammy in 2008 and their concerts gain a lot of praise both from critics and audience. More recently TSi has also been on a Scandinavian tour playing music in four Scandinavian countries to present the different types of contemporary musics from each country. TSi has also recently released a new CD on the world-renown BIS records with music by Lindquist, Sørensen, Hosokawa and Norderval.

Supported by: Det Norske Komponistfond, NTNU, Norges Komponist Foreningen

Bibliography

Texts, Videos & Presentations

Acosta, S. C. (2016). *Pour une écriture multimédia dans la composition musicale*. (Université Paris VIII, France).

Adams, J. L. (2004). *Winter music: Composing the north*. Wesleyan University Press.

Adams, J. L. (2009). *The place where you go to listen: In search of an ecology of music*. Wesleeyan University Press.

Agus, T. R., Suied, C. & Pressnitzer, D. (2019). Timbre recognition and sound source identification. In K. Siedenburg, C. Saitis, S. McAdams, A. N. Popper, & R. R. Fay (Eds.) *Timbre: Acoustics, Perception, and Cognition* (pp. 59-86). Springer International Publishing.

Akkermann, M. (2016). (Re-)performing early mixed music from the 1980s at Ircam: Pierre Boulez's Dialogue de l'ombre double. *Circuit: Musiques Contemporaines*, *26*(2), 51. https://doi.org/10.7202/1037303ar

Alperson, P. (1980). "Musical time" and music as an "art of time." *The Journal of Aesthetics and Art Criticism*, *38*(4), 407. https://doi.org/10.2307/430322

Alphant, M. & Bouhénic, P. (Directors) (2015). *Georges Didi-Huberman – 12 images pour le meilleur et pour le pire* [Film]. Zadig Productions.

Alsop, R. 1999. Exploring the self through algorithmic composition. *Leonardo Music Journal,* 89-94.

Alvarez, J. (1993). *Compositional strategies in music for solo instruments and electroacoustic sounds*. (City University London, London).

Arbo, A. (2003). *Le corps électrique: Voyage dans le son de Fausto Romitelli*. L'Harmattan.

Arlander, A. (2010). Characteristics of visual and performing arts. In M. Biggs, & H. Karlsson (Eds.) *The Routledge Companion to Research in the Arts* (pp. 315-332). Routledge.

Bachtrack (2019). Lenny Bernstein and women composers: The Bachtrack classical music statistics for 2018 (News article). Bachtrack. Retrieved from: https://bachtrack.com/classical-music-statistics-2018

Bacot, B., & Féron, F.-X. (2016). The creative process of *Sculpting the Air* by Jesper Nordin: Conceiving and performing a concerto for conductor with live electronics. *Contemporary Music Review*, *35*(4–5), 450–474. https://doi.org/10.1080/07494467.2016.1257569

Bahn, C., Hahn, T., & Trueman, D. (2001). *Physicality and feedback: A focus on the body in the performance of electronic music*. ICMC.

Baillet, J. (2001). Flèche du temps et processus dans les musique après 1965. In F. Lévy (Ed.) *Les écritures du temps* (musique, rythme, etc) (pp. 155-216). L'Harmattan.

Bailey, K. (1991). *The twelve-note music of Anton Webern: Old forms in a new language*. Cambridge University Press.

Barrett, N. (2002). Spatio-musical composition strategies. *Organised Sound*, *7*(3), 313–323. https://doi.org/10.1017/S1355771802003114

Barrett, N. (2012). Natasha Barrett, compositrice en residence 2012 présente son projet de recherche musicale à l'Ircam. April 13th, 2012 at IRCAM, Paris, France. Retrieved from : https://medias.ircam.fr/x6107bd_natasha-barrett-compositrice-en-residence

Barrett, N., & Otondo, F. (2007). Creating sonic spaces: An interview with Natasha Barrett. *Computer Music Journal*, *31*(2), 10–19.

Baschet, F. & Lemouton, S. (2019). Décryptage de BogenLied (video). Presentation at IRCAM, Paris, France March 18th 2019. Retrieved from: https://medias.ircam.fr/x281999

Bates, E. (2009). *The composition and performance of spatial music*. (Trinity College Dublin, Ireland).

Battier, M. (2003). A constructivist approach to the analysis of electronic music and audio art – between instruments and faktura. *Organised Sound*, *8*(03). https://doi.org/10.1017/S1355771803000220

Battier, M. (2004). Electroacoustic music studies and the danger of loss. *Organised Sound*, *9*(01). https://doi.org/10.1017/S135577180400007X

Battier, M., & Nouno, G. (2003). L'électronique dans l'opéra de Kaija Saariaho, L'amour de loin. *Musurgia*, *10*(2).

Baudry, O. & Bonardi, A. (2015). Enquête sur les frequency-shifters dans les oeuvres mixtes. October 9th, 2015 at IRCAM, Paris, France. Retrieved from : https://medias.ircam.fr/xb7bc3c

Belet, B. (2003). Live performance interaction for humans and machines in the early twenty-first century: One composer's aesthetics for composition and performance practice. *Organised Sound*, *8*(03). https://doi.org/10.1017/S1355771803000281

Bell, J. (2016). *Audio-Scores: A resource for composition and computer-aided performance*. (Guildhall School of Music, London, UK).

de Benedictis, A. E. (2018). Authorship and performance tradition in the age of technology: (with examples from the performance history of works by Luigi Nono, Luciano Berio and Karlheinz Stockhausen). In F. Sallis, V. Bertolani, J. Burle, & L. Zattra (Eds.) *Live-Electronic Music: Composition, Performance, Study* (pp. 195-216). Routledge.

Bennet, J. (2018). Songwriting, digital audio workstations, and the Internet. In N. Donin (Ed.) *The Oxford Handbook of the Creative Process in Music*. Oxford Press.

Bernard, J. W., & Carter, E. (1990). An interview with Elliott Carter. *Perspectives of New Music*, *28*(2), 180. https://doi.org/10.2307/833018

Berweck, S. (2012). *It worked yesterday: On (re-) performing electroacoustic music* (University of Huddersfield). Retrieved from http://eprints.hud.ac.uk/17540/

Bevilacqua, F., Baschet, F., & Lemouton, S. (2012). The augmented string quartet: Experiments and gesture following. *Journal of New Music Research*, *41*(1), 103–119. https://doi.org/10.1080/09298215.2011.647823

Bevilacqua F. , Rasamimanana, N. H., Fléty, E., Lemouton, S., Baschet, F. (2006). The augmented violin project: research, composition and performance report. 6th International Conference on New Interfaces for Musical Expression (NIME 06), Paris, France. pp.402-406.

Biasutti, M., Concina, E., Wasley, D., & Williamon, A. (2016). Music Regulators in Two String Quartets: A Comparison of Communicative Behaviors between Low- and High-Stress Performance Conditions. *Frontiers in Psychology*, *7:1229*. https://doi.org/10.3389/fpsyg.2016.01229

Blondeau, S. J. (N.D.) Namenlosen. Retrieved from : https://www.sasha-j-blondeau.com/namenlosen.html

Blondeau, S. J. (2013). Environnement, modélisation et singularisation : à la recherche d'un territoire compositionnel (video). April 8th 2013 at IRCAM, Paris, France. Retrieved from: https://medias.ircam.fr/x081de5_environnement-modelisation-et-singularisa

Blondeau, S. J. (2014). Tesla ou l'effet d'étrangeté (video). May 19th 2014 at IRCAM, Paris, France. Retrieved from: https://medias.ircam.fr/x312c52

Blondeau, S. J. (2017). *Espaces compositionnels et temps multiples: de la relation forme/matériau*. (Université Pierre et Marie Curie, Paris, France).

Blondeau, S. J. (2018). Electronic and temporal writing (Blog). Retrieved from: https://www.sasha-j-blondeau.com/electronic-and-temporal-writing.html

Bonardi, A. (2013). Pérenniser pour transmettre, transmettre pour pérenniser—Destins de l'œuvre mixte interactive. In É. Gayou (Ed.), *Musique et technologie—Préserver, archiver, re-produire* (pp. 105–126). Institut National de l'audiovisuel.

Bonardi, A., Bossis, B., Couprie, P. & Tiffon, V. (2017). *Analyser la musique mixte*. Éditions Delatour France.

Borgdorff, H. (2006). *The debate on research in the arts* (Vol. 2). Kunsthøgskolen i Bergen.

Borgdorff, H. (2012). *The conflict of the faculties: Perspectives on artistic research and academia*. Leiden University Press.

Born, G. (1995). *Rationalizing culture: IRCAM, Boulez and the institutionalization of the musical avant-garde*. University of California Press.

Boulez, P. (1963). *Penser la musique aujourd'hui*. Éditions Gonthier.

Boulez, P. (1968). *Notes of an apprenticeship*. American Biographical Services.

Boulez, P. (1971). *Boulez on music today* (S. Bradshaw & R. R. Bennett, trans.). Faber & Faber.

Boulez, P. (2005). *Leçons de musique: Points de repère III*. Christian Bourgois.

Boutard, G. (2016a). Solo works of mixed music with live electronics: A qualitative enquiry in timbre and gesture from the performer's perspective. *Musicae Scientiae*, *20*(3), 361–391. https://doi.org/10.1177/1029864916634421

Boutard, G. (2016b). Co-construction of meaning, creative processes and digital curation: The transmission of music with live electronics. *Journal of Documentation*, *72*(4), 755–780. https://doi.org/10.1108/JDOC-09-2015-0121

Boutard, G. (2019). Performing live electronics in Luigi Nono's works. In D. P. Biró, J. Goldman, D. Heusinger & C. Stratz (Eds.) *Live Electronics in the SWR Experimentalstudio* (pp. 183-192). Wolke Verlag.

Boutard, G. & Féron, X. (2017). La pratique interprétative des musiques mixtes avec électronique temps réel : Positionement et méthodologie pour étudier le travail des instrumentistes. In A. Bonardi, B. Bossis, P. Couprie, & V. Tiffon (Eds.) *Analyser la musique mixte* (pp. 39-60). Éditions Delatour.

Boutard, G., & Guastavino, C. (2012). Archiving electroacoustic and mixed music: Significant knowledge involved in the creative process of works with spatialisation. *Journal of Documentation*, *68*(6), 749–771. https://doi.org/10.1108/00220411211277028

Boutet, D. (2018). La création de soi par soi dans la recherche-création : comment la réflexivité augmente la conscience et l'expérience de soi. *Approches inductives*, 5(1), 289–310. https://doi.org/10.7202/1045161ar

Brooker, P. & Sharrock, W. (2016). Collaborate music-making with digital audio workstations: The "nth member" as a heuristic device for understanding the role of technologies in audio composition. *Symbolic Interaction, 39: 463-483*. https://doi.org/10.1002/symb.238

Brown A. R. & Dillon, S. (2013). Meaningful engagement with music composition. In D. Collins, (Ed.) *The Act of Musical Composition: Studies in the Creative Process* (pp. 79-110). Ashgate Publishing.

Bullock, J., Coccioli, L., Dooley, J., & Michailidis, T. (2013). Live electronics in practice: Approaches to training professional performers. *Organised Sound*, *18*(02), 170–177. https://doi.org/10.1017/S1355771813000083

Burloiu, G., Cont, A., & Poncelet, C. (2017). A visual framework for dynamic mixed music notation. *Journal of New Music Research*, *46*(1), 54–73. https://doi.org/10.1080/09298215.2016.1245345

Burtner, M. (2002). The metasaxophone: Concept, implementation, and mapping strategies for a new computer music instrument. *Organised Sound*, *7*(02). https://doi.org/10.1017/S1355771802002108

Cabanzo, D. (N.D.). Correspondance entre systèmes de représentation musicale et transformations électroniques dans les œuvres mixtes en temps réel entre 1990 à 2016 [Manuscript in Preparation]. (IRCAM – Sorbonne Université, France).

Cage, J. (1961). *Silence*. Wesleyan University Press.

Campion, E. (2017). Dual reflections: A conversation with Kaija Saariaho and Jean-Baptiste Barrière on music, art, and technology. *Computer Music Journal*, *41*(3), 9–20. https://doi.org/10.1162/comj_a_00426

Caplin, W. E. (1998). *Classical form: A theory of formal functions for the instrumental music of Haydn, Mozart, and Beethoven*. Oxford University Press.

Carter, E., Link, J. F., & Hopkins, N. (2002). *Elliott Carter harmony book*. Carl Fischer.

Castanet, P.-A. (2005). La poétique musicale: de l'extravaganse du matérieau à l'ek-stasis de la psyché. In A. Arbo (Ed.) *Le corps électrique : Voyage dans le son de Fausto Romitelli* (pp. 89-114). L'Harmattan.

Castanet, P.-A., & Fineberg, J. (2000). Gérard Grisey and the foliation of time. *Contemporary Music Review*, *19*(3), 29–40. https://doi.org/10.1080/07494460000640351

Ciciliani, M. (2017). Music in the expanded field- On recent approaches to interdisciplinary composition. *Darmstädter Beiträge zur Neuen Musik, 21, 23-35*.

Ciciliani, M., & Mojzysz, Z. (2015). Evaluating a method for the analysis of performance practices of electronic music. *ICLI 2014 Proceedings*, 45-50.

Chowning, J. (2007). "Stria": Lines to its reconstruction. *Computer Music Journal*, *31*(3,). http://www.jstor.org/stable/40072591

Clarke, M., Dufeu, F., & Manning, P. (2015*)*. Les relations entre technologie et créativité dans l'analyse des musiques électroacoustiques : Une étude comparative de Riverrun de Barry Truax et Imago de Trevor Wishart. *Musurgia, vol. XXII, No.1, 2015, 27-44*.

Clarke, M., Dufeu, F. & Manning, P. (2020). *Inside computer music*. Oxford University Press.

Coccioli, L. & Bullock, J. (2005). Modernising live electronics technology in the works of Jonathan Harvey. In *Proceedings of the International Computer Music Conference*, Barcelona, Spain, 2005.

Cohen-Levinas, D. (1999). *Causeries sur la musique: Entretiens avec des compositeurs*. L'Harmattan.

Cohen-Levinas, D. (2005). Salut petit frère – L'éternité se dresse pleine de musique. In A. Arbo (Ed.) *Le Corps Électrique : Voyage Dans le Son de Fausto Romitelli* (pp. 171-178(. L'Harmattan.

Cont, A. (2008). *Modeling musical anticipation: From the time of music to the music of time*. (University of California, USA).

Cont, A. (2012). Synchronisme musical et musiques mixtes: Du temps écrit au temps produit. *Circuit: Musiques contemporaines*, *22*(1), 9. https://doi.org/10.7202/1008965ar

Cont, A., & Gerzso, A. (2010). The C in IRCAM: Coordinating musical research at IRCAM. *International Computer Music Conference*. https://hal.archives-ouvertes.fr/hal-00839066/

Cook, N. (1987). *A guide to musical analysis*. Oxford University Press.

Cook, N. (2001). Between process and product: Music and/as performance. *MTO: A journal of the Society of Music Theory*, Vol. 7-2.

Cook, N. (2015). Performing research: Some institutional perspectives. In M. Dogantan-Dack (Ed.) *Artistic Practice as Research in Music: Theory, Criticism, Practice* (pp. 11-32). Ashgate Publishing.

Couprie, P. (2015). Algorithmique et technologies numériques dans la notation musicale. In S. L. Martin (Ed.) *Musiques Orales, Leur Notation et Encodage Numérique* (pp. 99-115).

Couprie, P. (2016). L'analyse de la musique mixte: vers une redéfinition des "workflows" en musicologie. In M. Battier (Ed.) *Musique et technologie: Regards sur les musiques mixtes* (pp. 232-247). Groupe de recherches musicales de l'INA.

Cox, F. (2006). Aura and electronic music. In C. S. Mahnkopf, F. Cox & W. Schurig, W. (Eds.) *Electronics in New Music* (pp. 52- 66). Wolke Verlag.

Cox, F. (2008). Recoil, for solo cello: Background and analysis. In C. S. Mahnkopf, F. Cox & W. Schurig, W. (Eds.) *Facets of Second Modernity* (pp. 57-98). Wolke Verlag.

Crispin, D. (2014). 'Scaling Parnassus in running shows': From the personal to the transpersonal via the medium of exposition in artistic research. In M. Schwab & H. Borgdorff (Eds.) *The Exposition of Artistic Research: Publishing Art in Academia* (pp. 139-152). Leiden University Press.

Croft, J. (2007). Theses on liveness. *Organised Sound*, *12*(01), 59. https://doi.org/10.1017/S1355771807001604

Cross, J., Harvey, J., Lachenmann, H., Wlbner, A., & Klein, R. (2004). *Identity and difference: Essays on music, language and time*. Leuven University Press.

Crowley, D. (2019). Introduction – 'The right to experiment'. In D. Crowley, (Ed.) *Ultra Sounds: The Sonic Art of Polish Radio Experimental Studio* (pp. 8-43). The Adam Mickiewicz Institute : Muzeum Sztuki: ZKM Centre for Art and Media

Cuddon, J.A. (2012). *Dictionary of literary terms and literary theory*. Penguin Books.

Dack, J. (1994). Pierre Schaeffer and the significance of radiophonic art. *Contemporary Music Review*, *10*(2), 3-11.

Daubresse, É. (2015). Autour d'Einspielung I d'Emmanuel Nunes. *Dissonance / Dissonanz*, *130*, 8.

Davidson, J. W. (1993). Visual perception of performance manner in the movements of solo musicians. *Psychology of Music*, *21*(2), 103–113. https://doi.org/10.1177/030573569302100201

Davidson, J. W. (1997). The social psychology of performance. In: D. J. Hargreaves and A. C. North (Eds.), *The Social Psychology of Music (*pp. 209-226). Oxford University Press.

Davidson, J. W. (2001). The role of the body in the production and perception of solo vocal performance: A case study of Annie Lennox. *Musicaie Scientiae,* V, 235-256.

Davidson, J. W., & Good, J. M. M. (2002). Social and musical co-ordination between members of a string quartet: An exploratory study. *Psychology of Music*, *30*(2), 186–201. https://doi.org/10.1177/0305735602302005

Day, T. (2000). *A century of recorded music : Listening to musical history*. Yale University Press.

Decarsin, F. (2001). Inventions rythmiques et écriture du temps dans les musiques après 1945. In F. Lévy (Ed.) *Les écritures du temps* (musique, rythme, etc) (pp. 155-216). L'Harmattan.

Delaere, M. (2009). Tempo, metre, rhythm. Time in twentieth-century music. In D. Crispin (Ed.) *Unfolding Time: Studies in Temporality in Twentieth-Century Music* (pp. 13-44). Leuven University Press.

Delalande, F. (1993). Analyser le style en musique électroacoustique: Approximation et pluralité en analyse comparative. *Analyse Musicale*, *32*, 11.

Delalande, F. (2007). Towards an analysis of compositional strategies. *Circuit: Musiques contemporaines*, *17*(1), 11. https://doi.org/10.7202/016771ar

Demoucron, M. (2008). *On the control of virtual violins: Physical modelling and control of bowed string instruments*. (Datavetenskap och kommunikation, Kungliga Tekniska högskolan, Sweden).

Derrien, J.-P. (1995). *Entretien avec Philippe Manoury*. Compositeurs d'aujourd'hui : Philippe Manoury. IRCAM – Centre Georges-Pompidou.

Deutsch, D. (1982). Organizational processes in music. In M. Clynes (Ed.) *Music, Mind, and Brain* (pp. 119-136). Springer US.

Di Scipio, A. (2018). Dwelling in a field of sonic relationships: 'instrument' and 'listening' in an ecosystemic view of live electronics performance. In F. Sallis, V. Bertolani, J. Burle & L. Zattra (Eds.) *Live-Electronic Music: Composition, Performance, Study* (pp. 17-45). Routledge.

Didi-Huberman, G. (2018). *Survival of the fireflies* (trans. Mitchell, L. S.). University of Minnesota Press.

Ding, S.-U. (2006). Developing a rhythmic performance practice in music for piano and tape. *Organised Sound*, *11*(03), 255. https://doi.org/10.1017/S1355771806001518

Dodge, C. & Jerse, T. (1997). *Computer music: Synthesis, composition and performance*. Schirmer Books.

Donin, N. (2006). Spatialization as a compositional tool and individual access to music in the future: Jonathan Harvey in conversation with Nicolas Donin. *Circuit: Musiques Contemporaines*, *16*(3), 75. https://doi.org/10.7202/902414ar

Donin, N. (2008). Enquête sur l'atelier d'un compositeur de musique contemporaine. *Revue de Synthèse*, *129*(3), 401–420. https://doi.org/10.1007/s11873-008-0051-6

Donin, N. (2013a). Empirical and historical musicologies of compositional processes: Towards a cross-fertilisation. In D. Collins (Ed.) *The Act of Musical Composition* (pp. 1-26). Ashgate Publishing.

Donin, N. (2013b). L'auto-analyse, une alternative à la théorisation ?. In N. Donin & L. Feneyrou, (Eds.) *Théories de la composition musicale au XXe siècle*. (pp. 1629-1664). Symétrie.

Donin, N. (2017). Domesticating gesture: the collaborative creative process of Florence Baschet's StreicherKreis for 'augmented' string quartet (2006-08). In E. F. Clarke & M. Doffman (Eds.) *Distributed Creativity: Collaboration and Improvisation in Contemporary Music* (pp. 70-90). Oxford University Press.

Donin, N. (2018). La musicologie des processus de composition: Entre histoire et cognition. *Transposition*, *Hors-série 1*. https://doi.org/10.4000/transposition.1689

Donin, N. (2019). Un siècle d'écrits réflexifs sur la composition musicale : Anthologie d'uato-analyses de Janáček à nos jours. Haute école de musique de Genève.

Donin, N., & Féron, F.-X. (2012). Tracking the composer's cognition in the course of a creative process: Stefano Gervasoni and the beginning of *Gramigna*. *Musicae Scientiae*, *16*(3), 262–285. https://doi.org/10.1177/1029864912448328

Donin, N., & Theureau, J. (2005). Voi(rex) de Philippe Leroux. *Dissonance / Dissonanz.*

Donin, N., Fierro, D., Misdariis, N., Pecquet, F., & Zattra, L. (2019). *Labex CAP - Création, Arts et Patrimoine* (presentation). *s*. 32. Sound Design Days, Paris, November 28-29, 2019.

Donnadieu, S. (2007). Mental representation of the timbre of complex sounds. In J. Beauchamp (Ed.) *Analysis, Synthesis and Perception of Musical Sounds* (pp. 272-311). Springer.

Doornbusch, P. (2002). Composers' views on mapping in algorithmic composition. *Organised Sound*, *7*(02). https://doi.org/10.1017/S1355771802002066

Draus, A. (2019). The past in the music of the digital natives of the 21st century: The sense or nonsense of post-material aesthetics. *Polsi Rocznik Muzykologiczny XVII* (pp. 136-148).

Duchez, M.E. (1991). L'évolution scientifique de la notion de matérieau musical. In J.-B. Barrière (Ed.) *Le timbre, métaphore pour la composition* (pp.47-81). IRCAM / Christian Bourgois.

Ducros, J. (2012). *L'atonalisme. Et après?* [Video Presentation]. Collège de France, France. Retrieved from: https://www.college-de-france.fr/site/karol-beffa/seminar-2012-12-20-15h00.htm

Dudas, R. (2015). *Another take on renovating dated technology for concert performance*. ICMC 2015, September 25-October 1, Texas, USA.

Dufeu, F., & Bonardi, A. (2014). Analysing the creative process through a modelling of tools and methods for composition in Hans Tutschku's Entwurzelt. *Proceedings of the Electronic Music Studies 2014*.

Dufourt, H. (2007). *Mathesis et subjectivité: des conditions historiques de possibilité de la musique occidentale*. Éditions MF.

Dufourt, H. (2014a). *Musique pouvoir écriture*. Éditions Delatour.

Dufourt, H. (2014b). *Spectres: composer l'écoute*. Shelter Press.

Dusapin, P. (2012). *Flux, trace, temps, inconscient : Entretiens sur la musique et la psychanalyse*. Éditions Cécile Defaut.

Dusapin, P. (2013). Lettre de Pascal Dusapin au directeur du Collège de France [web log comment]. Retrieved from: http://brunoserrou.blogspot.com/2013/04/lettre-de-pascal-dusapin-au-directeur.html

Dusapin, P., & McKinley, M. (2017). *Imaginer la composition musicale*. Presse universitaires du Septentrion.

Echeveste, J.-M. (2015). *Un langage de programmation pour composer l'intéraction musicale: La gestion du temps et des évènements dans Antescofo*. (Université Pierre et Marie Curie – Paris VI, Paris, France).

Eigenfeldt, A. (2007). Real-time composition or computer improvisation? A composer's search for intelligent tools in interactive computer music. *Proceedings of the Electronic Music Studies 2007*. http://www.sfu.ca/~eigenfel/RealTimeComposition.pdf

Emmerson, S. (1986). *The language of electroacoustic music*. Macmillian Press.

Emmerson, S. (2000). Crossing cultural boundaries through technology? In S. Emmerson (Ed.) *Music, electronic media, and culture* (pp. 115-137). Ashgate.

Emmerson, S. (2006). In what form can « live electronic music" live on?. *Organised Sound* 11/3: 209-19.

Emmerson, S. (2007). Where next? New music, new musicology. *Proceedings of the Electroacoustic Music Studies Network Conference*, 1–6. Retrieved from http://www.ems-network.org/IMG/pdf_EmmersonEMS07.pdf

Emmerson, S. (2016). The analysis of live and interactive electroacoustic music: Hans Tutschku – Zellen-Linien (2007). In S. Emmerson & L. Leigh (Eds.) *Expanding the Horizon of Electroacoustic Music Analysis* (pp. 333-354). Cambridge University Press.

Emmerson, S. (2018a). Introduction: Music practice – reaching out with technology. In S. Emmerson (Ed.) *The Routledge Research Companion to Electronic Music: Reaching Out With Technology* (pp. 1-18). *Routledge*.

Emmerson, S. (2018b). Electroacoustic music before language. *Proceedings of the Electroacoustic Music Studies Network Conference, Florence* (Italy), June 20-23 2018.

Emerson, G., & Egermann, H. (2018). Gesture-sound causality from the audience's perspective: Investigating the aesthetic experience of performances with digital musical instruments. *Psychology of Aesthetics, Creativity, and the Arts*, *12*(1), 96–109. https://doi.org/10.1037/aca0000114

Emmerson, S., & Leigh, L. (2016). *Expanding the horizon of electroacoustic music analysis*. Cambridge University Press.

Engum, T. (2012). *Beat the Distance: Music technological strategies for composition and production*. (NTNU, Trondheim, Norway).

Enns, S. (2017). *Towards a self-sufficient approach for the electro-acoustic clarinetist: A resource for performers and educators*. (McGill University, Montreal, Canada).

Enns, S. (2018). From curiosity to self-sufficiency: Mixed-music pedagogy and the performer. *International Conference on Mixed Music Pedagogy* 2018, 16-19 November 2018, Montreal, Canada.

Errante, F. G. (1985). Performing with tape: Music for clarinet and electronics. *Music Educators Journal*, *72*(3), 49. https://doi.org/10.2307/3400538

Essl, G. & O'Modhrain, S. (2006). An enactive approach to the design of new tangible musical instruments. *Organised Sound, 11(3), 285-296.*

Exarchos, D. (2018). The skin of spectral time in Grisey's Le noir de l'étoile. *Twentieth-Century Music, 15*(1), 31-55. doi:10.1017/S1478572218000051

Faia, C. (2014). *Collaborative computer music composition and the emergence of the computer music designer*. (Brunel University, England).

Farra, R. D. (2018). Research-creation in Latin American. In S. Emmerson (Ed.) *The Routledge Research Companion to Electronic Music: Reaching Out With Technology* (pp. 21-48). Routledge.

Fassol, L. (2017). *Une compositrice en recherche. Entretien avec Julia Blondeau. Ensemble Intercontemporain*. Retrieved from : https://www.ensembleintercontemporain.com/fr/2017/05/une-compositrice-en-recherche-entretien-avec-julia-blondeau/

Feder, G. (2011). *Music philology: An introduction to musical textual criticism, hermeneutics, and editorial technique*. Pendragon Press.

Felici, C. (2017). Inner structures and spirituality in Jonathan Harvey's music. *9th European Music Analysis Conference – Euromac, June 28th to 1st of July, 2017, Strasbourg, France.*

Ferneyhough, B. (1995). *Collected writings*. Routledge.

Feneyrou, L. (2011). Seuils. Autour du triptyque …auf… de Mark Andre. *Circuit*, *21*(1), 23–35. https://doi.org/10.7202/1001160ar

Féron, F.-X. (2011). The emergence of spectra in Gérard Grisey's compositional process: From *Dérives* (1973–74) to *Les espaces acoustiques* (1974–85). *Contemporary Music Review*, *30*(5), 343–375. https://doi.org/10.1080/07494467.2011.665582

Féron, F.-X. & Boutard, G. (2018). Instrumentalists on solo works with live electronics: Towards a contemporary form of chamber music?. In F. Sallis, V. Bertolani, J. Burle & L. Zattra (Eds.) *Live-Electronic Music: Composition, Performance, Study* (pp. 101-130). Routledge.

Fitch, L. (2014). *Brian Ferneyhough*. Intellect Books.

Frengel, M. (2010). A multidimensional approach to relationships between live and non-live sound sources in mixed works. *Organised Sound*, *15*(02), 96–106. https://doi.org/10.1017/S1355771810000087

Friedman, B. H. (Ed.). (2000). *Give my regards to Eighth Street—Collected writings of Morton Feldman*. Exact Change.

Furniss, P., & Dudas, R. (2014). *Transcription, adaptation and maintenance in live electronic performance with acoustic instruments*. Computer Music Association.

Gayou, É. (2007). *GRM: Le groupe de recherches musicales*. Fayard.

Gerzso, A., Manoury, P., Menger, P. M., & Dorin, S. (2012). Questions de Philippe Manoury à Pierre-Michel Menger (CNRS, EHESS) / Stéphane Dorin (Université Paris VIII). Manifeste, June 12th 2012, IRCAM, Paris France. Retrieved from : https://medias.ircam.fr/xebd041_questions-de-philippe-manoury-a-pierre-mic

Ghisi, D. (2017). *Music across music: Towards a corpus-based, interactive computer-aided composition*. (Université Pierre et Marie Curie, Paris).

Glover, R., Gottschalk, J., & Harrison, B. (Eds.). (2019). *Being time: Case studies in musical temporality*. Bloomsbury Academic.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Psychology Press.

Gilmore, B. (2009). On Claude Vivier's Lonely Child. In R. Hirs, & B. Gilmore (Eds.) *Contemporary Compositional Techniques and OpenMusic* (pp. 15-30). IRCAM-Centre Pompidou / Delatour France.

Gingras, B., Pearce, M. T., Goodchild, M., Dean, R. T., Wiggins, G., & McAdams, S. (2016). Linking melodic expectation to expressive performance timing and perceived musical tension. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(4), 594–609. https://doi.org/10.1037/xhp0000141

Godlovitch, S. (1993). The integrity of musical performance. *The Journal of Aesthetics and Art Criticism*, *51*(4), 573. https://doi.org/10.2307/431890

Goldman, J. (2011). *The musical language of Pierre Boulez: Writings and compositions*. Cambridge University Press.

Gould, G. (1966). The prospects of recording. *High Fidelity*, *16*(4), 46-63.

Grábocz, M. (2012). Les métamorphoses du matérieau musical dans Tensio de Philippe Manoury. Manifeste Festival, June 12th 2012, IRCAM, Paris, France. Retrieved from : https://medias.ircam.fr/x19b23a_les-metamorphoses-du-materiau-musical-dans

Grabócz, M. (2013). *Entre naturalisme sonore et synthèse en temps réel: Images et formes expressives dans la musique contemporaines*. Archives contemporaines.

Gray, C. (1996). Inquiry through practice: developing appropriate research strategies. *No guru, no method*, 1-28.

Green, O. (2013). *User serviceable parts: Practice, technology, sociality and method in live electronic musicking* (City University London, England). http://openaccess.city.ac.uk/2730/

Griffiths, P. (1984). Three works by Jonathan Harvey: The electronic mirror. *Contemporary Music Review*, *1*(1), 87–109. https://doi.org/10.1080/07494468400640101

Griffiths, P. (2011). *Modern music and after* (3rd edition). Oxford University Press.

Grisey, G. (1987). *Tempus ex Machina:* A composer's reflections on musical time. *Contemporary Music Review*, *2*(1), 239–275. https://doi.org/10.1080/07494468708567060

Groth, S. K. (2014). *Politics and aesthetics in electronic music – A study of EMS—Elektronmusikstudion Stockholmd, 1964-1979*. Kehrer Verlag.

Haas, J. (2019). Die musikalische darstellung des zwischenraums. Ein werkstattbericht über die entwicklung und bedeutung der elektronischen transformationen in der oper Wunderzaichen von Mark Andre. In D. P. Biró, J. Goldman, D. Heusinger & C. Stratz (Eds) *Live Electronics in the SWR Experimentalstudio* (pp. 211-242). Wolke Verlag.

Hagan, K. L. (2016). The intersection of 'live' and 'real-time.' *Organised Sound*, *21*(02), 138–146. https://doi.org/10.1017/S1355771816000066

Harrison, B. (2007). *Cyclical structures and the organisation of time*. (University of Huddersfield).

Harrison, J. (1998). Sound, space, sculpture: Some thoughts on the 'what','how'and 'why'of sound diffusion. *Organised Sound*, *3*(02), 117–127.

Harvey, J. (1965). *The composer's idea of his inspiration*. (University of Glasgow, UK).

Harvey, J. (1975). *The music of Stockhausen: An introduction*. University of California Press.

Harvey, J. (1999). The metaphysics of live electronics. *Contemporary Music Review*, *18*(3), 79–82. https://doi.org/10.1080/07494469900640351

Harvey, J. (2000). Spectralism. *Contemporary Music Review*, *19*(3), 11–14. https://doi.org/10.1080/07494460000640331

Harvey, J. (2004). The genesis of Quartet No. 4. In J. Cross, J. Harvey, H. Lachenmann, A. Wellmer & R. Klein (Eds.) *Identity and Difference: Essays on Music, Language and Time* (pp. 43-54). Leuven University Press.

Harvey, J. (2008). How do I compose? (Reflections on Wagner Dream). *Circuit: Musiques Contemporaines*, *18*(1), 38. https://doi.org/10.7202/017907ar

Häusler, J., & Boulez, P. (1985). Pierre Boulez on Répons. Teilton, Schriftenreihe, der Heinrich-Strobel-Stiftung des Südwestfunks, Vol. 4, pp. 7-14, Kassel, Bärenreiter, translated from the German by Clemens Merkel and Christina Unger, 1985.

Heron, J., & Reason, P. (1997). A participatory inquiry paradigm. *Qualitative inquiry*, *3*(3), 274-294.

Hervé, J.L. (1999). *L'image sonore: regarde sur la création musicale*. (Université de Lille III-Charles-de-Gaulle, France).

Hess, D. J. (1997). *Science studies: An advanced introduction*. NYU press.

Hewett, I. (2016). *Why is new classical music left to wither and die?* (July 21st 2016). Telegraph, UK. Retrieved from: https://www.telegraph.co.uk/music/what-to-listen-to/why-is-new-classical-music-left-to-wither-and-die/

Hirs, R. (2009a). Frequency-based compositional techniques in the music of Tristan Murail. In R. Hirs & B. Gilmore, (Eds.) *Contemporary Compositional Techniques and OpenMusic* (pp. 97-196). IRCAM-Centre Pompidou / Delatour France.

Hirs, R. (2009b). On Tristan Murail's Le lac. In R. Hirs & B. Gilmore, (Eds.) *Contemporary Compositional Techniques and OpenMusic* (pp. 45-92). IRCAM-Centre Pompidou / Delatour France.

Hoitenga, C. (2012). *The flute music of Kaija Saariaho: Some notes on the musical language*. Retrieved from: http://www.hoitenga.org/new/wp-content/uploads/2018/02/saariaho-musical-language.pdf

Holmes, T. B. (2016). *Electronic and experimental music: Technology, music, and culture*. Routledge.

Houlès, F. (2017). *Le premier quatuor à cordes hybride : L'exemple de Smaqra de Juan Arroyo*. L'harmattan.

Howatt, R. (2009). *The art of French piano music: Debussy, Ravel, Fauré, Chabrier*. Yale University Press.

Howell, T., Hargreaves, J., & Rofe (Eds.). (2011). *Kaija Saariaho: Visions, narratives, dialogues*. Ashgate Publishing Limited.

Hunt, A., & Wanderley, M. M. (2002). Mapping performer parameters to synthesis engines. *Organised Sound*, *7*(02). https://doi.org/10.1017/S1355771802002030

Iddon, M. (2013). *New music at Darmstadt: Nono, Stockhausen, Cage & Boulez*. Cambridge University Press.

Iddon, M. (2019). Desert echoes: About Chaya Czernowin. In D. P. Biró, J. Goldman, D. Heusinger & C. Stratz (Eds) *Live Electronics in the SWR Experimentalstudio* (pp. 133-154). Wolke Verlag.

IRCAM (2003). PMA LIB : les musiques électroniques de Philippe Manoury [Multimedia DVD]. IRCAM, Paris, France.

Jameux, D. (1991). *Pierre Boulez* (S. Bradshaw, Trans.). Faber and Faber.

Jensen, J. F. (1998). *Tracking a new concept in media and communication studies*. 20. Retrieved from: *http://www.organicode.net/jenson.pdf*

Jeschke, L. (2019). Ab, Auf, Über: Perspektiven der live-elektronik bei Mark Andre. In D. P. Biró, J. Goldman, D. Heusinger & C. Stratz (Eds) *Live Electronics in the SWR Experimentalstudio* (pp. 125-132). Wolke Verlag.

Jodlowski, P. (N.D.). *60 Loops*. Retrieved from: http://www.pierrejodlowski.com/index.php?post/60-Loops

Jodlowski, P. (2012). Reflection about music with electronics. *Revue et Corrigée #91*.

Jodlowski, P. & Suescun, K. (2009). *Série Noire – Writing process*. Retrieved from: http://www.pierrejodlowski.com/index.php?post/S%C3%A9rie-Noire-%E2%80%93-Writing-process-%282009%29

Kaltenecker, M. & Bahier, C. (2010). Images d'une oeuvre No. 10: «Tensio» de Philippe Manoury [Video]. IRCAM, Paris, France. Retrieved from : https://www.youtube.com/watch?v=eljcSFgi-LU

Kanga, Z., & Schubert, A. (2016). Flaws in the body and how we work with them: An interview with composer Alexander Schubert. *Contemporary Music Review*, *35*(4–5), 535–553. https://doi.org/10.1080/07494467.2016.1258105

Katz, M. (2004). *Capturing sound: how technology has changed music*. University of California Press.

Kawase, S. (2014). Importance of communication cues in music performance according to performers and audience. *International Journal of Psychological Studies, 6(2)*.

Kimura, M. (1995). Performance practice in computer music. *Computer Music Journal*, *19*(1), 64. https://doi.org/10.2307/3681300

Kimura, M. (2003). Creative process and performance practice of interactive computer music: A performer's tale. *Organised Sound*, *8*(03). https://doi.org/10.1017/S1355771803000268

Kimura, M. (2008). *Making of VITESSIMO for augmented violin: Compositional Process and Performance*. In *NIME* (pp. 219-220).

King, R. (2017). *Recording orchestra and other classical music ensemble*. Routledge.

Knutsen, T. (2020). *Solo fløyte med elektronikk. Hva gir elektronikken, og hva tar den?* Concert presentation, 15th of February 2020. Dokkhuset, Trondheim, Norway.

Kramer, J. D. (1988). *The time of music: new meanings, new temporalities, new listening strategies*. Schirmer Books ; Collier Macmillan Publishers.

Lacroix, M. (2016). *The producer/composer – The hybridization of roles and how it affects production and composition of production music* [MA thesis]. (NTNU, Trondheim, Norway).

Lacroix, M. (2018). Deux ex machina: Methods, processes and analysis of mixed music. *Proceedings of the Electroacoustic Music Studies Network Conference, Florence, Italy, June 20-23, 2018*. Retrieved from: http://www.ems-network.org/IMG/pdf_LACROIX_Mathieu_EMS18.pdf

Lacroix, M. (2020). The inface as an extension of composition in mixed music. *International Conference on Live Interfaces (ICLI) 2020, Trondheim, Norway, March 9-11, 2020*. Retrieved from: https://www.researchcatalogue.net/view/908792/908793

Lacroix, M. (2021). String quartets & electronics: A look at a forgotten repertoire [Forthcoming]. *Studia Musica Norvegica*.

Lalitte, P. (2017). Tepo-analyse de la musique mixte. In A. Bonardi, B. Bossis, P. Couprie, P. & V. Tiffon (Eds.). *Analyser la musique mixte* (pp. 21-38). Éditions Delatour.

Landy, L. (2006). Electroacoustic music studies and accepted terminology: You can't have one without the other. *Electroacoustic Music Studies Conference, Beijing, Oktober*. Retrieved from http://www.ems-network.org/IMG/EMS06-LLandy.pdf

Landy, L. (2007). *Understanding the art of sound organization*. MIT Press.

Landy, L. (2018). The three paths: Cultural retention in contemporary Chinese electroacoustic music. In S. Emmerson (Ed.) *The Routledge Research Companion to Electronic Music: Reaching Out With Technology* (pp. 77-95). Routledge

Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory*. Oxford University Press.

Laurel, B. (1986). Interface as mimesis. In D. A. Norman & S. Draper (Eds.*), User Centered System Design: New Perspectives on Human-Computer Interaction*. Lawrence Erlbaum Associates.

Laurel, B. (1990). Interface agents: Metaphors with character. In B. Laurel (Ed.), *The Art of Human-Computer Interface Design*. Addison-Wesley.

Leavy, P. (2017). *Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*. Guildord Press.

Lemouton, S. (2009). Utilisation musicale de dispositifs de captation du mouvement de l'archet dans quelques œuvres récentes. *JIM* 2009.

Lippe, C. (1996). Real-time interactive digital signal processing: A view of computer music. *Computer Music Journal*, *20*(4), 21. https://doi.org/10.2307/3680412

Lizère, E. (2018). Mixed music for young performers. *International Conference on Mixed Music Pedagogy*, McGill University, Montreal, Canada, 16-19 November 2018.

Lorieux, G. (N.D.). Analyse de NoaNoa de Saariaho. IRCAM Brahms. Retrieved from : http://brahms.ircam.fr/analyses/noanoa/

Lorieux, G. (2004). Une analyse d'Amers de Kaija Saariaho. *DEMéter*. http://demeter.revue.univ-lille3.fr/analyse/lorieux.pdf

London, J. (2004). *Hearing in time: Psychological aspects of musical meter*. Oxford University Press.

Luminet, J.P. (2008). *The wraparound universe*. Taylor Francis.

Machover, T. (1984). A view of music at IRCAM. *Contemporary Music Review*, *1*(1), 1–10. https://doi.org/10.1080/07494468400640021

Maestri, E. (2016). *Geste et texture / Homme et machine: Une étude comparative sur la production et la réception de la musique mixte*. (Université de Strasbourg, France).

Magnusson, T. (2009). Of epistemic tools: musical instruments as cognitive extensions. *Organised Sound 14 (2): 168–176*.

Magnusson, T. (2019). *Sonic writing : Technologies of material, symbolic & signal inscriptions*. Bloomsbury Academic.

Mahnkopf, C.-S. (2010). *Klaus Huber: From time—To time the complete oeuvre*. Wolke Verlag.

Malt, M. (2017). Descripteurs sonores et écriture musicale. 6th of June 2017, Collège de France, Paris, France. Retrieved from : https://www.college-de-france.fr/site/philippe-manoury/symposium-2017-06-06-10h15.htm

Manoury, P. (1998). *La note et le son: Écits et entretiens 1981-1998*. L'Harmattan.

Manoury, P. (2007). *Considérations (toujours actuelles) sur l'était de la musique en temps réel* (Blog post). Retrieved from : http://www.philippemanoury.com/?p=319

Manoury, P. (2012a). *La musique du temps réel: Entretiens avec Omer Corlaix et Jean-Guillaume Lebrun*. Édition MF.

Manoury, P. (2012b). *Autour de Tensio*. Acanthes 2012. Retrieved from : https://medias.ircam.fr/x27c58f_philippe-manoury-autour-de-tensio

Manoury, P. (2013a). *Mais de quoi donc ce "néo" veut-il nous parler?* [web log comment]. Retrieved from: http://www.philippemanoury.com/?p=5182

Manoury, P. (2013b). Compositional procedures in *Tensio*. *Contemporary Music Review*, *32*(1), 61–97. https://doi.org/10.1080/07494467.2013.774514

Manoury, P. (2015). *Les chaines de Markov…. A l'infini* (Blog post). Retrieved from : http://www.philippemanoury.com/?p=5685

Manoury, P. (2017a). *Temps et musique II: les formes temporelles* [Presentation]. Collège de France, France. Retrieved from: https://www.college-de-france.fr/site/philippe-manoury/course-2017-06-02-14h00.htm

Manoury, P. (2017b). *L'invention de la musique* [Presentation]. Collège de France, France. Retrieved from : https://www.college-de-france.fr/site/philippe-manoury/inaugural-lecture-2017-01-26-18h00.htm

Manoury, P. (2017c). *Repenser les formes I : Les écritures du sonore* [Presentation]. Collège de France, France. Retrieved from : https://www.college-de-france.fr/site/philippe-manoury/course-2017-02-03-14h00.htm

Manoury, P. (2019). Conférence compositeur invité - Cursus Ircam : Philippe Manoury. March 25th, 2019, IRCAM, Paris, France. Retrieved from : https://medias.ircam.fr/x8eaa7a

May, A. (2006). Philippe Manoury's Jupiter. In M. Simoni (Ed.) *Analytical Methods of Electroacoustic Music* (pp.145-186). Routledge.

McAdams, S. (1989). Psychological constraints on form-bearing dimensions in music. *Contemporary Music Review*, *4*(1), 181–198. https://doi.org/10.1080/07494468900640281

McAdams, S. (1993). Recognition of sound sources and events. In S. McAdams & E. Bigand (Eds.) *Thinking in Sound: The Cognitive Psychology of Human Audition* (pp.146-198). Oxford University Press.

McAdams, S. (2004). Problem-solving strategies in music composition: A case study. *Music Perception*, *21*(3), 391–429. https://doi.org/10.1525/mp.2004.21.3.391

McAdams, S., & Bregman, A. (1979). Hearing musical streams. *Computer Music Journal*, *3*(4), 26-43+60.

McCaffery, S. (1978). Sound poetry: A survey. In S. McCaffery & B. Nichol, (Eds.) *Sound Poetry: A Catalogue* (pp. 16-18). Underwhich Editions.

McGrenere, J., & Ho, W. (2000, May). Affordances: Clarifying and evolving a concept. In *Graphics interface* (Vol. 2000, pp. 179-186).

McNutt, E. (2003). Performing electroacoustic music: a wider view of interactivity. *Organised Sound*, *8*(03). https://doi.org/10.1017/S135577180300027X

Mead, P. (2013). In and out of exactitude: Jonathan Harvey's Tombeau de Messiaen'in. *RFIM Numéros*, *3*.

Meneghini, M. (2007). An analysis of the compositional techniques in John Chowning's *Stria*. *Computer Music Journal*, *31*(3), 26–37. https://doi.org/10.1162/comj.2007.31.3.26

Merriam-Webster (n.d.). Cue. In *Merriam-Webster.com dictionary*. Retrieved June 4th, 2021, from: https://www.merriam-webster.com/dictionary/cue

Merlin, A. (2019). *L'univers d'un créateur d'aujourd'hui… Nicolas Tzortzis, composer en situation – Manifeste-2019* (Radio program, June 26th 2019). France Musique. Retrieved from : https://www.francemusique.fr/emissions/le-portrait-contemporain/le-portrait-contemporain-du-mercredi-26-juin-2019-73172

Meyer, J. (2009). *Acoustics and the performance of music: Manual for acousticians, audio engineers, musicians, architects and musical instrument makers*. Springer Science & Business Media.

Michaud, P. & Bonardi, A. (2018). Comparison of tools recently developed at Paris 8 and Université de Montréal favoring collaborative approaches in mixed music pedagogy. *International Conference on Mixed Music Pedagogy*, McGill University, Montreal, Canada.

Moisala, P. (2009). *Kaija Saariaho*. University of Illinois Press.

Molino, J. (1991). La théorie d'hier à demain. *Inharmonique. Musique, recherche et théorie 8/9, Paris, IRCAM – Centre Georges Pompidou*.

Moore, A. (2016). *Sonic art – An introduction to electroacoustic music composition*. Routledge.

Moore, T. (2020). Hybrid conductor - Case study and analysis of Alexander Schubert's Point Ones. *Proceedings of the 5th International Conference on Live Interfaces*. NTNU, Trondheim, Norway.

Nattiez, J.-J. (1987). *Musicologie génerale et sémiologie* (trad. ital. *Musicologia generale e semiologia*, Torino, EDT, 1989).

Nattiez, J.-J. (1990). *Music and discourse: Toward a semiology of music*. Princeton University Press.

Nicolas, F. (2010). Pierre Boulez dans ses rapports avec les mathématiques, la philosophie, le cinéma, la choréographie et l'enseignement. In J. Goldman, J.-J. Nattiez & F. Nicolas (eds.) *La pensée de Pierre Boulez à travers ses écrits*. Éditions Delatour: France.

Nichols, C. (2002). The vBow: A virtual violin bow controller for mapping gesture to synthesis with haptic feedback. *Organised Sound*, *7*(02). https://doi.org/10.1017/S135577180200211X

Nordal, O. (2018). *Between poetry and catastrope – A study on the electroacoustic music of Arne Nordheim*. (Norwegian University of Science and Technology, Trondheim, Norway).

Norman, D. A. (1988). *The psychology of everyday things*. Basic Books.

Norwegian Government (2018). *Ny doktorgrad – ph.d. i kunstnerisk utviklingsarbeid*. Regjeringen Nyheter. https://www.regjeringen.no/no/aktuelt/ny-doktorgrad--ph.d.-i-kunstnerisk-utviklingsarbeid/id2583604/

Nouno, G., Cont, A., Carpentier, G., & Harvey, J. (2009). Making an orchestra speak. In *Sound and Music Computing*.

Nowotny, H., Scott, P., & Gibbons, M. (2003). Introduction:'Mode 2'revisited: The new production of knowledge. *Minerva*, *41*(3), 179-194.

O'Callaghan, J., & Eigenfeldt, A. (2010). Gesture transformation through electronics in the music of Kaija Saariaho. *Proceedings of the Electronic Music Studies 2010*. http://www.ems-network.org/IMG/pdf_EMS10_OCallaghan_Eigenfeldt.pdf

Oliveira, J. P. (2019, August 26th). *Spatialisation methods in composition* [Presentation]. Musiques & recherches académie d'éte, Belgium.

Oliveros, P. (2005). *Deep listening: A composer's sound practice*. IUniverse.

Pages, S. (2003). La synchronisation dans les œuvres de musique mixtes avec suivi de geste et de partition (video presentation). December 9th 2013, IRCAM, Paris, France. Retrieved from : https://medias.ircam.fr/xf3bd1b_la-synchronisation-dans-les-uvres-de-musi

Paine, G. (2002). Interactivity, where to from here? *Organised Sound*, *7*(3), 295–304. https://doi.org/10.1017/S1355771802003096

Paquin, L.-C. & Noury, C. (2018). Définir la recherche-création ou cartographier ses pratiques ? *Association francophone pour le savoir (ACFAS)*.

Pestova, X. (2008). *Models of interaction in works for piano and live electronics*. (McGill University, Canada).

Pestova, X. (2018). Approaches to notation in music for piano and live electronics: The performer's perspective. In F. Sallis, V. Bertolani, J. Burle & L. Zattra (Eds.) *Live-Electronic Music: Composition, Performance, Study* (pp. 131-159). Routledge.

Piekut, B. (2011). *Experimentalism otherwise: The New York avant-garde and its limits* (Vol. 11). University of California Press.

Piekut, B. (2014). Actor-Networks in Music History: Clarifications and Critiques. *Twentieth-Century Music*, *11*(2), 191–215. https://doi.org/10.1017/S147857221400005X

Puckette, M. (2004). A divide between 'compositional'and 'performative'aspects of Pd. *Proc. First International Pd Convention, Graz, Austria*. https://pd-graz.mur.at/community/conventions/convention04/lectures/tk-puckette/puckette-pd04.pdf

Puckette, M. (2017, November 3rd). *Experiences with Philippe MAnoury and Julianna Snapper, thoughts on instrumental control, and a performance* [Presentation]. Crossadaptive Processing Seminar, NTNU, Trondheim, Norway.

Puckette, M., & Lippe, C. (1992). Score following in practice. *Proceedings of the International Computer Music Conference*, 182–182. Retrieved from http://www.music.buffalo.edu/sites/www.music.buffalo.edu/files/pdfs/Lippe-SanJose.pdf

Puckette, M., & Settel, Z. (1993, September). Nonobvious roles for electronics in performance enhancement. In *Proceedings of the International Computer Music Conference* (pp. 134-134).

Raboisson, N. & Couprie, P. (2017). Une expérience de captation et d'analyse de l'interprétation acousmatique. *Journées d'informatique musicale, Collegium Musicæ, May 2017, Paris, France*. hal-01525481

Rasmussen, B. (2010). The 'good enough' drama: reinterpreting constructivist aesthetics and epistemology in drama education. *Research in Drama Education: The Journal of Applied Theatre and Performance*, *15*(4), 529–546. https://doi.org/10.1080/13569783.2010.512187

Rasmussen, B. (2018). *ESTET8863 – Kunstbasert forskningsmetoder* [Class]. Norwegian University of Science and Technology (NTNU). Trondheim, Norway.

Reich, S. (1968). Music as a gradual process. *Writings on Music, 1965-2000*, 34-36.

Reynolds, R. (2004a). Compositional strategies in The Angel of Death for piano, chamber orchestra, and computer-processed sound. *Music Perception: An Interdisciplinary Journal*, *22*(2), 173–205. https://doi.org/10.1525/mp.2004.22.2.173

Reynolds, R. (2004b). Epilog: Reflections on psychological testing with The Angel of Death. *Music Perception: An Interdisciplinary Journal*, *22*(2), 351–356. https://doi.org/10.1525/mp.2004.22.2.351

Rigaudière, P. (2014). La saturation, métaphore pour la composition ? *Circuit: Musiques contemporaines*, *24*(3), 37. https://doi.org/10.7202/1027609ar

Riikonen, T. (2003). Shaken or stirred virtual reverberation spaces and transformative gender identities in Kaija Saariaho's NoaNoa (1992) for flute and electronics. *Organised Sound*, *8*(1), 109–115. https://doi.org/10.1017/S1355771803001122

Risset, J.-C. (1999). Composing in real-time? *Contemporary Music Review*, *18*(3), 31–39. https://doi.org/10.1080/07494469900640331

Risset, J.-C. (2008). *Du songe au son: Entretiens avec Matthieu Guillot*. L'Harmattan.

Risset, J.-C., & Duyne, S. V. (1996). Real-time performance interaction with a computer-controlled acoustic piano. *Computer Music Journal*, *20*(1), 62. https://doi.org/10.2307/3681273

Roads, C. (2004). *Microsound*. MIT press.

Roels, H. (2016). Comparing the main compositional activities in a study of eight composers. *Musicae Scientiae*, *20*(3), 413–435. https://doi.org/10.1177/1029864915624737

Rofe, M. (2014). Dualisms of Time. *Contemporary Music Review*, *33*(4), 341–354. https://doi.org/10.1080/07494467.2014.977024

Romitelli, F. (2005a). Le compositeur comme virus. In A. Arvo (Ed.) *Le corps électrique – Voyage dans le son de Fausto Romitelli* (pp. 131-134). Translated by Arbo, A. M., Arbo, A., & Zanuttini, M. T. L'Harmattan.

Romitelli, F. (2005b). An Index of Metals : note d'intention. In A. Arvo (Ed.) *Le corps électrique – Voyage dans le son de Fausto Romitelli* (pp. 139-1142). Translated by Arbo, A. M., Arbo, A., & Zanuttini, M. T. L'Harmattan.

Rosen, C. (1998). *The Classical Style: Haydn, Mozart, Beethoven* (No. 653). WW Norton & Company.

Ross, A. (2009). *The rest is noise: Listening to the twentieth century*. Macmillan.

Roxburgh, E. (2014). *Conducting for a New Era*. Boydell & Brewer, Boydell Press. http://www.jstor.org/stable/10.7722/j.ctt6wp8xr.20

Roy, S. (2003). *L'analyse des musique électroacoustiques: Modèles et propositions*. L'Harmattan.

Rudi, J. (2019). *Elektrisk lyd i Norge fra 1930 til 2005*. Novus Forlag.

Rudi, J., & Bullock, J. (2011). The Integra Project. *Proceedings of the 2011 Electroacoustic Music Society Conference*. Retrieved from https://www.researchgate.net/profile/Jamie_Bullock/publication/228464847_The_Integra_Project/links/00b7d52cae28adfec9000000.pdf

Rutherford-Johnson, T. (2017). *Music after the fall: Modern composition and culture since 1989*. University of California Press.

Saariaho, K. (1987). Timbre and harmony: Interpolations of timbral structures. *Contemporary Music Review*, *2*(1), 93–133. https://doi.org/10.1080/07494468708567055

Saariaho, K. (2013). *Le passage des frontières: Écrits sur la musique* (S. Roth, Ed.). Édition MF.

Sallis, F., Bertolani, V., Burle, J., & Zattra, L. (Eds.). (2018). *Live-electronic music: Composition, performance, study*. Routledge.

Sani, N. (2014). Musical thought and technology – Composing by means of the present (Trans. Hoban, W.). In C.-S. Mahnkopf (Ed.) *The Foundations of Contemporary Composing* (pp. 187-196). Wolke Verlag.

Schaeffer, P. (1952). *A la recherche d'une musique concrète*. Le Seuil.

Schaeffer, P. (1966). *Traité des objets musicaux*. Editions du Seuil.

Schoenberg, A. (1983). *Theory of harmony*. University of California Press.

Schoenberg, A. (2010). *Style and idea: Selected writings*. University of California Press.

Schubert, A. (2019). The error aesthetic: The opportunity to understand systems via fractures in coding. *Tempo*, *73*(289), 21–29. https://doi.org/10.1017/S0040298219000081

Schubert, A. (2021). *Switching Worlds*. Folke Verlag.

Servière, A. (2012). Processus de composition et artisanat. *Dissonance / Dissonanz*, *120*, 16.

Seo, J. R. (2003). *Jonathan Harvey's string quartets*. (University of Illinois at Urbana-Champaign, USA).

Shapiro, A. (2014). The e-frontier: Electroacoustic music, multimedia, education and audiences in the digital world (Part 1-2) (June & September 2014). WASBE World: 8-12 / 8-13.

Silverman, M. (2007). Musical interpretation: Philosophical and practical issues. *International Journal of Music Education*, *25*(2), 101–117. https://doi.org/10.1177/0255761407079950

Smalley, D. (1994). Defining timbre—Refining timbre. *Contemporary Music Review*, *10*(2), 35–48. https://doi.org/10.1080/07494469400640281

Smalley, D. (1996). The listening imagination Listening in the electroacoustic era. *Contemporary Music Review*, *13*(2). https://doi.org/10.1080/07494469600640071

Smalley, D. (1997). Spectromorphology: Explaining sound-shapes. *Organised Sound*, *2*(2), 107–126. https://doi.org/10.1017/S1355771897009059

Smalley, D. & Austin, L. (2000). Sound diffusion in composition and performance: An interview with Denis Smalley. Computer Music Journal, Vol. 24(2), pp. 10-21, MIT Press.

Smith, R. B. (2000). An Interview with Tristan Murail. *Computer Music Journal*, *24*(1), 11–19.

Stévance, S., & Lacasse, S. (2013). *Les enjeux de la recherche-création en musique*. Les presses de l'université Laval.

Stockhausen, K. (1972 / 2000). Four criteria of electronic music. In R. Maconie (Ed.) *Stockhausen on music* (pp. 88-111).

Stockhausen, K. (2017). *Comment passe le temps : Essais sur la musique 1952-1961*. Contrechamps.

Stromer-Galley, J. (2004). Interactivity-as-product and interactivity-as-process. *The Information Society*, *20*(5), 391–394. https://doi.org/10.1080/01972240490508081

Stroppa, M. (1989). Musical information organisms: An approach to composition. *Contemporary Music Review*, *4*(1), 131–163. https://doi.org/10.1080/07494468900640251

Stroppa, M. (1999). Live electronics or…live music? Towards a critique of interaction. *Contemporary Music Review*, *18*(3), 41–77. https://doi.org/10.1080/07494469900640341

Stroppa, M. & Echeveste, J. (2015). Étude des strategies de synchronisation dans le langage Antescofo (video presentation). IRCAM, Paris, France. Retrieved from : https://medias.ircam.fr/xe788b5

Tan, A. (2019). Memory and synchronicity: Two approaches to live electronics. In D. P. Biró, J. Goldman, D. Heusinger & C. Stratz (Eds.) *Live Electronics in the SWR Experimentalstudio* (pp. 271-282). Wolke Verlag.

Teruggi, Daniel. (2016) Esquisse d'une taxonomie des musiques mixtes. In M. Battier (Ed.) *Musique et technologie : Regards sur les musiques mixtes* (pp.12-20). Institut national de l'audiovisuel.

Thordarson, H. (2019). ConDiS – Conducting digital system: Extended role of the conductor in mixed music performance. (Norwegian University of Science and Technology, Trondheim, Norway).

Thoresen, L. (2006). Spectromorphological analysis of sound objects: An adaptation of Pierre Scaheffer's typomorphology. *Proceedings of the Electroacoustic Music Studies Network Conference*.

Thoresen, L. (2009). Sound-objects, Values and Characters in Åke Parmerud's Les objets obscurs, 3rd Section. *Organised Sound*, *14*(03), 310. https://doi.org/10.1017/S1355771809990124

Thoresen, L. (2010). Form-Building Patterns and Metaphorical Meaning. *Organised Sound*, *15*(02), 82–95. https://doi.org/10.1017/S1355771810000075

Tiffon, V. (1994). *Recherches sur les musiques mixtes*. (Université d'Aix-Marseille I).

Tiffon, V. (2005). Les musiques mixtes: Entre pérennité et obsolescence. *Musurgia*, pp. 23–45.

Tiffon, V. (N.D.). *Analyse de Traiettoria de Marco Stroppa*. IRCAM Brahms. Retrieved from : http://brahms.ircam.fr/analyses/traiettoria/

Tiffon, V., & Sprenger-Ohana, N. (2011a). The creative process in *Traiettoria*: An account of the genesis of Marco Stroppa's musical thought. *Contemporary Music Review*, *30*(5), 377–409. https://doi.org/10.1080/07494467.2011.665580

Tiffon, V., & Sprenger-Ohana, N. (2011b). Marco Stroppa's compositional process and scientific knowledge between 1980-1991. *SMC, Jul 2011, Padova, Italy*, 8.

Trapani, C., & Echeveste, J. (2014). *Real time tempo canons with Antescofo*. In *International Computer Music Conference* (p. 207).

Tremblay, P. A. (2012). Considérations pragmatiques en musique mixtes: une approche systémique de l'inter-influence entre la composition, l'interprétation et la technique. In *Actes du colloque: Soixante ans de musiques mixtes*. MINT-Université Sorbonne.

Tremblay, P.A. (2017). Tuning to trust: System calibration as creative enabler. *Proceedings of the International Computer Music Conference 2017*, 15-20 October 2017, Shanghai, China.

Tremblay, P. A., & McLaughlin, S. (2009). Thinking inside the box: A new integrated approach to mixed music composition and performance. *International Computer Music Conference Proceedings*, *2009*, 379–386. http://eprints.hud.ac.uk/4081

Trottier, G. (2019). *Travail synthèse : Inventory and development of new performance tools in the horn repertoire of the XXth and XXIst centuries*. (Université de Montréal, Montreal, Canada).

Tsay, C.-J. (2013). Sight over sound in the judgment of music performance. Proceedings of the National Academy of Sciences of the United States of America. 110. 10.1073/pnas.1221454110.

Tutschku, H. (1999). *L'application des paramètres compositionnels au traitement sonore*. (Université de Paris IV Sorbonne, France).

Tutschku, H. (2011). Using the iPhone for live-electronics in my composition Irrgaerten for two pianos. In *Proceedings of the International Computer Music Conference* (ICMC), Huddersfield, 395–8, 2011.

Tutschku, H. (2014). The use of iOs devices in recent compositions of mixed music. *Journal of the Japanese Society for Sonic Arts*, *6*(1), 12-15.

Tutschku, H. (2015). *Physical gesture and space in my creative process* [Video presentation]. CCRMA, Stanford University, USA. Retrieved from: https://tutschku.com/physical-gesture-and-space-in-my-creative-process/

Tutschku, H. & Nez, K. (2003). An interview with Hans Tutschku. *Computer Music Journal, 27:4, 14-26*.

Underriner, C. F. (2017). The Sound-Poetry of the Instability of Reality: The audio reality effect and mimesis. *Organised Sound*, *22*(1), 20–31. https://doi.org/10.1017/S1355771816000303

Vande Gorne, A. (2018). *Treatise on writing acousmatic music on fixed media*. Éditions Musiques et recherches.

Vidolin, A. (2009). I documenti sonori della musica elettronica. *Musica/Tecnologia*, 49-65 Pages, 217 kB. https://doi.org/10.13128/MUSIC_TEC-3207

Walshe, J. (2016). The New Discipline: a compositional manifesto. *Borealis, http://www. borealisfestival. no/2016/the-new-discipline-4/Borealis*.

Waters, S. (2007). Performance Ecosystems: Ecological approaches to musical interaction. *EMS: Electroacoustic Music Studies Network*. http://webuser.fh-furtwangen.de/~friedm/PerformEcosystems.pdf

Wierzbicki, J. E. (2011). *Elliott Carter*. University of Illinois Press.

Wilmers, H. (n.d.). Bowsense—An open wireless motion sensing platform. *NOTAM*, 4.

Wishart, T. (2000). Sonic composition in Tongues of Fire. *Computer Music Journal*, *24*(2), 22–30.

Wroe, N. (2011). *A life in art: Anselm Kiefer* (21st of March 2011). The Guardian. Retrieved from: https://www.theguardian.com/artanddesign/2011/mar/21/anselm-kiefer-painting-life-art

Xenakis, I. (1992). *Formalized music—Thought and mathematics in music*. Pendragon.

Young, M. (2016). Interactive and generative music: A quagmire for the musical analyst. In S. Emmerson & L. Landy (Eds.). *Expanding the Horizon of Electroacoustic Music Analysis* (pp. 80-101). Cambridge University Press.

Zattra, L. (2003). *Science et technologie comme sources d'inspiration au CSC de Padoue et à l'IRCAM de Paris*. (Université de Paris-Sorbonne Paris IV, Paris, France).

Zattra, L. (2004). Searching for lost data: Outlines of aesthesic–poietic analysis. *Organised Sound*, *9*(01). https://doi.org/10.1017/S1355771804000068

Zattra, L. (2006). The identity of the work: Agents and processes of electroacoustic music. *Organised Sound*, *11*(02), 113. https://doi.org/10.1017/S1355771806001361

Zattra, L. (2007). The assembling of "Stria" by John Chowning: A philological investigation. *Computer Music Journal*, *31*(3,). http://www.jstor.org/stable/40072593

Zattra, L. (2018). *Symmetrical Collaborations. Jonathan Harvey and his computer music designers*. *Symmetrical Collaborations: Jonathan Harvey and his computer music designers*, 29-57.

Zattra, L., & Donin, N. (2016). A questionnaire-based investigation of the skills and roles of Computer Music Designers. *Musicae Scientiae*, *20*(3), 436–456. https://doi.org/10.1177/1029864915624136

Zell, M. (2011). Rembrandt's gifts: A case study of actor-network-theory. *Journal of Historians of Netherlandish Art*, *3*(2). https://doi.org/10.5092/jhna.2011.3.2.2

Compositions

Adès, T. (2008). In Seven Days. Faber Music.

Alvarez, J. (1987). Papalotl.

Andre, M. (2007). … Auf ... III. Edition Peters.

Andre, M. (2013). Wunderzaichen. Edition Peters.

Andriessen, L. (1991). Facing Death Quartet. Schott Music.

Bach, J. S. (1947). Der Musikalske Opfer.

Barrett, N. (2000). Utility of Space. NB Noter.

Barrett, N. (2001). Push-me-pull-me. NB Noter.

Barrett, N. (2002). Symbiosis. NB Noter.

Barrett, N. (2017). Islands of Lost Passports. NB Noter.

Baschet, F. (2005). BogenLied. Jobert Éditions.

Baschet, F. (2007-8). StreicherKreis. Jobert Éditions.

Berio, L. (1958-2002). Sequenza Pieces. Universal Edition.

Blondeau, S. (2017). Namenlosen.

Blondeau, S. (2014). Tesla ou l'effet d'étrangeté.

Boulez, P. (1945-46/78-84/1997). Notations. Universal Edition.

Boulez, P. (1965). Éclat. Universal Edition.

Boulez, P. (1971). Explosante-fixe. Universal Edition.

Boulez, P. (1981-85). Répons. Universal Edition.

Boulez, P. (1984). Dérive 1. Universal Edition.

Boulez, P. (1985). Dialogue de l'ombre double. Universal Edition.

Boulez, P. (1997). Anthèmes 2. Universal Edition.

Brockman, J. (1997). Tagore Songs. Diaphonous Music.

Cage, J. (1939). Imaginary Landscape No. 1. Edition Peters

Cage, J. (1952). Imaginary Landscape No. 5. Edition Peters.

Cage, J. (1987-92). Number Pieces.

Carter, E. (1959). String Quartet No. 2. Paul Sacher Stiftung.

Chowning, J. (1977). Stria.

Couperin, F. (1660). Prélude sans mesure.

Crumb, G. (1971). Black Angels. Edition Peters.

Di Scipio, A. (2009-10). Two Pieces of Listening and Surveillance.

Einbond, A. (2012). Resistance.

Emmerson, S. (1985). Piano Piece IV.

Fernandez, J. M. (2014). Dispersion de trajectoire.

Fure, A. (2017). Anima.

Gobeil, G. (1988-89). Voix blanche.

Grisey, G. (1989-90). Le noir de l'étoile. Ricordi.

Harvey, J. (1980). Mortuos Plango, Vivos Voce. Faber Music.

Harvey, J. (1982). Bhakti. Faber Music.

Harvey, J. (1984). Ricercare una melodica. Faber Music.

Harvey, J. (1986). Madonna of Winter and Spring. Faber Music.

Harvey, J. (1994). Tombeau de Messiaen. Faber Music.

Harvey, J. (2003). String Quartet No. 4. Faber Music.

Harvey, J. (2007). Wagner Dream. Faber Music.

Harvey, J. (2008). Speakings. Faber Music.

Huber, K. (1970-71). …Inwendig voller Figur... . Schott Music.

Ives, C. (1908). The Unanswered Question.

Jacobs, B. (2008). Songs from the Moment.

Jodlowski, P. (2006). 60 Loops. Éditions Pierre Jodlowski.

Jodlowski, P. (2006). Série noire. Éditions Pierre Jodlowski.

Jodlowski, P. (2008). Respire. Éditions Pierre Jodlowski.

Jodlowski, P. (2011). L'aire du dire. Éditions Pierre Jodlowski.

Lacroix, M. (2013). Moby Dick ; or the Whale.

Lacroix, M. (2014). Studie I – Dissolving Time. NB Noter.

Lacroix, M. (2018). Anomie. NB Noter.

Lacroix, M. (2018). North Star. NB Noter.

Lacroix, M. (2020). Quasar. NB Noter.

Leroux, P. (2002). Voi(rex). Billaudot.

Leroux, P. (2005-6). Apocalypsis. Billaudot.

Ligeti, G. (1962). Poème symphonique. Schott Music.

Ligeti, G. (1968). Second string quartet. Schott Music.

Liszt, F. (1854). Sonata in B minor.

Lorieux, G. (2008). Branche, étude électrique 1.

Luther Adams, J. (2002). Mathematics of Resonant Bodies. Chester Music.

Lutoslawski, W. (1961). Jeux vénétien. Polskie Wydawnictwo Muzyczne.

Mâche, F.-B. (1981). Nocturne. Durand.

Maderna, B. (1952/58). Musica su due dimensioni. Suvini Zerboni.

Manoury, P. (1982). Zeitlauf. Amphion.

Manoury, P. (1987). Jupiter. Durand.

Manoury, P. (1988-89). Pluton. Durand.

Manoury, P. (1989). La partition du ciel et de l'enfer. Durand.

Manoury, P. (1991). Neptune. Durand.

Manoury, P. (1995-96). 60e Parallèle. Durand.

Manoury, P. (2003). Noon. Durand.

Manoury, P. (2006). Partita I. Durand.

Manoury, P. (2010). Tensio. Durand.

Manoury, P. (2012). Partita II. Durand.

Manoury, P. (2014). Le temps, mode d'emploi. Durand.

Manoury, P. (2017). Kein Licht. Durand.

Michaud, P. (2018). … N I E N T E … .

Murail, T. (1975-6). Mémoire/érosion. Éditions Musicales Transatlantiques.

Murail, T. (1982). Désintégrations. Éditions Salabert.

Murail, T. (1984). Vampyr. Éditions Salabert.

Murail, T. (1990). Allégories. Lemoine.

Murail, T. (1994). L'esprit des dunes. Lemoine.

Murail, T. (2000). Winter Fragments. Lemoine.

Murail, T. (2001). Le lac. Lemoine.

Nordheim, A. (1963). Epitaffio. Edition Wilheim Hansen.

Nono, L. (1985). A Pierre: Dell'azzurro silenzio, inquietum. Ricordi.

Nordin, J. (2015). Sculpting Air. C.F. Peters.

Nordin, J. (2018). Emergin from Currents and Waves. C.F. Peters.

Nunes, E. (1988-91). Lichtung I. Ricordi.

Nunes, E. (2011). Einspielung I. Éditions Jobert.

Palacio, P. & Romero, M. (2016). Piano & Dancer.

Parmerud, Å (2006). Rituals.

Penderecki, K. (1968). 2nd String Quartet. Schott Music.

Reich, S. (1988). Different Trains 1988. Boosey & Hawkes.

Respighi, O. (1924). Pini di Roma. Ricordi.

Reynolds, R. (1994). Ariadne's Thread. Edition Peters.

Reynolds, R. (1998-2001). The Angel of Death. Edition Peters.

Risset, J.-C. (1989). Duet for One Pianist.

Romitelli, F. (2003). An Index of Metals. Ricordi.

Saariaho, K. (1982). Laconisme de l'aile. Jasemusiikki.

Saariaho, K. (1986). Lichtbogen. Wilhelm Hansen.

Saariaho, K. (1987). Nymphéa. Wilhelm Hansen.

Saariaho, K. (1992). NoaNoa. Chester Music.

Saariaho, K. (1994). Six Japanese Gardens. Chester Music.

Saariaho, K. (2000). L'amour de loin. Chester Music.

Saariaho, K. (2006). Vent nocturne. Chester Music.

Schaeffer, P. & Henry, P. (1951). Orphée 51.

Schubert, A. (2012). Point Ones.

Schubert, A. (2014). Hello.

Schubert, A. (2014). Sensate Focus.

Schubert, A. (2015). Star Me Kitten.

Smalley, D. (1990). Piano Nets.

Smalley, R. (1972). Monody. Faber Music.

Steen-Andersen, S. (2007). Chambered Music.

Stockhausen, K. (1955-56). Zeitmasse. Universal Edition.

Stockhausen, K. (1956). Gesang der Jünglige. Stockhausen Verlag.

Stockhausen, K. (1955-57). Gruppen. Universal Edition.

Stockhausen, K. (1955). Mikrophonie I. Universal Edition.

Stockhausen, K. (1956). Mikrophonie II. Universal Edition.

Stockhausen, K. (1958-60). Kontakte. Stockhausen Verlag.

Stockhausen, K. (1959-60). Carré. Universal Edition.

Stockhausen, K. (1964). Mixtur. Universal Edition.

Stockhausen, K. (1970). Mantra. Stockhausen Verlag.

Stockhausen, K. (1985). Katinka's Gesang. Stockhausen Verlag.

Stroppa, M. (1984). Traiettoria…Deviata. Ricordi.

Stroppa, M. (1984). Dialoghi. Ricordi.

Stroppa, M. (1988). Spirali. Ricordi.

Stroppa, M. (2007). …Of Silence. Ricordi.

Stroppa, M. (2016). Come Play With Me. Ricordi.

Thordarson, H. (2019). Kuki No Sukima. NB Noter.

Thorvaldsdóttir, A. (2016). Fields. Chester Music.

Thoresen, L. (2011). Økofanfare. NB Noter.

Truax, B. (1986). Riverrrun.

Tutschku, H. (1999). Das Bleierne Klavier.

Tutschku, H. (2007). Zellen-Linien. BabelScores.

Tutschku, H. (2011). Behind the Light. BabelScores.

Tutschku, H. (2013). Still Air 1. BabelScores.

Tzortzis, N. (2010). Incompatible(s) IV. BabelScores.

Vaage, K. (2015). Futuration. NB Noter.

Varèse, E. (1929-31). Ionisation. Ricordi.

Varèse, E. (1954). Déserts. Ricordi.

Walker, F. (1997). Eye Masking. MCN.

Webern, A. (1927). Streichtrio, Op. 20. Universal Edition.

Webern, A. (1928). Symphonie, Op. 21. Universal Edition.

Webern, A. (1930). Quartett, Op. 22. Universal Edition.

Webern, A. (1940-43). II. Kantate, Op. 31. Universal Edition.

Xenakis, I. (1969). Kraanerg. Boosey & Hawkes.

Recordings

Arditti Quartet (2009). String String No. 4 (Track 2-2). On J. Harvey (Composer) Complete String Quartets and Trio. Aeon.

BBC Scottish Orchestra (2010). Speakings (Tracks 3-6). On J. Harvey (Composer) Speakings. Aeon.

Berweck, S. (2011). Zellen-Linien. Retrieved from : https://tutschku.com/zellen-linien/

Desjardins, C. (2009). Partita I (Tracks 8-16). On P. Manoury (Composer). Fragments Pour un Portrait. Kairos.

Gutschmidt, F (2010). Zellen-Linien. Retrieved from : https://tutschku.com/zellen-linien/

Ictus Ensemble (2006). Fausto Romitelli – An Index of Metals. Cypres.

Manoury, P. (No performer listed) (1997). Jupiter. On P. Manoury (Composer) La Partition du Ciel et de L'enfer, Jupiter. Accord.

Mead, P. (1999). Tombeau de Messiaen (Track 1). On J. Harvey (Composer) Tombeau de Messiaen. Sargasso.

Mead, P. (2004). Piano Nets (Tracks 2-4). On D. Smalley (Composer) Impact Intérieurs. Empreintes DIGITALes.

Lan, C. T. [Lan Cao] (2014). Marco Stroppa (*1959) - Traiettoria...deviata (1982/1984) - for piano and electronics. Retrieved from: https://www.youtube.com/watch?v=YsAyZ-Nj0iU

No author [Sicicua Hibrido] (2015). Fausto Romitelli An Index of Metals. Retrieved from: https://www.youtube.com/watch?v=9CN10YxG3p0

Pestova, X. (2008). Zellen-Linien. Retrieved from : https://tutschku.com/zellen-linien/

Pestova, X. (2018). Zellen-Linien. Retrieved from : https://tutschku.com/zellen-linien/

Quatuor Élisée (2011). 60 Loops (Track 1). On P. Jodlowski (Composer) Cumulative Music. éOle Records.

Sato, A. & Acierto, A. (2014). Still Air 3. Retrieved from: https://tutschku.com/still-air-3/

Sistema Michoacano de radio y tele (2015). "An Index of Metals (video-opera)". Retrieved from: https://www.youtube.com/watch?v=kU-SLHbk7kE&t=141s

Stipek, J. (2014). Fausto Romitelli: An Index of Metals [Part I] (On the Boards, Seattle; Feb 16, 2014). Retrieved from: https://www.youtube.com/watch?v=F4SjjJ-hm1g

ISBN 978-82-326-5317-1 (printed ver.)
ISBN 978-82-326-5197-9 (electronic ver.)
ISSN 1503-8181 (printed ver.)
ISSN 2703-8084 (online ver.)

NTNU
Norwegian University of
Science and Technology