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DISSERTATION

THE NOISE–PITCH CONTINUUM IN TIMBRAL MUSIC

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D e c l a r a t i o n

I declare that I have prepared my Dissertation independently on the following topic:

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Abstracts

The rich acoustic world of noisy sounds has been used to different effects by composers during the last decades. However, only limited theorisation exists of noise composition and methodical saturated timbral composition, a lack which this study will address. Analysis of musical scores is conducted on recent works by acclaimed composers such as Bauckholt, Furrer, and Sciarrino. Passages are analysed using a set of timbral-morphological descriptors that are developed for the pitch–noise continuum and its intermediate timbral region. A spectrally reductive analytical tool is proposed to facilitate theory formation and composing, particularly with the rare instrumental sounds that lie perceptually between noise and pitch, here labelled Froise. Different functions and contexts of Froise sounds are demonstrated in the repertoire to derive common strategies of timbral movement.

Keywords: timbre, pitch–noise continuum, music analysis, timbral composition, Froise, noise music, spectromorphology.

Das Ton–Rauschen-Kontinuum in klangbasierter Musik. In der umfangreichen Welt der akustischen Rauschklänge sind in den letzten Jahrzehnten Komponierenden auf unterschiedlichsten Weisen tätig gewesen. Jedoch sind nur begrenzte Theorien über Geräuschkomposition und methodische Klangkomposition entstanden, und auf diesem Mangel wird die vorliegende Studie ansprechen. Partiturbezogene Analyse wird an aktuellen Kompositionen bekannter Schaffenden wie Bauckholt, Furrer und Sciarrino angewandt. Musikalische Passagen werden mittels einer Menge von klangmorphologischen Beschreibern untersucht, die für das Kontinuum zwischen Tonhöhe und Rauschen und für ihre zwischenliegende klangliche Region entwickelt werden. Ein spektral reduzierendes Analyseverfahren wird vorgeschlagen, um die zukünftige Theorieformung und das Komponieren zu erleichtern – besonders bei den seltenen instrumentalen Klängen, die in der Wahrnehmung zwischen Rauschen und Ton liegen, mit dem Terminus »Froise« benannt. Mehrere Funktionen und Kontexte für den Gebrauch von Froise-Klängen werden im Repertoire demonstriert, um davon häufige Strategien der klanglichen Bewegung abzuleiten.

Schlagworte: Klangfarbe, Ton–Rauschen-Kontinuum, Musikanalyse, Klangkomposition, Froise, Geräuschmusik, Spektromorphologie.

Kontinuum bílého šumu a tónu v témbrově orientované hudbě.

V posledních desetiletích využívají skladatelé akusticky bohatý svět šumově orientovaných zvuků k různým efektům. Existuje ale pouze omezená teoretická reflexe šumově orientované, respektive témbrově orientované kompozice, což je téma, kterým se zabývá tato studie. Nejnovější díla uznávaných skladatelů, jako např. Bauckholt, Furrer a Sciarrino, jsou podrobena analýze na základě partitury.

Vybrané úseky jsou analyzovány za použití soustavy témbrově-morfologických deskriptorů, které jsou vyvinuty pro popis kontinua mezi bílým šumem a tónem, resp. oblastí, která je jimi vymezena. Je navržena spektrálně reduktivní analytická metoda s cílem usnadnit teoretickou reflexi i vlastní kompoziční praxi ve vztahu k neobvyklým instrumentálním zvukům, které se percepčně nacházejí mezi bílým šumem a tónem - pro jejich označení je užíván pojem Froise. V konkrétním repertoáru skladeb jsou demonstrovány různé funkce a kontexty zvuků typu Froise, z nichž lze odvodit specifické strategie témbrálního pohybu.

Klíčová slova: témbr, kontinuum bílého šumu a tónu, hudební analýza, témbrově orientovaná kompozice, Froise, noise, hluková hudba, spektromorfologie.

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1. Introduction

1.1. Aims and preliminaries in this dissertation

This study presents an analytical method that enables an understanding of the recent decades' noise-based compositions and can also address noises in the wider timbral repertoire. Here we focus on a repertoire of acoustic music for which an analytical method is yet to be found and in which pitches and harmony even play a negligible role [1]. It provides interpretations for composed sonic situations where sounds of noisy quality in different degrees combine with other timbres, and observes some of the auditory-cognitive principles at play.

The rich acoustic world of noisy sounds [2] has been used to various effect by composers of different aesthetics, and recently we have seen a proliferation of **instrumental sounds that perceptually lie between noise and pitch**. However, the understanding of these sounds' functioning remains limited, and noise composition methods generally need to be charted more extensively. We conduct score-based analysis without forgetting the perceptual aspect of music, on recent works by composers such as Bauckholt, Furrer, and Sciarrino. To prove the centrality of these in-between timbres, passages are dissected using a set of timbral-morphological descriptors developed for this intermediate timbral region. A spectrally reductive analytical and compositional tool is proposed to facilitate composing particularly with the sounds that lie perceptually between noise and pitch, called **Froise** [3]. We demonstrate uses and contexts of Froise sounds in voice-leading in the timbre-based repertoire and derive common strategies.

By the use of the term "noise-based", we do not mean noise as a negative aesthetic value-category but as an acoustic type of sound. With the term, we automatically assume "timbre-based" music for which timbre has surpassed pitch as the main factor that drives perceived musical form and thus the salience and/or presence of pitch is minimal.

With this study, we aspire to more closely develop the following thesis:

> **Froise** sounds are timbres that exist at a perceptual balance between pitch and noise, and the concept of Froise is indicated to be **unsurpassable and central** for the **functioning** and **voice-leading** of **noise-based music.**

This multifaceted and ambitious statement will be eventually articulated in

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[1] Under the exchangeable terms *sound-based* (known from LANDY 2012), *timbre-based*, and *timbral* music, we do not consider spectral music since we skip pitch organisation and focus on the non-pitch features of timbre.
[2] We understand the term *noise* not through volume but as a quality of sound, and *noisiness* as a gradation and accumulation of one or more noise features.
[3] This new word derives from "noise with pitch cores" in my translation from Finnish. The original Finnish term *sole* is etymologically unclear yet resembles the Finnish words for pitch and musical noise. Its earlier known uses are in TOLONEN (1969:75) and LYYTIKÄINEN 2009. Since Tolonen's definition is unfortunately minimal and fleeting, our Froise is a considerably elaborating extension and reworking of the Finnish term.

smaller expositions of each of the concepts that were marked in bold [4]. We hope to prove them by our analytical method in the course of this dissertation. We will mostly follow along with the findings in timbral studies this far, yet in the case of Froise, we will bring a marginal branch of study in Finland to the wider English-speaking audience.

The need for the present study is personal and pragmatic. Here I hope to answer an urgent need for effective methods for analysing recent sound-based repertoire and my own compositional sketches or multi-instrument improvisations from the last decades. After my master's thesis on piano multiphonics (VESIKKALA 2016), I wanted to find creative applications for voice-leading with these and other complex sounds, using the musical instruments and means typically available. My method seeks, apparently, a first systematic sound-based analysis of this repertoire. I also seek to fill the corresponding lack in composers', theorists', and performers' educational curricula.

The field of **timbre studies** which was most active in the past decades, is currently somewhat stalled and is calling for integration with composition and music analysis. Froise sounds as the middle region between noise and pitch, are the sounds at the threshold of audibility[5] or breaking whose role in the repertoire has lately fascinated me with their dialectics of unpredictability versus steadiness and the sheer number of listening strategies they support.

Only the establishing of terminology will allow wider discussion of the intentional compositional use of Froise sounds which composers may occasionally have entertained as an idea at most as a side product of microtonality and noise [6]. Nevertheless, instruments such as the human voice have always been able to produce Froise sounds, and recent fortunate technical advances in instruments have made these sounds even more possible to perform.

This study does not intend to provide a full account of all past and present composers with a Froise and timbral outlook. The works and approaches here are instead chosen to give a balanced overview, with a slight preference for the kind of compositional thinking that is found in my compositional portfolio section, separate from this written dissertation.

An **analytical method** will be shown that facilitates access to and speeds up the analysis as well as compositional processes of timbral music. We will advance the goal of making the composition of timbre-based music more enjoyable, by facilitating many steps in the process and analysing it more accurately. The reader will see how a skilful use of this timbral analysis method will bring success to its user, compared to existing methods or to no method at all.

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[4] For instance, the scope of the term voice-leading will be updated to embrace sound-based music and its connection with its vertical aspect, *voicing*, will be understood through the term *aggregation* that has been used by timbre studies.
[5] See STREET 2019 and VALLE 2015.
[6] Indeed, I started work on this study as a foray into the widest collection of acoustic noise sounds with the aim of deriving noisiness from free microtonality, and later focused on Froise.

After showing the results in this method, we will seek improvements and adjustments of the method. This will enable analysis of further repertoire and plans for new compositions.

1.1.1. Structure of the chapters

The structure of this study should **serve music theorists and composers alike**. A linear consistent reading of this thesis is strongly advised since many of the terms put forth are novel to theorists and composers and combine different branches of recent knowledge.

However, an expert in timbral analysis and timbral music theory should be able to read from chapter 4 onwards without having read about the theoretical framework and terminology of the preceding chapters. For composers we suggest chapters 4, 5, and the appendix 2 with the descriptor listing as especially enlightening, while for music theorists, we further suggest a detailed understanding of the methodological choices taken (chapter 3) as beneficial.

The chapters in outline are as follows:

In the introductory chapter 1, we define central topics for a coming perceptual timbre analysis method. We introduce Froise as a novel concept in the noise–pitch continuum theoretically and perceptually and show its proliferation on the example of the recent repertoire. The researcher position and expectations for the study are defined and common opposing arguments to timbral research refuted.

Chapter 2 is a thorough review of the recent literature in the related fields of study, by refutations, comments, and evidence tables. This chapter will help identify and exclude such related topics that are of interest to some that will be however superfluous to our study.

In **chapter 3**, a robust analytical method is formed for timbral analysis for portable use (without computer assistance), with a focus on Froise in sound-based recent and current acoustic repertoire. Existing phenomena from the literature are conceptualised and brought under one method which has three modules. In the first, a taxonomy and listing of timbres are made according to a balanced selection of spectral descriptors for noisiness. In the second, timbres receive their visualisation and positioning in timbral space. The third module is no longer a mechanical step.

In **chapter 4**, we introduce and implement the third module of the analytical method. The prospects of different types of timbral space are studied on the example of short analyses of various compositions that portray Froise in different ways and to different extents. The analyses and derived graphs indicate various compositional strategies with Froise and its participation in voice-leading that bears musical form. Each analysed passage is organised under common timbral strategies and trajectories in timbral space. Score-based analysis is the main approach to the repertoire, complemented by analytical listening. The reader would benefit from access to FFT visualisation software and libraries of recorded instrumental sounds to verify our findings more rapidly. An understanding of timbral descriptions of the noisy sounds available on individual instruments are taken as the basis on which the compositional use of those sounds can be discussed.

A discussion ensues in **chapter 5** of the previously found Froise strategies and general timbral strategies. We apply the term voice-leading now in the context of sound-based music and bring up possible psychoacoustic or dialectical basis of the strategies. We discuss variants to the analytical method and point towards directions where further study is needed. The found timbral strategies can be applied as compositional strategies, and we locate both prospects for composition and more general principles behind them. Finally, each part of the original thesis is proven and the findings of the study summed up.

All referenced information is given in the **Bibliography** and **Appendices**.

The study shortly presents my timeline of doctoral studies ranging from October 2018 to the Spring of 2022, and the resources needed for the research (in chapter 2). The above agenda, together with the components of the stated thesis shows how to proceed, and to this we will insert compositions and outside perspectives as we go. A few "prototype" timbral analysis methods will be prepared in the course of the methodology and discussion (chapters 3 and 5). At the end of chapters, it is possible to trace the progress of the method and gathered argumentation for the thesis and measure the results that arise with the method.

The conclusion explores the effects that the method and analysis results can have on composers and theorists worldwide, and the future prospects for theorists and composers who work particularly with timbre-based repertoire. With the reading suggestions, the reader will be given time to see what the study brings to them and how it answers the needs of communities, for instance when timbral analysis is to be included in academic curricula.

In the rest of the present chapter, the methodology will be explained in outline, central concepts defined and the relevant repertoire for chapters 4 and 5 laid out in more detail.

1.2. Current state of composition and research

Before chapter 2 studies the research fields linked to our topic, we will elucidate what needs to be studied and why. According to the "centrality" condition of our thesis, Froise is increasingly present in recent compositions, thanks to a more timbral focus in composition to which Froise has been intrinsically linked. **Timbral composition**, composing timbre-based music, has developed as an independent branch of music since the time of the earliest studios. Although timbral aspects have also been present in the best composers of the common-practice period, timbral aspects were a common choice whenever a composer abandoned tonal or serial pitch organisation or set it lower in a perceptual hierarchy. Indeed, timbre most often took the perceptual priority place that had been allocated to pitch earlier. When timbre intentionally received added perceptual and structural weight, it linked to a proliferation in the use of rarely used instrumental combinations as well as noise and Froise sounds. However, this process has been slow, and **timbral composition still faces many challenges** since

◆ it does not have a **timbral theory detached from intervallic composition** to support composers in stages of their work process with noisy timbres and to convince composers of the functionality of what they have created. Such theories for which timbre spaces are central only exist for the pitch-based uses of timbre. At this stage, our study will be an extension.

◆ in acoustic music, it suffers from the **limits of notational conventions**, while in electroacoustic music, the sheer amount of possibilities seems to many composers intimidating (BAUCKHOLT 2011:59) or too abstract (see MERER et al. 2011 and KOZIK 2014).

◆ its present focus on **computer-aided composition,** especially in the form of sampling timbres, does transform the compositional workflow and process. This may, like any tool, steer the created music off from the composer's intention in ways both beneficial and not.

◆ it is widely excluded from academic curricula for composers, theorists, and performers; and as a result, continues to be considered inaccessible to inexperienced composers and theorists and forces them to abandon the timbre-based compositions and genres in favour of more familiar ones.

◆ it has very few ways of **distinguishing** between different timbre-based pieces (which can be changed with our study) or **reverse-engineering** functional and appreciated compositions.

Thanks to sufficient research on timbral analysis and composition, we can engage logically with the claims made in the literature. The heavy appreciable work done on timbre, both compositionally and theoretically, in the decades leading to this moment is the ground on which we can build. Many composers around the 1990s operated within a **transitional period** in which noise sounds were not fully and eagerly embraced since ways of organising them were only developing. One central influence was the concept of spectromorphology by Denis Smalley, which even as a mere verbal method and guide to listening added concreteness to the sound taxonomy of Pierre Schaeffer [7]. **Numeric, quantitative, and systematic analytical methods** as known from conventional music analysis are still lacking. Also by this time, Froise sounds as a mediating material between pitch and noise had started to emerge in new works in separate passages and as an identifiable expressive device. As far as is known, the evasive phenomenon of Froise has not been accurately addressed by composers or theorists to this day. **The need for the concept of Froise is likewise urgent** since Froise is experientially and structurally important in many musical contexts – according to the parts of our theses which we hope to verify;

◆ Froise is a type of sound unlike pitch and noise. If listeners distinguish between those two listening strategies, then Froise likely evokes and requires a third, novel listening strategy or several, alongside the less effective strategy of

[7] A historical overview to these and more sources follows in chapter 2.

constant switching between pitch-based listening and noise-based listening. Froise would thus provide listeners with different experiences and let them access a wider range of associations from sounds than pitched and noisy music alternatingly or alone. Such an understanding would contribute towards the ongoing re-evaluation of timbral features in common practice music. Consequently, one reason to use Froise is for a composer's individuality and stylistic branding.[8]

◆ Froise entails, by maintaining the perceptual balance, those sounds for which listeners face a genuine choice between a pitched or noise-based listening strategy. This positions Froise far from a *terminus technicus* or a mere compositional device. It is a challenge to categories in human listening, a **boundary object** [9] and an additional distinction in the pitch–noise continuum. This in-between category will require more auditory training both separately and in the context of pieces of music, as in German *Hörerziehung* and *Werkhören,* and which many writers have facilitated with their typologies.

◆ if Froise is the missing link in understanding timbral functionality, Froise contributes towards a theory of timbre-based music and possibly to wider music theory

◆ Froise is a different type of timbre than noise or pitch. In repertoire that functions based on timbre (that is, sound-based music instead of interval-based), Froise allows for novel strategies and unforeseen variety in timbral dramaturgy[10].

◆ Froise links similar questions from different genres that are somewhat or strongly timbre-based such as spectral and extreme noise music

◆ Froise participates in voice-leading, for instance as an intermediate category to facilitate and bridge the perceptual divide between noise and pitch.

Even the most relevant source for timbral analysis, PEETERS (2004), does not have internal laboratory data or other exact data for the studied timbres available. We not only face a mismatch of data formats (Peeters' study was primed for timbre, not for the question of noisiness), but also the absence of **any secondary research data** to re-analyse, interpret variables of, add missing data, or to reformat. The values for a numerical method have to be made first-hand.

Furthermore, the phenomenon of Froise is not discussed, and neither explicitly refuted, by the fields of timbre or psychoacoustics studies[11]. This lies in the fact

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[8] This skillful "individualism in Western art music" may induce "cultural costs" (SUBOTNIK 1991:239ff.)
[9] In the sense of category studies. See BOWKER & STAR 2002:297.
[10] Froise may bridge sound into other time-based dramaturgies; see SZATKOWSKI 2019.
[11] For instance, RAINBOLT & SCHUBERT 1968 did study "noise pitch" and use sounds synthesised from narrow noise bands as psychoacoustic listening test instruments. It seems to have essentially given Froise, yet steps toward their categorisation or compositional use were not taken at the time. The test found that listeners assigned "unitary pitch to a bandpass noise" and gave characterisations such as "pitch", "loudness", "volume", or "density" for this auditory situation in which a narrow noise

that such study settings seldom cross the line between noise and pitch – they concentrate on one of them. We can hardly attempt to prove the **historical evolution of audiences' perceptions** of noisiness or any tendencies in it in the past decades – this research project does not allow such longitudinal scope. We also have to exclude Froise perception tests with hired acousticians and listeners, though this would provide data in formats that we need. More extensive **listening tests in laboratory conditions** would considerably aid in proving the perceptually mediating nature of Froise – yet this would not contribute to our final goal, an understanding of the use of Froise in the repertoire, for which composer and theorist experience is crucial. Froise may not spark the interest of (psycho-)acousticians and others who are not directly affected by its audible implications for music. The topic may be seen as too complex and not directly connected to the cravings of either professional acousticians or of those living composers who may meanwhile have had to set their sights elsewhere, precisely because of the lack of a feasible analysis and compositional understanding of noise and Froise [12].

1.3. Narrowing points of focus

The objectives that we aim to fulfil in the first part of our thesis do align between the two main academic approaches to taxonomic timbre analysis in the literature. Without delving too deeply into the literature beyond our needs here, we can note that these approaches, embodied by Thoresen's (2015) visualising and Peeters' (2004) quantifying-numeric, are in countless ways opposite.

The quantifying lineage especially tracks developments in computing and audio technology, of which here Peeters will be our representative, and can be considered to have started with writers who had similar goals, such as Grey (1977). Thoresen's listening-focused approach to the relations between sounds follows in the footsteps of many a composer and strives to **qualify, verbalise, sketch, and classify timbres**, often for subjective compositional purposes. Similar foundational examples include Denis Smalley's (1996) spectromorphology or Pierre Schaeffer's (1966) sound typology, influenced by studio practice as well as earlier historical precedents. Our analysis method will not quite resemble any of the existing methods.

Peeters (2004:23) gives descriptors that subdivide into 166 features of timbres.

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band appeared over a wider noise band and constituted a more pitched core, a Froise cluster. Similar is the study by SMALL & DANILOFF 1967 and CHOCHOLLE et al. 1974. FASTL's 1971 study was more limited. YOST (1996) considered the "pitch-evoking stimulus" from "rippled noise". A different pitch perception phenomenon amid noise is studied by HARTMANN et al 2019.

[12] Moreover, Froise may be seen as the last possible step in composers' continuing tendency towards novel-sounding musical substance which Harry Lehmann (2016, passim) calls "*Materialfortschritt*". At this point of a material paradigm shift ("gehaltsästhetische Wende"), a point at which no particularly novel timbral instrumental material is likely to be found (LEHMANN 2016, passim) even by experimental lutherie, practitioners of current music should be ready to halt and write down the interim results of a successful evolution which may remain final. That will be a byproduct of our study.

The main classification addresses the chronological aspects of analysis, being the **global** and **instantaneous descriptors** (PEETERS 2004:1) and correspond with spectrotemporality vs. spectrality, that is, to the presence or lack of the temporal dimension discussed above. Thoresen's method requires a smaller set of descriptors, which, although not requiring a computer, also has a long learning curve.

We study the main differences in their approaches, and our needs are mostly between them (Table 1.3-1).

Table 1.3-1. Comparison of our method relative to two opposite stances to timbral analysis.

	Thoresen's approach to timbral analysis	Peeters' approach to timbral analysis	The stance of our method
qualitative vs. quantitative	qualitative	quantitative	we aim for a balance
graphic vs. numeric	graphic	numeric and verbal	preference on the numeric, with several suggestions provided for visualisation. The first part of our thesis is possible to prove with FFT, a graphic method.
applicability to multi-layered music	yes; elegantly notated individual parts yet does not address the holistic perception	not able to mimic human discerning abilities between simultaneous different sound sources	this is our goal yet masses of sound will be difficult to address due to a lack of related study literature in stream segregation and timbral blending, especially with noisy timbres.
reveal when several spectrotem poral elements jointly cooperate towards or from noisiness	no; does not have such internal definition within the noisiness	no; has the resolution yet lacks thresholds for noisiness in each descriptor. Lacks perceptual rationale for weighting individual descriptors and preferences on some descriptors above others	yes, this is central to our method

humanly vs. computerised	humanly and subjective	entirely computerised except for the choice of the analysed audio segments	humanly
pitch-focused vs. noisiness-focused	can show different types of noise and inharmonic sounds, and this standard set of graphics may be extended. Thoresen distinguishes between interval-based and sound-based music.	includes noisiness only as one of the descriptors and does not treat it preferentially (at least not sufficiently to counterbalance a bias towards pitch in many of the existing theoretical methods)	neither
thresholds for a perception along the continuum noise–Froise–pitch are tightly-defined vs. loosely-defined	hints at loosely-defined (timbrally contextual and temporarily elliptical) thresholds and does not consider a middle ground such as Froise	does not focus on the noisiness axis and hence does not answer the pressing question about noisiness thresholds	tightly-defined. Most of our descriptors consist of yes/no statements, providing discrete borders between values. When we bring together the descriptors, we consider the phenomenon of Froise to be elliptical and contextual.
verbal semantic description vs. verbal spectral-technical description	visualisations are neither	spectral–technical	both
verbal description vs. dissimilarity rating	neither	dissimilarity ratings are not explicitly mentioned yet could be calculated from the values	both

On these preferences, our analytical method will be built in chapter 3. In it, we will have to grapple with the deplorably missing timbral analysis methods and develop our own [13]. For testing the method, we will use pieces that we consider to be timbre-based, which are roughly indicated by the fact that they do rely only on sounding (preferably acoustic) media yet not on tonal nor atonal functionalities. There also is not much else than timbre that perception in this repertoire could be shaped by, since the motivic work might be indiscernible or intentionally underdeveloped – likewise for frequency organisation and volume organisation. Density may be a driving factor in many cases and can support timbres more than pitches. Such historical shifts in compositional practice[14] have permitted the proliferation of **timbral listening** which in turn permits an appreciation of Froise-based musical dramaturgy.

Any kinds of abstractions to timbre are detrimental yet reductive choices are needed for a useful timbral analysis method; in our case, features of Froise should mostly survive such reductions [15].

The proof for the later part of our thesis (functioning and voice-leading with Froise sounds) will accumulate mostly by applying our analysis method to the repertoire. Apart from the argumentation for the parts of our thesis, additional insights into Froise and noisy timbre analysis from the literature are given in chapters 2 and 6.

1.4. Definitions of the central terms

Thanks to our topic's unorthodox footing relative to established approaches to music, we will follow mostly uncontroversial terminology from various fields, as defined below [16].

Sound

Both physical and human conditions for **sound** characteristically allow music in the widest sense. Sounds are "elastic molecular oscillations in air or other media" and strong enough "that they can be sensed by human hearing." (BRIXEN 2011:1)

Pitch, note, tone, interval

Pitch is the "subjective sensation of sound on [the] low/high scale" (KARJALAINEN 2001). A definition of pitch does not strictly require diatonicity, or a temperament system of any kind as long as we can refer to pitches using a

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[13] Afterall, noise sounds have no generally known analysis method and pitch-based analysis methods cannot answer the needs of Froise repertoire, which is based on timbral differences and in many cases foregoes elaborate pitch organisation entirely. Without an analysis method for Froise, this repertoire is understood only superficially, and the musically effective solutions with Froise cannot be replicated in an informed manner by new compositions.
[14] For instance, early compositional approaches such as stochastic pitch organisation and sonorism.
[15] On the philosophy of reductibility, see AUDI 2020 and CASSIN 2014.
[16] This literature from various interdisciplinary and non-music fields will be dealt with in the literature review in chapter 2.

system made for measurement, such as Hertz or musically labelled frequencies relative to a fixed frequency (such as a[1] at 440 Hz) **[17]**. The concept of pitch has "a complex relationship to physical properties of a signal" (KARJALAINEN & TOLONEN 1999) yet is capable of a conceptual reduction at which it does not imply any timbre, only a fundamental frequency. In the case of regular harmonic sounds, an entire spectrum can be reduced to one fundamental. When the sensation of a fundament does not arise, we speak of perceptually **inharmonic sounds**. An especially reduced state of sound is found in sine tones which can be called "pure tones" (BRIXEN 2011:19). The auditively ambivalent term **note** will only be used in the context of notation.

We aim to normalise the related concept of **tone** as a combination of "a constant pitch, loudness, and timbre" (LOY 2011a:456) and as a narrow and rare phenomenon different from the concept of pitch. Tone sensations rely on beneficial stabilising circumstances in a pitch. Most traditional definitions of any of these terms do not address complex sounds such as multiphonics. Complex sounds are best addressed by the terms timbre and sound, and *Klang* in German. The distance between two pure tones originating at the same or different sound source can be called **intervals**. They imply the strongest conceptual reduction of all these terms, since this concept rarely addresses timbre or loudness.

Noise

Noise is a central topic for current sound-based music. We now give attention to many of its aspects that we will not develop further in our study. Noise conceptually divides into A) **human reactions** to the presence of inharmonic sounds and into B) **objectively measurable sound content** in inharmonic sounds.

The five common human and sociological aspects to noise include:

1) any sound that is real and is **contextually louder than or foreign to** its surroundings, regardless of its content. This means an extreme **audibility**: either a sound that is **too loud** to be evaluated for its internal qualities or, especially in the presence of a louder sound, a softer sound – **too soft** that it cannot be evaluated for its internal qualities, and typically deemed merely disturbing. Writers from the health research field embraced noise attenuation also for health concerns **[18]**.

2) any sounds that are **beyond the intentional**, or when the connection to musical performative intention cannot be determined, are judged as noise. A sound that is judged to be **out of context** might not get fully processed by listeners, since it was perhaps sounded by mistake or instrument malfunction (organological noise), is impossible to be repeated, and devoid of human

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[17] We will use the German system for octave numbering and the letters b and # as accidental markings.

[18] It is still unclear how much the health consequences of noise can be diminished by simply adopting a musical listening mindset in the presence of that same noise.

intentionality[19].

3) an individual's **incapacity to process** the sounds or the surrounding (performance-auditory) context. Many aspects of noise lie, in addition to acoustic criteria, between the realms of auditory cognition, musical convention, and individual judgement and include any of the following criteria:

■ a **too abundant**, simultaneous steady mass of sound, a multiplicity of implications and internal connections. This happens in considerable inharmonicity such as in **extreme noise**, which has been seen as the antithesis of either a soft sine tone in a non-reverberant space (LYYTIKÄINEN 2009) or of silence (VAN DIJK 2017).

■ a chaotic, **too rapid sequence** of sounds – the sounds are too short to be evaluated for what listeners typically would evaluate them for; thus sounds lose individuality and become statistically perceived, akin to white noise.

■ otherwise **unstable**, evading, noncontinuous sound, prone to such changes that make the listener **miss discernible patterns and closure**.

■ **obscured** by an obstacle or filter, no more providing a direct connection or a source of information [20]. Noises are, for their uncertain and uncontrollable aspects, a **leap in the dark, to the edge of meaning and/or knowledge** (VAN DIJK 2017). One may find something new, or, by controlling this leap, create something new.

■ subjectively, a sequence of sounds that is identified and is **beyond the personal adequate processing capacity** or the **expectations** of a listener at that time, and cannot be processed as music. It is thus non-music, which equates to noise by its social definition.

■ subjectively, a single sound that has such **internally complex proportions and relationships** that it goes without full processing and is beyond the personal adequate processing capacity or the cultural expectations of a listener at that time and cannot be processed as a musical sound; it could however be understood as a sound effect.

4) a sound "for which **no sensation of tone occurs**" (BRIXEN 2011:22, our emphasis). In this distinction any sounds that are not pitch are noise as in a remainder category. Noises may also be considered as characterising informants as to the exact instrumental origin of a pitched sound (BRIXEN 2011:26), yet having little importance beyond that. Composer-theorists including SAARIAHO (1987) consider noise as belonging to a seamless **continuum of sounds from noisy to pitched sound**. Such definitions seldom delve deeper into the conceptual basis, such as whether a sound's stability or register can constitute noisiness. However, the strictest concept of pitch requires stability (SCHMICKING 2003: 316) and one clear judgement on a scale of high to low, both of which are scalar and not absolute concepts.

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[19] From a feigned non-intentionality grows the wider concept and aesthetic of glitch.
[20] To the information aspect, see BRECH 1995.

5) an individual's **unfamiliarity or unwillingness to engage** with the sound and/or its source, despite being able to. The notion of noise is then based on social-cultural coding and conventions in fields other than music. This is seen in some early writers such as Helmholtz as a *bona fide* contention of worthwhile music as the opposite of noise. This musically exclusive or essentialist view rejected any avenues for discussion until the modern opposite pairing of signal and noise was established (WITTJE 2016:202). Occasionally even today, a sound becomes **(de)valued** as noise. A common statement to this effect is that subjectively **uncomfortable** sounds are understood as noise [21] and it follows that music devoid of noise becomes associated with **comfort** [22].

The aspect of noise as a **measurable** feature of a sound wave at any point in space is favoured by laboratory studies, is more straightforward and includes:

■ non-periodical sound from which periodic component waves cannot consistently be extracted.
■ a sound that does not include any fundamental frequency (SCHMICKING 2003: 313)
■ a measurement of inharmonicity, which leaves out all the other aspects of noise, yet allows for understanding noisiness as a smooth continuum.

Froise

Froise is the term that I have used since October 2018 for those sounds that have "frequency cores in noise" (VESIKKALA 2018). Accounting for individual hearing differences, Froise means an exact balance between perceived pitchedness and noisiness. Froise as a perceived and possibly maintainable state between noise and pitch might be best reflected in the results of a listening-test questionnaire. Froise as a concept is necessary to bridge the situations where a pitched and noise-based approach to composition (and to listening) meet. We may further remark of Froise:
■ those sounds for which composers either cannot effectively apply pitched or noisy compositional techniques and strategies
■ the active choice between listening strategies that Froise induces may compass an entire piece and become a compositional dialectic
■ those sounds that **receive medium values** in calculations of signal-to-noise ratio, inharmonicity, or noise energy in the signal (or by any remaining algorithms for noisiness)
■ those sounds that **combine considerably many aspects** that are known from noises and many aspects that are known from pitches
■ may originate in one sound source, or as a compound from two or more disparate sources and from musical texture as long as the result is a **blended perception**
■ the states of pitch and noise have to be perceptually merged and **simultaneously present, not alternating**.
■ our development of the term Froise is likely to detach from the original

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[21] See for instance SCHMICKING 2003: 316.
[22] On the meanings of comfort in culture studies, see SCHMIDT-LAUBER 2003.

intentions of Tolonen (1969:75), whose minimal definition of the equivalent Finnish term *sole* skipped all its compositional and analytical ramifications.

Timbre, spectrum, FFT analysis

Timbre is what in the sound realm distinguishes different instruments, natural sound sources, and/or their electronic reproductions from each other. Every instrument has a limited timbral range, which has traditionally helped perceive different lines in polyphony, to blend with or to detach from another instrument, and to summon unique associations. Timbre has continued to become an even more potent force in composition in the recent centuries. Timbre has also been studied in popular music where it drives renewal and stylistic diversity since other features of sound are not greatly varied.

Several early definitions of timbre required a perceivable pitch, such as when timbre was considered the feature by which "two sounds similarly presented and having the same loudness and pitch are dissimilar" (RISSET & WESSEL 1982:26, citing American Standards Association (1960)). To this we may add the notions about a similar duration and the ability to name the sound source (LOY 2011a:456).

Some historical attempts at a definition, such as "tone colour" drew false analogies to timbre, for example by not addressing the mixing of timbres. By presupposing a stationary sound, it either did not allow or did not consider small fluctuations within, which create much of the musical evolution and meaning to the listener (HALMRAST et al. 2010: 183). These arise in the sound's **spectrum,** which includes pitches as well as the timbral parts of the sound that are often unaddressed by musical notation. The spectral aspects have to be discovered by the ear when listening or exploring on an instrument, or with computer assistance. The spectrum also includes many features that will never become audible even to the most experienced (studio) musician and listener.

Wider definitions of timbre that include noise are in the minority, whereas spectrum-based approaches to timbre are common – however, timbre is not revealed merely by pitch or dynamic level, duration, or the location of a sound; the phenomenon is much wider.

Perhaps the most objective method to describe timbres and their differences is mathematically or with computer assistance, for example by using **fast Fourier transform (FFT)**. It indicates the "frequency content of a digital signal" using a "numerical technique, optimised for rapid computer execution" (DODGE & JERSE 1997:432). The results of **FFT analyses** are often visualised and theorists do not necessarily have to deal with exact numeric values, and this stage of usability is what everyday parlance often means, although Fourier analysis and Fourier transform are not identical procedures (DODGE & JERSE 1997:432).

Contour and morphology

A study of **contour** in a spectrum can reduce any quantifiable aspect of music that proceeds in time to its individual occurrences and sort them by their mutual level differences and temporal order. These points in time can then be presented again numbered (see SCHULTZ 2016) and contours can be further compared (see SAMPAIO 2012), reduced or varied using mathematical operations. The study of musical contours started with describing pitch progressions as steps in equal tuning. Today contour can apply to a fluid pitch space instead of systematic steps, and more and more elements of music [23] were later understood to be worthy of similar attention: "The theory of musical contours [...] can be generalized to any pair of sequential dimensions." (MARVIN 1988:218) [24]. We will apply contour analysis to several timbral aspects of the repertoire.

Contours typically operate in one dimension in addition to the temporal dimension, which is given as absolute or scalable. The terms contour and **envelope** are related in that envelope has been given a finite duration, as when Marvin suggest the following beyond mere pitch contour analysis: "generalization of musical contours by using a sequential dimension of noise content ordered by loudness, location ordered by c-pitches[25], and envelope ordered by vowel color, among others." (MARVIN 1988:219 [26]). We will prefer the term **trajectory** to describe timbral movements of undetermined duration, some transferability, yet clear order of members. Such trajectories are always temporal, and there are one or more other dimensions of sound. Timbral trajectories are what make timbre alive whereas the FFT analyses show timbre in such short segments of time that most trajectories cannot be discerned.

When applied from linguistics to music, as is often done, **morphology** refers to the changes that a sound undergoes during its course in time. These are also essentially two-dimensional contours, since in time either a frequency mutes completely or one of its nearby frequencies gains in amplitude, which results in a perceivably changed core of the frequency[27].

Proximity, parsimony, voice-leading, and Gestalt theory

Theorists of pitch-based music have traditionally valued smoothness in any audible phenomena under scrutiny. This **proximity** is in keeping with the most direct and short, least diverging routes when a movement between objects of any kind is observed. In the pitch realm, this has proliferated in rules of proximity when pitch-based composition styles have been codified [28]. The maximal amount of proximity, when routes from one sound to the next are the shortest available, is known as **parsimony**. The accumulation of further rules resulted in the discovery of **voice-leading**, although any perceivable progression

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[23] Including rhythmic durations, see BOR 2009.
[24] See also MOREIRA 2016 and WU 2013.
[25] Abstracted pitches that participate in a contour.
[26] Referring to Robert Morris' "Composition with Pitch Classes: A Theory of Compositional Design" (1987).
[27] For the auditory processing of dynamics as a spectral property, see REES & MALMIERCA 2005.
[28] For the late Renaissance styles see JEPPESEN 1992/1931 and for common practice music ALDWELL & SCHACHTER 2003. Requirements for proximity reached distinct zeniths with the galant Neapolitan school and late-Romantic chromaticism, and this preference for similarity is even present in Forte's set class theory.

from sounds to perceivably different sounds is heard as voice-leading even when no rules have been intentionally applied to them or when not all movements are parsimonious. The basic human tendency to look for exact identicality, similarities and at least familiarities is found on the level of the individual stimulus or object, as well as in comparing patterns with other patterns [29]. Since the term voice-leading is a simplified human interpretation of the workings of auditory cognition, not a term of the exact sciences, it is possible to observe the cognition of all kinds of sounds under this term [30]. Noise sounds have previously not been studied from the voice-leading perspective. When the notion of timbre is understood as part of voice-leading, an observation of lines in an essentially one-dimensional pitch space becomes multidimensional. Simplifying and reductive approaches are also common to contour theory and **Gestalt theory** which studies holistic perceptions and their correlates to basic cognitive, in our case psychoacoustic, patterns and conceptualisations. Many music analyses tend to approach music via visual shapes (in proximities, parsimony, voice-leading, contours, Gestalt, and ultimately musical notation itself) to create an analogy with the visual world [31], yet an analytical method can make visualisations of complex musical phenomena without claiming such a deep analogy between these human senses.

These topics in the literature will be reviewed in more detail in chapter 2.

1.5. Researcher's position and objectives with analysis and composition

Our goals from the analyst's and (secondarily) composer's point of view are intertwined, as evidenced by the main thesis. This tough endeavour will call for multiple perspectives and analytical methods, as well as theoretical knowledge and capacity to process that information.

A good use of online resources and academic music libraries in 16 countries on-site all over Europe verified that even though academic interest in timbral composition has slightly surged since the start of this study in October 2018, the topic of Froise is academically novel. By the Spring of 2022, not enough written material has been published on even the nearby topics to make comparisons of all aspects of our coming methodology.

Even though the altruistic goals and the perspectives of this study are balanced, I see in embarking on this study some risks for **subjectivity**, and an inherent subjectivity more severe than with most other studied topics of music. This will

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[29] This is apparent in melodic memory by comparisons of contour, see WU 2012. We need not exclude the possibility of timbral contour also being such a comparable feature.
[30] The difference between voice-leading and **auditory stream segregation** has been that the "voices" imply a compositional intentionality in timbral space, however abstract. Moreover, sounds are segregated into streams by perception yet many pieces have worked to create its opposite percept, aggregates, which are not streams yet result from voice-leading. The associational difference between the terms is small while voice-leading conceptually retains both the possibility of sequence and aggregation.
[31] For similar recent questions in visual cognition, see ELDER 2018 and TSIROS 2013.

be addressed in the next subchapter. My responsibility as a researcher with limited time and resources is to counteract subjectivity that stems from the topic (the kind that exists regardless of who conducts the study) and to not add further subjective filters of my own, particularly when psychoacoustics questions can only indirectly studied (ROSS 1992:25). Thus, the proper incorporation of psychoacoustics and taxonomy into Froise and timbre-based music will be a task for professional, committed psychoacousticians.

1.6. Subjectivity, restrictions, and disclaimers

Our thesis runs against the traditionalist yet rare argument that music should be based on pitch and intervals. Robust counterevidence has accumulated with sound-based recent repertoire yet music theory has fallen behind. We now address the challenges with sound-based analysis.

The shift towards timbral and later sound-based compositions was slow and thus no composer can be singled out as "responsible" for promoting this multidimensional compositional medium that is extremely difficult to decipher for theorists. Likewise, tonal-functional analysis has an acute **need to spread psychoacoustically informed perspectives**. Since timbral analysis cannot possibly fulfil psychoacoustic criteria that have not yet been found, those who are closer to music analysis than to clinical or experimental psychoacoustics may be discouraged to make further investments to timbral analysis, which also halts composers' progress in this field.[32]

Within tonal music analysis, the psychoacoustics that can be incorporated are becoming more widely embraced in addition to earlier analytical machinery. We wish to see the same progress in the analysis of sound-based music, and this starts by establishing the analytical machinery for sound-based music. This way, the conditions of composers and theorists who have worked with limited timbral analysis methods in a trial-and-error discourse can be improved. Compositions might even directly address the auditive-cognitive result in the listening brain, which would spell a drastic change to composers who have used novel ways of listening and rare timbres precisely to **create listening experiences and rewards that did not previously exist**. Froise sounds have widened the range of such dramaturgies and experiences, although they are only a small part of the auditive-cognitive leap underway. Our approach is **informed by sounds in time**. There are however other subjectivity arguments which we now list and consider.

Table 1.6-1. Aspects of subjectivity in timbral analysis that have inhibited earlier research.

Anti-subjectivist argument against timbre analysis	Counterarguments, conditions

[32] The rather recent consensus that the analysability of a piece does not increase or decrease its musical value is also a contributing factor.

1A) No selection of verbal descriptors for timbre and their weightings can **match the psychoacoustics** present in this repertoire – after all, not enough research has been done.	The psychoacoustics of timbral music has been, for decades, a work in progress, and may perhaps never be satisfyingly and integrally finished. Not being psychoacousticians, we may only answer with **a method that at least has more merit and validity than the ones currently in use** – a comprehensive analytical method may well be underway or might never be possible to construct. This method must stand against scrutiny from existing psychoacoustics research. Stipulations with which psychoacoustic aspects to explicitly incorporate, or their weights to each other, are unrealistic at this state when any solutions are urgently needed by fields such as music theory and composition. Our method will be **an intermediate explication** instead of an ultimate one.
1B) Even if a set of timbral verbal descriptors has been defined, **correctly and unambiguously assigning values** or ticking the box will be difficult.	The word choices in the descriptor criteria will be as unambiguous as possible. Where two or more criteria overlap in the case of one sound, the sound should still match **one criterion above the others**. Auditory perception makes fast judgements in individual cases such as fulfilment of criteria, yet when consistently given ambiguity, it can recognise that ambiguity (as in the case of Froise as an intermediary position). The sound is likely to neatly receive values for the remaining descriptors, such that the ambiguity is mitigated. Common to taxonomies that are based on **trait inventories** [33], the inventories need to be large enough so that irregularities in the inventory or in the input data balance out each other. Our inventory size for noisiness will be 15 and the inventory items (traits) are **timbral descriptors** that also will receive any value out of 5 options.
2) Uncertainty and random fluctuation resulting from an individual's hearing and auditory cognition will affect the perception of any sound. Ultimately,	Our method is primed toward an average listener. A listener who greatly deviates from an average listener is likely to have accommodated and adapted when listening to any music. In the case of Froise, this may make our criteria seem to either cover larger or smaller perceptual ground, yet the basic judgement is the same – to tick the most appropriate criteria. Even the verbalisations that are expressed in ostensibly absolute terms will still be compared to the verbalisations in other criteria – thus our method

[33] Such as polygenic trait scores in genetics, or personality traits in differential psychology.

we cannot ever express how we hear timbres since others will likely hear them differently.	addresses how timbres are heard relatively.
3) Many (noisy) timbres cannot always be **performed consistently** and depend on the **acoustics of the space**.	Our method relies on the compositional intentionality of sounds and is supported by the notation that was seen fit by the composers. When a composer surrenders some of that intentionality by composing sounds that cannot be quite controlled, this is taken into account in some of our criteria which address listener expectations. These are accustomed filters in listening that account for a fragile instrumental origin or the type of performance space.
4) The meeting point between noisiness and pitchedness has not been found, so composers and performers have intended it to be exact instead of elliptic.	The conventional view about this meeting point is paradoxical. Border points in the noise–pitch continuum have been designated arbitrarily (by composers, theorists, performers) as long as the exact inner factors of noisiness have not been considered. This has led to the avoidance of crossing from noise to pitch and vice versa, as well as to limiting the amount of Froise timbres that are used in a piece. This conveniently diminished the distinguishing density (or definition, or pixelation) in the Froise region. When only few Froise timbres were used at a time, individuals would not make differing judgements about the border. Yet even then, Froisiness was defined relative to two timbres on the borders, and not by any absolute measure.
5) Theorists who rely on notation receive less help in timbre-based music which **lacks a notational standard**.	Writers such as Thoresen have worked towards a visual analysis system that, while not replacing the insufficient notational system found in recent repertoire, will help to identify timbral similarity and congruence when it is not obvious from notation.
6) Timbre seems to require some level of **lexicalisation or verbalisation** which is foreign to conventional theory, which is mostly scalar and numeric	Lexical and verbal models and typologies are the standard in many other fields in the sciences and humanities, apart from noise in music. Lexicalisation and verbalisation may be the closest to scientific results that we can aim at. Words are used in most taxonomies such as study of dialectal borders, colour perception, stones, in molecular gastronomy and aromas (THIS & RUTLEDGE 2009; GREEN et al. 1996; THIS 2006;

(e.g. pitch, rhythm, chordal steps). Ultimately, we cannot ever verbalise timbres since other listeners are likely to describe them differently.	VILLAMOR & ROSS 2013), while numeric methods are used in sorting RGB colours **[34]** or calculating soil makeup in geology, personality studies in psychology **[35]**, population genetics **[36]**, in addition to the lexical trait inventories (or facet scales) mentioned above **[37].** They differ structurally from each other and are not as such transferable to timbre. Such complex objects tend to have considerable overlap with several of the descriptive categories that human researchers could ever define, so no system will be even nearly perfect, and individuals' perceptive abilities differ greatly. Most extremely in the case of music, taxonomies of timbre or spectromorphology such as by Schaeffer, Smalley or Lachenmann do not even seek scientific validation yet remain in use. As a field in which studies are long overdue, timbral composition needs at least one preliminary method that relies on discoveries on many fronts and paves the way to comprehensive discoveries in the form of new compositions.

[34] Colour is a commonly presented analogy to timbre and has a complex taxonomy, yet when perception is concerned the phenomena are not comparable. Visible colour occurs on a continuum of frequencies from violet to red yet this is by no means acknowledged by human vision, whereas the noise-pitch continuum is. For instance, "grey noise" is a noise that is perceptually flat throughout the spectrum and adjusted to human hearing and may be perceived uniformly by listeners and even as a Froise sound. It builds an unsatisfying analogy between timbre and colour, one phenomenon that is scalar in multiple ways and one that is also scalar using many scales that are not humanly perceived, that also differ in their number of dimensions.

[35] The case of personality studies is typical since one standard, currently the "Five-Factor Model" is used for most quick purposes as well as for correlation studies. See MCCRAE & COSTA 2010. perhaps the largest set is the International Personality Item Pool with 2036 inventory items (ASHTON et al. 2007:1518), which would be beyond practical for a non-computerised approach.

[36] See SEPAS-MOGHADDAM et al. 2020., and BROOKS (2011:10) on the human tendency towards group vs. self-identity work. This general skill benefits timbre recognition.

[37] Humans may rely on their classificatory skills even when they are used hastily and are far from accurate. Music perception forms no exception, and timbres are identified particularly quickly by auditory perception – THORESEN calls this "taxonomic listening" (2015:16, crediting Francois Delalande's 1998 threefold listening strategies in *Music analysis and reception*). When we contextualise with taxonomies in other nonexact fields (that share none of our descriptors), the use of very rough classifications to phenomena that would require much more complex methods has in the everyday world led to exotisation (see AFFERGAN 1987), xenophobia and racism (see DORON 2016; SAPERSTEIN et al. 2013), and enforced conformity to gender norms (see HALBERSTAM 1998), particularly when classification has only based on an object's outer manifestation (a phenotype) and when the nature of the phenomenon is fluid and no exact dividing point can be assigned (see DAVENPORT 2020). Some taxonomies and tools built on them such as G.Hofstede's theory of cultural competence have been contested mainly on grounds of causality yet not replaced by more apt models. Lately these complex questions have been studied scientifically, for example with the principal component analysis (PCA) method, although its results in genetic population studies have been met with opposition (ELHAIK 2021). Chapter 2.3. considers taxonomies in timbre specifically.

These anti-subjectivist arguments share in common that they do not consider that an objectivist stance to timbre could ever be achieved. Also in our coming classification method, a PCA analysis might show non-verbalisable higher-abstraction features of the timbral dataset. Yet PCA analysis will not be conducted because of our avoidance of stages requiring computation, and precisely since we cannot assess the "principality" of such heavily derived components that originated from insufficiently weighed timbral factor data – and a correct weighing of the timbral factors is not known.

We will balance the mentioned lack of a **listener test** with a large database of timbres. This corpus of data will help in the formation of a preliminary model. This study filled in numeric timbral data over the years 2020–2021, each time individually without extensive coordination with other timbres in the database.

Our taxonomy will start with a small number of timbres (the timbres in the Sciarrino piece in chapter 3) that are categorised as a pilot sample. After this, taxonomic criteria will be made more exact, so that a good value can be found for all kinds of sounds. Values of the same descriptor across several timbres were referred to occasionally in the process to verify uniformity. This way we can refine the descriptor criteria and administer as streamlined a model as possible.

Our way of classifying timbres by reduction is by no means to say that any other remarks about a sound, such as its FFT visualisation, would be incorrect. Instead, we should reasonably expect that two timbres, that in a rare case share the exact same 15 descriptor values, will differ by some perceivable features that are not addressed by our reductive method. They include for instance frequency in those cases when it is not taken to dramatically affect timbre. Due to the scalar nature of noisiness, **some criteria inter-correlate** and will be listed not only under one but under two distinct values for a descriptor.

The pieces in the analysed repertoire must be **fixed compositions**, with either notation or a recording available where Froise sounds are audible. We will aim to follow the analytical standards conventionally set to "non-timbral" music [38] and use the analytical means, those existing and those particularly developed here, to answer noise music, to **show that Froise is a musical element**. When we study fixed compositions, we will have to deal with the distinction between a composer's stylistic preferences and the general wider range of functionality that Froise timbres can have. Each compositional style with noisy timbres might be described as an "idiosyncratic dialect" and "deliberately deviant" (CORDER 1971, to borrow a term from language learning studies), with nobody ever even attempting to reach a pure syntax; a composed order of sounds that would match a perfected ruleset of timbral music.

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[38] We should not speak of pre-timbral music as entirely devoid of such intentionality that we are accustomed to listen for in recent music: "To tell the truth, refocusing on sound does not signal the complete disappearance of work on the note, and not only in 'music', but also in the 'art of sounds'. And the inverse: a number of works from the past, however much centred on the note, would also deserve to be listened for their work on sound as well as for their energy work. The two models have therefore always coexisted – even though the second waited for modernity to assert itself." (SOLOMOS 2020:242).

We will undertake this study with high hopes and expecting results that at least complement musical analysis or composition. Our results will be enabled by works that can be analysed using our **perceptual taxonomy based on 15 descriptors, two-dimensional presentation method**, and interpretation of criteria that can relate to timbral operation, structural segmentation or changes to aural infrastructure achieved by Froise. **A set of refined methods to tackle analysis of the Froise repertoire is itself the strongest expected result**.

We will select a **most representative collection of works** from the limited Froise repertoire and concentrate on those **existing theories** that are closest to questions of Froise. Here we are content with **a new toolbox of distinct analytical methods** instead of one all-encompassing analytical method. Theorists can combine the open-ended methods with historical analytical tools to the noise repertoire while bearing in mind that noises are perceived inherently differently than pitches and harmonies. This will also mean greater backwards compatibility of our methods with existing music analysis conventions.

Our methods can hopefully **explain musical functionality of Froise and at the same time noise**, which can in this case be understood at least analytically as a reduced form of Froise [39]. Just like pitch-based analysis can explain why certain pitches that occur close to each other are grouped in perception– this is where tonal music boasts more effective analytical tools than atonal music – noise-based analysis also should be able to **explain why some noises co-occur often**, why some not, and why some co-occur only in certain circumstances. Once this has been satisfyingly explained, we must be able to find possible explanations for passages and entire compositions [40]. We expect to overcome all these obstacles in our subsequent analyses (chapter 4) and possible refinements (chapter 5) to the analytical method.

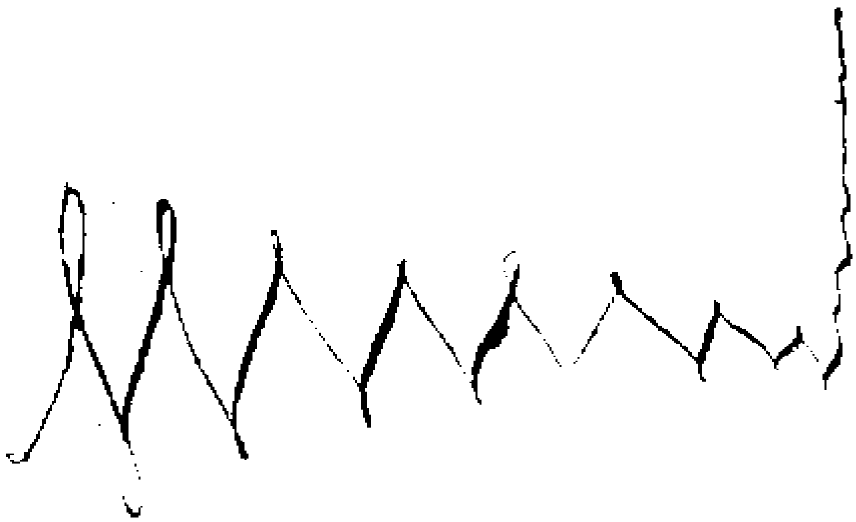
1.7. Summary of expected results

In this chapter, we have introduced Froise and its established parent fields (mainly noise, pitch, timbre, and voice-leading) such that the following chapters may expand on them in the study of Froise repertoire and discuss our questions. To support both parts of our thesis [41], **our first objective** intends to comparatively search the repertoire for **distinct types of voice-leading** (understood broadly) that employ Froise as a complex sound and perceptually intermediate category between noise and pitch. The **second objective** is to **briefly incorporate applicable psychoacoustic and perceptual theories** to support any timbral principles found and to allow theorists to identify the same

[39] Again, the opposite direction is untrue – pitch without a timbral focus or processes has been theorised extensively and should not be included as a feature.
[40] This is where analysis of, for instance, traditional atonal and spectral repertoire still faces difficulties due to lack of combinable methods. Any deviations that the composer might have made from an exact serial pre-organisation or from a pure spectrum tend to be explained away rather than engaged with using analytical literature.
[41] Froise's intermediacy between noise and pitch, and its perceptual role in voice-leading.

principles in further musical passages in the repertoire. [42]

Central to our thesis, will be charting the variety of commonly used Froise sounds and referring to subjectively interesting mostly complex situations that feature several instrumental lines with Froise sounds. This will be done regardless of different composers’ styles or their reasons for using Froise sounds. The design of the main analytical method will consist of three parts and should lead us to observe commonalities and principles in the use of Froise. We hope this will aid both composition and analysis of Froise repertoire in the future. We hope to meet the objectives with the help of both analysis and literature – which will be the content of the next chapter.



[42] Due to these objectives, our study emulates its close kindred pair and a classic of analytical literature, Joachim Burmeister’s *Musica Poetica* (1606). We have the same aim of categorising existing recent repertoire and giving inspiration and overall insight for future compositions. We even utilise similar methods: verbally summing up the repertoire in search for compositional devices (of rhetorics for Burmeister, of timbre for us) and forming general categories of them.

2. Froise in the repertoire and literature

This chapter will review theories and other texts in the fields that are essential for answering our main thesis, closest to the topic of composition and analysis with noise and Froise sounds. Our main thesis opens avenues to several directions, and many of them have not been presented in prior literature and due to this are likely to face opposition. Since Froise is still far from an established discipline of study, we will review a corpus of literature that is situated under several disciplines within music, acoustics, and nearby disciplines, mostly in the arts and humanities. Beside the actual acoustic **repertoire**, the closest already established theoretical discipline is that of **timbre studies**. It is where we will give an overview of prior progress, terminology, and methodologies. Other fields of study will play a supporting role to our timbre-based argumentation; such is the case with conventional **music analysis** and **psychoacoustics and perception** literature (particularly for the voice-leading discourse). Thus we will not refer to the historical lineage in those fields as thoroughly. In addition to the definitions given previously, usage of some terms will differ between the disciplines. Conflicts arising from endemic methodology or terminology will be explicated and rather avoided.

All literature mentioned throughout is listed in the **bibliography** and annotated according to their discipline (using numbers in the classification below) and whether also citations from the mentioned work were taken (using bolded titles).

We should select from these sources and further develop only those state-of-the-art statements that can help either solve or revoke our study question. After all, our goal is to introduce an intermediate timbral category and an analytical-compositional toolset related to it as one of the urgently needed tools for this repertoire that benefits listening, analysis, and composition. It is not necessary for us to discuss or argue every point made by a source – we aim to reproduce statements that are in keeping with best practises, and are neither obsolete nor irrelevant to our topic. This procedure with our large amount of literature saves space – it does however forgo the standard academic practice that would recommend us to outline all sources' context in the literature and full (yet for us partly irrelevant) argumentation process. Some of this standard treatment will be afforded to literature in the timbre studies discipline.

Since none of the titles is spot-on to our topic, and the existing **fields of research** position themselves somewhat tangentially relative to our topic, it would be beyond the point to bother readers with conventional abstracts of our large corpus of literature. The fields have their own parlance and internal divisions each, and this will be given minimal attention; even when writers disagree about a secondary topic within their field, the topics of disagreement tend to be for us irrelevant. Instead, for each discipline a general overview is assembled and complemented with written-out evidence tables or review matrices that list its relevant introduced ideas, views, and arguments – statements and aspects from several titles combined in a compact format, with occasional explanatory comments when allowed by the scope of our dissertation. By such a table of evidence we can notice different study branches and schools of thought along with the chronology, genealogy or dissemination, and rough estimate of supporters and clustering for each idea or argument. The majority of ideas and terms present in this literature will be thus only pointed towards and left as irrelevant to carrying out our thesis. Another aspect that the table procedure will filter out is the differential nature of the texts studied; writers will have various backgrounds and (exterior) goals with the ideas they put forth, as well as different arenas in which they publish. Yet after a text has passed a primary choice of inclusion in our literature corpus, we will take every argument as being made in good faith, regardless of the experience and status of the writer, the language, format, and prestige of a publication, and degree of peer-reviewing. Since some of the ideas may have derived from falsely understood or obsolete premises – such as those developed for the needs of tonal music or the exclusion of noisy sounds – or been developed with fallacious logic, our task after the charting remains to pool and recontextualise all the ideas and arguments. From the third chapter on, we only continue with arguments for which a logically supporting foundation can be found from within the pool of other supportable ideas. Some of the most commonly held erroneous, refuted views could let us start afresh with a deeper understanding in the form of an **error theory,** of why an incorrect notion or disconnect (especially with noisy timbres) emerged. Froise lets us read our following method as an error theory of many earlier approaches to timbre. At its core, our main thesis posits that the common understanding of noise and pitch as separate entities leaves many long-existing sounds unaddressed, that the noise–pitch continuum should include a notion of an intermediate Froise region, as well as that even this refined continuum is not enough to describe timbral processes in time. The study of timbre has also been rife with unmentioned limitations that has prevented researchers from considering noise as timbre.

In the literature on **timbre**, the subcategory closest to our topic is timbre-categories and timbral composition, while the latter subcategory has yet to grow. In **noise**, there is no particular focus. In the field of **voice-leading and stream segregation**, our focus lies on the subcategories of spectrotemporality, stream segregation of noises, and prolongation.

There are eight **baskets of literature**, described in the order of their proximity and applicability to our theme at hand:

Basket 1: Froise literature

This dissertation intends to establish a new praxis and discipline around Froise. Presently, there is enormous potential since the only questions similar to Froise are mentioned in LYYTIKÄINEN (2009) as taken over from the (likely) originator of the term, Jouko Tolonen.

Basket 2: Literature on timbre, pitch, noise, and spectrotemporality

This is the largest group of literature studied, internally very divided and with a long history in both the social and technical aspects of each. Literature on timbre is available on a different degree of magnitude and not always concerns music, compared to the small fields of musical noise and pitch space. Our main interest is timbral categories, and noise in its musical meaning and its prospects to widen timbre discourse. Both in the case of noise and timbre, the compositional literature is the most relevant. This basket is required especially by our focus on sound-based music.

Basket 3: Scores and recordings of the Froise repertoire

Notated and audible materials for the pieces analysed in the analysis chapter 4 make up this basket. Purely descriptive literature intended to accompany our analysed pieces is also included. This basket is required widely for our thesis and constitutes an altogether different use of sources.

Basket 4: Music analysis literature

This basket includes the widest number of approaches and literary formats, is our second-largest studied category, and has the longest history. While this basket includes some classics of the analytical literature, many of the approaches promoted are of experimental nature and are awaiting application in analyses like ours. This basket will contribute to our thesis as a whole.

Basket 5: Music analyses of noise and Froise repertoire

For this basket, we adopt a stricter focus by only considering analytical approaches that were developed for particular pieces of recent repertoire. For instance, work descriptions and analyses of the repertoire constitute an overarching field of literature with a closer repertoire connection, and deal sporadically also with topics from the other baskets. This basket will contribute to our thesis as a whole.

Basket 6: Perception and psychoacoustics literature

The rather large and recently rapidly developing literature in this basket stems, among others, from empirical research for technical applications. A minority of it has been developed for music and the purposes of music composition or analysis, even though the findings can be applied in a most straightforward way. We focus mainly on material about timbral listening, noise listening, and secondarily on formal topics. This basket is required especially by the voice-leading discourse in our thesis.

Basket 7: Taxonomy literature

This basket corresponds to any literature that will be helpful in forming statistics and taxonomies of timbres and setting formal criteria to our theories. Some of this literature is focused on music yet does not fit the previous baskets as well.

Basket 8: Other fields of literature and study

The contents of this basket include everything not related to music nor to the specific branches of research mentioned. This basket also includes literature on electronic music and *musique concrète* in cases where it does not address timbre, analysis, or composition explicitly. Here we consider fields such as theory of narrative or analogous studies in the visual arts or in literary theory. We also include citations of fiction. This literature is only to support, not to contribute to the development of ideas, and will be introduced only at their proper place. Since we will make use of this literature to set in motion music-related argumentation, the selected source works may not entirely concur with the most recent developments in their respective fields. These supporting fields have had varying degrees of presence during the research and writing, thanks especially to discussions and discoveries of rare material.

Our previous division into three would correlate "timbre studies" with the literature baskets primarily 2 and secondarily 1 and 6, "music analysis" mostly with 4 and 5 although its methods can be at times found in 2, and "categorical perception and psychoacoustics" with baskets 6 and 7. Critical scrutiny will only be directed at the literature in baskets 1, 4, and 5 which deal with Froise at least tangentially. Our target of critique should not be composers, publishers, or performers (basket 3) or those fields that did not encounter Froise (baskets 6, 7, and 8). We can roughly say that the larger the number of the basket, the more embellishing its role for our argumentation.

What we will need to answer our ideas about Froise is to develop a **Froise analysis method** (in chapter 3 by taxonomy and visualisation, and refined in chapter 4), since no existing analytical tools can be as such applied for Froise analysis. It will be closest to baskets 4, 5, and 6 yet is not satisfactorily supported by any existing literature in them. Our method will fill a gap in these fields of study.

The repertoire addressed with this method (in chapter 4) will include works of several instrumentations, styles, and composers from the last almost 50 years. A wide selection is needed to ensure that many possible functions of Froise are presented. Some pieces are analysed in full, while most analyses only consider the relevant passages for the study of Froise. Some Froise sounds may be even shared between pieces yet play out differently in their musical dramaturgies, which can further underline the difference between Froise taxonomy and timbral function. These works from basket 3 are included in our Bibliography and Appendix 4 has most of the notation. The passages are from the following works:

Mark Andre: *auf...II* (2007, for orchestra), Antti Auvinen: *Autuus* (2015, multimedia opera), Carola Bauckholt: *Atempause* (2000–2001 for orchestra), Chaya Czernowin: *Sahaf* (2008, for quartet), Beat Furrer: *Wüstenbuch* (2010 for ensemble and stage performers), Helmut Lachenmann: *Schreiben* (2003, for orchestra), Gérard Pesson: *Catch Sonata* (2016, for trio), Horațiu Rădulescu: *Thirteen dreams ago* (1977, for strings and electronics), Fausto Romitelli: *Seascape* (1994, for Paetzold recorder), Kaija Saariaho: *Six Japanese Gardens* (1993–1995, for percussionist and electronics), Salvatore Sciarrino: *Quaderno di strada* (2003, for baritone and ensemble), and Agata Zubel: *Cascando* (2007, for quintet). These passages represent diverse setups: choir (Auvinen), solo instrument (Romitelli, Saariaho), chamber music instrumentations (Auvinen, Czernowin, Pesson, Zubel), large ensembles (Rădulescu), orchestra (Andre, Bauckholt, Lachenmann) and large ensemble with speaker or vocalist (Furrer, Sciarrino). The presence of electronics in amplification or a clearly secondary role in some works can be reduced out.

Especially in the literature of baskets 2, 4, 6, **chronology and lineages between the sources** are significant, since at times results have been refuted by recent research. Thus, for each subtopic, the most recent literature is preferred, whereas older literature abounds in speculative valuable approaches that were no longer taken up elsewhere. We will now critically introduce that literature in the baskets 1...8 which is either central to our argumentation or otherwise enjoys a central position in its respective field. While the baskets are based on large thematic areas, chapter 2.3 will compare the existing methods that are closest to our future analytical method. Much of our study will situate itself primarily into the baskets 1 and 5.

For readers who want more grounding on the application of timbre studies, psychoacoustics, and timbral analysis, we suggest reading through all the eight baskets. Since this literature and its discussion is extensive, **we recommend those readers who are already familiar with the subject to read Froise literature (chapter 2.2.2.) only and skip forward to chapter 2.3.**

Each field of literature has its characteristic pace, stage of documentation and establishing, lacks and missing perspectives, prior terminological parlance, methodology and its own served interest groups, which need not however reflect in the arguments and statements that we select from the literature. There are consequential differences between composers' writings about their own work while still possibly mired in the process, theorists grappling with the topic of timbre that is hardly addressed by analytical literature nor helped by notation-based analysis, studio engineers and technicians often unconcerned with concert repertoire and with how Froise sounds feature in their work (applies to both timbre literature as to the recordings of works), taxonomers with a sociological focus whose only most general findings are to be applied to form timbral taxonomies, or psychoacousticians who have not agreed about the role of noise as an independent musical material nor about the existence of Froise. By combining many perspectives and declaring their limits, the individual blind spots of each field may be largely mitigated. All the knowledge related to our topic can be found on **three levels of establishing and access in the literature**:

1) **The known and well-documented fields** where we propose no changes or new methods (acoustics, spectromorphology, FFT analysis, notation, organology or sound aetiology, notation, and the chosen repertoire itself). Even if the literature has faulty argumentation or true results that were derived from partly wrong axioms or generalisations, our interactions with this literature will remain referential.

2) **"known unknowns"** describes information from the less researched corners in fields whose argumentation is individually sound yet where a lack of both

perspectives and depth in the corpus of literature is evident. These include stream segregation with noises, cognition and perception, timbral descriptors in practice, and timbral functionality (as compared to tonal functionality). We will occasionally discuss the prospects for the inclusion of Froise in this literature and its limits of applicability.

3) **"unknown unknowns"** emerge in topics such as acoustic perception that are occasionally hinted at in the more established literature yet not further discussed by it. This includes two types of literature:

● speculative theory or fringe literature that typically has a narrow applicability and great depth that cannot be fully supported from more general disciplines – thus the support used is often multi-disciplinary. Even if the findings are labelled and defined, the evaluation of this literature proceeds slowly and can often be forgotten for years before it gains new relevance.

● very local phenomena that writers have been unable to verbalise or to connect with other instances or with a wider context. We consider both Froise and timbral voice-leading to be such topics, yet we strive to move Froise from the "unknown unknown" to the sphere of "known unknowns".

Topics in the "unknown unknowns" category include still unestablished literature on, in descending order of importance for our topic: spectral blending which connects both to the theory of Just-intonation and to acoustics (HESSE 1989), reduced listening, residue sounds (DE BOER 1976), phase differences, and timbral memory. A more helpful grouping of questions will be used from now on: **acoustical, cognitive**, and **taxonomic**. These three aspects are dispersed in the above thematic and ideological baskets of literature. The taxonomic aspect can be hierarchically grouped under the cognitive rubric where needed. This forms a twofold distinction, since borrowing Wallmark's (2014) terminology, Froise exists in both its auditory aspects (*p-noise*) and as a physically exact type of sound (*a-noise*).

Since the eight baskets present lots of topics that some readers may find potentially relevant, their relevance for the Froise repertoire analysis will be evaluated; in most cases we decide to provide the reader a basic understanding of that field to show that its literature is not at a stage to yet address, critique, or accommodate Froise. These introductions in these less relevant fields are shown in smaller font to save space for the relevant fields.

2.1. The cognitive basis of Froise

The main aspect that divides our literature of interest is **cognition research** versus **acoustic research**. Baskets 6 and 7 clearly answer cognition aspects while baskets 2 and 3 neatly align under the acoustic questions. Baskets 1, 4, 5 often combine both. Basket 8 lies outside this division altogether. In this and the following chapter we will answer the cognition (2.1.) and acoustic-related (2.2) baskets, while basket 8 as a remainder will not be addressed. Basket 3 consists of the selected compositions, as listed in the Bibliography and discussed in chapter 4.

2.1.1. Froise in auditory perception (Basket 6)

Under this rubric, we understand the literature on psychoacoustics most relevantly integrable with Froise: listening modes, acousmatic music, segmentation, blending, aggregative perception, timbral fusion, auditory stream segregation, auditory scenes, voice-leading, proximity, parsimony, contour, Gestalt theory, form, categorical perception, hyletic information, multistability, and phenotype vs. genotype, not all of which can be discussed within our scope.

These fields deal with all the steps that take place after the sound has been produced, less with the acoustic physical origins of the Froise sound (which is collected into baskets 1 and 2). These fields do neither address the categorisation that happens after audition (found in basket 7). Much of the critique toward Froise can stem from the mentioned fields of study, and in many cases the axioms held by these fields are not tenable considering our axioms that allow Froise. We should not propose changes to each field's fundamental axioms here; such changes are for the practitioners of that field when eventually incorporating Froise. Our engagement with the most conflicting fields in baskets 6 and 7 will amount to only mentions below and to numbered mentions in the bibliography.

In chapter 5 some such partly obsolete perspectives can be acknowledged again.

A close look at the psychoacoustics literature has reproduced the same conceptual limitations time and again, especially in the earlier studies on which many later sources are built. The lacks consist mainly of the axioms made for the circumstances of the majority of Western repertoire before about the 1950s and Western educated listeners [43], that music requires pitch and melody, timbre is not a salient feature of the repertoire, unstable situations in music cannot be studied or have to be reduced to either one of the stable states, a stability hierarchy such as consonance–dissonance reference has to be available, and that embodied and mimetic perception or personal memorised associations do not influence perception [44].

It would be particularly helpful to address the **nonlinear features [45] in the perception of noise music** (any features that feed back between an auditory percept and its reflective judgement), yet currently we must reduce out nonlinearity in audition and make such phenomena seem linear, as well as explain the Froise repertoire mainly without any underlying psychoacoustics knowledge [46]. Our method will retain the linear reductive approach yet will build

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[43] Froise particularly appears in music cultures around the world. On the global perspectives of sound studies, see FALES 2002, FERMONT & DELLA FAILLE 2016, KUBIK 2011, HIGGINS 2012, DE SETA 2011, and UTZ 2021.
[44] Indeed, some studies attack some of these axioms yet paradoxically still rely on the other mentioned axioms. When we present reasoning based on the Froise repertoire, these axioms can be simply bypassed.
[45] See generally in BERTUGLIA & VAIO 2012; for musical implications see TRUAX 1992.
[46] This is not without frustration, however. An earlier sketch for this chapter studied psychoacoustics terms extensively yet had to be abandoned because of the increasing discrepancy in axioms compared to the Froise repertoire.

in acknowledgements and approximations of many of the relevant nonlinear features, so that their recognition and apprehension can gradually begin in music analysis at least. Two fields that can direct a critical outlook at the axioms in psychoacoustics are the study of **listening modes** and of **blending**, below.

Listening modes

Music functions differently based on the way it is listened to. JÄGGI (2020:30–41) introduces the five most commonly theorised **listening strategies**: the **causal** (related to sound aetiology), **semantic** (related to topics and decoding), **structural** (related to models, patterns, and segments), **reductive** (or analytical listening for timbral and morphological characteristics, introduced by P.Schaeffer)[47], and **associating** (relative to subjective meanings that music can have in memories, experiences, and various other avenues than sound) [48]. In what might differentiate structural listening, SCHNEIDER & WENGENROTH (2009:315) mention features of the auditory cortex as reasons why "'holistic' or 'synthetic' listeners recognize the sound as a whole, and appreciate its pitch and timbre as characteristic qualities of the entire sound; and 'spectral' or 'analytical' listeners break up the sound into its harmonic constituents, at the expense of timbral qualities of the sound as a whole." To these we should add embodied or (vicarious) **mimetic** listening as laid out in eight "avenues of musical affect" by COX (2016:198). HURON (2002) further distinguishes between listening style and listening strategy. It is notable that none of these aspects of listening exclude noise or Froise. Other strategies redirect listening habits "in recent forms of music: **acousmatic**, composition starting from what is perceived, minimalism, 'authentic' listening, amplified listening or equipped listening" (SOLOMOS 2020:8, our emphasis). An **aesthetic** mode of listening, by an analogy from the visual arts, might exist: "An aesthetic attitude is a voluntary, human manner of perceiving things, and the attitude can be turned on and off; that is, it is not automatically triggered by something in the world. To perceive something aesthetically is to perceive it with concern only for its aesthetic features, that is, aspects of sensory beauty. [...] One can also choose *not* to view something aesthetically, even if it was designed to be experienced that way" (BARRETT 2017:118-119). Noise music aesthetics is approached in VANHANEN 2018.

The causal strategy also in noisy repertoire has been embraced by the Lachenmannian repertoire [49], while the associative, semantic and structural strategies and the mimetic aspect are present at varying ratios in common-practice music. The (Schaefferian) reduced listening relies on "repeated listening of a sound in order to focus on its intrinsic qualities, disconnected from its

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47 On reduced listening see KOCHER 2013, TUURI et al. 2007, and THOMAS 1999. This listening is also used for nonmusical sounds, see FREYMANN 1993 or KREBS 2014.
48 On human affects from timbre, see EEROLA et al. 2012. Much of THORESEN's (2015) analytical system also builds on a treatment of listening strategies in the early chapters.
49 Lachenmann characterises *musique concrète instrumentale* by the "aspect of observing an acoustic event from the perspective of 'What happened?'" (STEENHUISEN 2004:10). On Lachenmannian discourse see HEATHCOTE 2003 and McCARTHY 2018. For the original, electronic *musique concrète* see Bertrand 2017; USKE 1992; and DELIÈGE (2003:149-151).

source" (TAN 2019: 278) and more detached from notation than conventional analysis.

When noisy acoustic sounds are used without focus on instrumental aetiology, one can speak of a "post-acousmatic practice" (ADKINS et al. 2016). Acousmatic listening is akin to reductive listening in that 'acousmatics' "is pure sound without a discernible origin and whose key characteristic is timbre" (VAN ELFEREN 2021:58). Yet acousmatic listening is only one **meaning-bringing strategy** among many (ATKINSON 2007; MARTY 2017; FORT 1991), and listeners choose their listening modes (or strategies) according to their interpretation of the type of music and their listening skills. Music listening regardless of instrumental source "exploits the grouping, streaming, and aggregating principles of ordinary" as well as "an intentionality of its own" (SCRUTON 2009:66) [50]. The reductive spectral hearing of sounds differs from to a **holistic** approach, strategies that combine the other strategies [51]. No listening strategies can be considered fully unsuitable to Froise listening.

Blending

Blending, also called **aggregation** and **timbral fusion,** is a central perceptual feature for the study of Froise, since the pitched and noisy component must be heard as one entity. In listening, **aggregates** are made of simultaneously sounding sounds that are perceived as an inseparable unit (PIRRÒ 2018:142) [52]. Aggregates address timbral coherence particularly well (UTZ 2016:553, UTZ 2016:624). BREGMAN (et al. 1990a and 1990b) is the classical source on auditory (timbral and pitched) fusion [53]. However, since this state "when different structures in perception merge into a single timbre" (ROSSETTI 2017:262) needs to be actively maintained, we will call this phenomenon **blending**. Its opposite, sound separation in the brain (see CARLYON 2004), may be consciously controlled to some extent.

Aggregative perception is not self-evident, sometimes since the listener has focused on the processes by individual instruments (MCADAMS & GIORDANO 2009:78). Lachenmannian practice is known for its intentionally disparate

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[50] See the related concept of performative listening in UTZ 2014. Furthermore, human individuals differ as to their "cognitive spare capacity" and effort which influences listening results (RUDNER 2016), perceptual focus (SCHNEIDER & WENGENROTH 2009) which has possible genetic origins due to different types of musicality (OIKKONEN 2016a and 2016b and JÄRVELÄ 2018).

[51] See SCHNEIDER & WENGENROTH 2009 and KRUKOWSKI 2019. On acousmatic music, see also TSCHINKEL 2008; VON BLUMRÖDER 2018; DELIÈGE 2003:421-441, on Schaeffer see KANE 2014.

[52] "Babbitt systematized" Schoenberg's (pitch) aggregates (LOCANTO 2019:xxix), and timbral aggregates can be a repeating central feature of a composition, such as a "*Geräusch-Rahmen*" noise sonority (ENDER 2019:163).

[53] See also "synthetic hearing" (SCHMICKING 2003:312), "sonic permeability" (ELIA 2017:200), or aggregative perception. Smalley replaces the term "fusion" by "integration-disintegration continuum" (SMALLEY 1994:42), since the phenomenon is more complex than initially may seem.

timbres and strongly associative sounds [54] that do not aim at blending (seen in one of our analyses in chapter 4). The products of unsuccessful aggregation may be called composites or chimaeras yet not compounds: "A compound is an aggregate state of multiple elements. [...] The elements that form the compound cannot be taken apart or separated from the others without destroying the compound itself or without generating a new compound. The elements in the compound are defined by and exist only in the interaction with the other elements. A transposition is a compound." (PIRRÒ 2018:142) [55].

Traditional orchestration and instrumentation have sought blend to achieve a "single timbral image" (SANDELL 1995), which requires fusion of both pitched aspects (LOY 2011b:174-175) and timbral aspects of the sounds involved. The timbral aspects in blend mostly concern the spectral centroids and similarity of the attacks (MCADAMS & GIORDANO 2009:77). Successful aggregation selects some attended features, especially the simultaneous ones, and discards others (see FRIES 2015), and thus might be biassed toward a beneficial synchronicity of events in addition to what the sounds are [56]. Blend often concerns vertical integration, with simultaneously occurring sounds, although its alternation with temporal or "horizontal integration and/or segregation" (HIRST 2004) is required by structural listening strategies. Indeed, at longer and multiple time frames, the blend phenomenon is witnessed in **auditory scene segregation or analysis** (see CHAKRABARTY & ELHILALI 2019), in which "decisions are made as to which parts of an auditory event integrate into one percept" (BEERENDS 2001:24, citing BREGMAN 1990).

McADAMS & GIORDANO (2009:77) expand from SANDELL's findings (1995) by writing about **three degrees of timbral blending**: "timbral heterogeneity" maintains the instruments "perceptually distinct" (also ROSSETTI 2017:276), while in "timbral augmentation" "one instrument embellishes another one that perceptually dominates the combination", and in "timbral emergence" [57] "a new sound results that is identified as none of its constituents". We consider the latter two cases by blending, and the two latter stages form a continuum of blend. Since added blend means less identifiability and our future list of individual instruments' timbral values will require knowledge of a sound's aetiology, the

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[54] These expressive aspects for Lachenmann are the tonal-aesthetic apparatus, the acoustic-physical experience and typology which is also closest to our study, organisation and disorganisation, and the aura of associations and memories (LACHENMANN 1995:98)

[55] Early Greek philosophers (see DEXIPPUS 1990) grappled with the distinction between aggregates (*sunkrima)* and composites (*sunthetos*). "Our auditory system has the ability to listen to complex sounds in different modes. When we listen *analytically*, we hear the different partials separately; when we listen *synthetically* or holistically, we focus on the whole sound and pay little attention to the partial sounds." (ROSSING et al. 2002:142), yet such aggregative perception is not entirely voluntary and faces problems (McADAMS & GIORDANO 2009:78).

[56] For the two kinds of perceptual processes behind this, see CIOCCA (2008) according to whom "different amounts of a given cue (say, frequency separation or onset asynchrony) produce varying amounts of segregation or fusion. [...] research on the perceptual grouping of complex sounds suggests that general-purpose and schema-based processes are likely to be active at the same time." (CIOCCA 2008:164, reference omitted)

[57] See ROSSETTI & MANZOLLI 2018.

strongest types of blend are inaccessible to our method, compound timbres in which original features of the component sounds are almost discarded. We present **three reasons for perceptual blending**, some of which might also contribute more greatly to the strength of blending (see Fig. 2.1.1.-1), slightly influenced by SANDELL 1995.

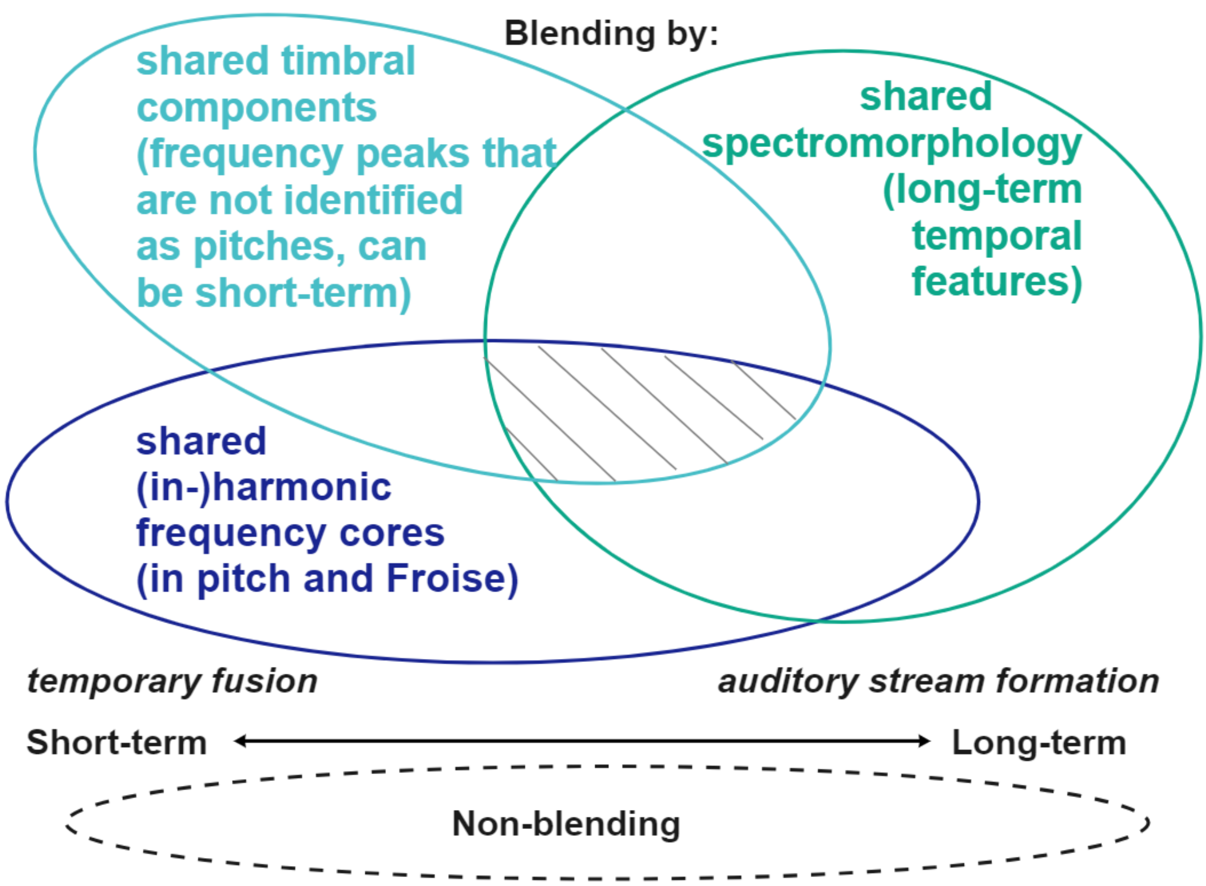

Fig. 2.1.1.-1. Our view of the three common reasons for perceptual blending (or fusion): shared spectromorphology, shared (high) timbral components, and shared (low) pitched components. Classification addressing their spectrotemporal basis, time used for perceiving, overlaps, and affinity to auditory streams. Each of the three perceptual reasons may rely on a different listening strategy.

In "timbral heterogeneity", the least degree of blend, probably none of our three reasons for blending would be present, while higher degrees of blend would have increasing amounts of at least one of the three features. The literature separately addresses spectromorphological listening (which allows our spectromorphological blend [58]) while the two other reasons of blend concentrate on steady frequencies – either frequencies in the nameable pitch range or as part of harmonic or inharmonic constructs. Blending is eventually determined by individual listening and possibly by different listening focuses. Blending is

[58] The spectromorphological reasons for (non-)blending are the most numerous, yet not necessarily the most determinant, and include jitter and permeability (see ROSSETTI 2017:274ff.), and texture-derived timbre (or *Bewegungsfarbe* as known from G.M.König and G.Ligeti, see VITALE 2016).

enabled emergently, by each reason of blending separately and in combinations, which can be compositionally operated with.

As one predecessor to our analytical method, one of our approaches was to **numerically study blend in the pitch realm** where blend is a more studied concept than in noise. The timbre emerges from clearly pitched intervals and chords [59] as well as from their **overtone interference structures** [60].

While noise can in many cases be considered a state of not blending, Froise has features of blending and independence, and is in some cases an accumulative effect [61] and "a single auditory object" (ZENDEL & ALAIN 2009:1489). Yet in other cases blending comes from a shared linear contour of several components that maintain an interval, while noisiness spells a lack of such connections. **Many Froise sounds balance between being divided and fused** – particularly in the case of many multiphonic sounds [62]. In those multiphonics that include audible friction or brokenness, blend is achieved by pitch-based interference (or lack thereof) as well as non-pitched timbral features, all the while at least two states of the sound can be discerned. This is what JOST (2004:51–74) addresses under "Wechselwirkungen zwischen simultanen Klängen".

The rest of the psychoacoustic terminology will be engaged only where strictly necessary (in chapter 5 in most cases), again for the reason of false axioms.

2.1.2. Froise in the taxonomical mind (Basket 7)

"All classification, whether artificial or natural, is the arrangement of objects according to ideas." (PEIRCE 1998 [1902]:128)

Chapter 1 laid out with everyday examples that the general categorising capabilities that listeners use are not absent in Froise listening. On the wider level, classification creates taxonomy. Much of the taxonomic capability determines harmony, a central feature of tonal music. Differences between harmonies, whichever type of harmonies is chosen by a composer, are in a typical piece small and yet used to perceive its structuration (TYMOCZKO 2011).

The taxonomy literature directly applicable to Froise will be considered in subchapter 2.3. General taxonomy literature does not have similar disadvantageous axioms for Froise as psychoacoustics has since taxonomy literature is rarely applied to music analysis at all. We can generalise much from taxonomists, however non-existent their connections to music may be.

Here we study the two extreme aspects of Froise sound at which it may be classified: the point of its emergence as physical measurable sound, and the

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[59] See for instance MRKVIČKA 2008.

[60] This developed into a computer program to make spectral information more conveniently accessible and pitch-based blending a more graspable phenomenon. The software was presented in VESIKKALA (2019).

[61] See FLEMING 2014:46.

[62] We should point to JOST's (2004:28ff.) comparison of the concepts of "Spaltklang" and "Schmelzklang", which seem to lack an English equivalent.

point in the auditory cognition at which it has been perceived and will undergo classification and value judgements. Both points observe taxonomy and will contribute to the timbral taxonomy in our analytical method. More generally, this is literature for classifying and comparing data. In building a taxonomy of timbres, we cannot rely on previous musical taxonomies which are based on much simpler phenomena.

Precise observations and comparisons enable groupings, also known as taxonomies and typologies. Almost all taxonomies will be flawed precisely because the starting point or preference can hardly be counteracted. In our case, taxonomy relies on humanly perceived features of acoustic timbres and is a personal matter of precision (SOLOMOS 2020), reduction, and deconstructive ability (WALTHAM-SMITH 2021).

Our analytical method will **apply taxonomy literature to music**. Any study of the factors influencing a phenomenon is the starting point for its taxonomy [63].

To proceed with large amounts of information, taxonomies are unavoidable: "Categorization eliminates much of the richness of the raw data extracted from the source, but it is essential if the data are to be processed statistically" (LEMERCIER 2019:62). The older, conventional well-established taxonomies in music have concentrated on pitch [64]. Our approach is the opposite, yet with ways to later re-incorporate exact pitch information if the theorist so wishes. Among the traditional taxonomies known to music is the classification of instruments, organology, which combines "both scientific and cultural perspectives" (DAWE 2003:276; see also HERRERA-BOYER et al. 2003), and more generally, taxonomies of vibrating systems (LOY 2011b:251 ff.). Likewise, categorisation of motivic patterns (LARTILLOT 2009) has been meaningful for understanding form in common-practice music. Taxonomies can be made from audio information, for instance to recognise instruments and to help segmentation (REYMORE & HURON 2018 and 2020; ESSID et al. 2006; for advanced playing modes see LOSTANLEN et al. 2018). Our first focus before analysis is **timbral taxonomy**, and an early statement for the importance of technical analysis of timbre is found in GREY (1977). From this point on, timbral taxonomy strongly divides into two branches of literature, mainly to those who do and those who do not work closely with music performance. Taxonomy is inevitably limited by how observations are made, and timbral analysis has relied particularly on verbalisation (by large listener groups) and on computer analysis of audio. For perceptual taxonomies of (nonspectral) complex sounds, see CIOCCA 2008. Verbalisation of timbral perceptions have been studied (DARKE 2005; FRITZ et al. 2012; in sound generation KREKOVIĆ et al. 2016; for a semantic scale for chord perceptions see KUUSI 2011) and the perceptually valid timbral attributes considered (TERASAWA 2009).

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[63] Taxonomies have been introduced in music with music genres classification (LI & OGIHARA 2005), the subjective factors that affect the evaluation of sung music (HIMONIDES 2009) and expression in music (ASMUS 2009) and have consequently expanded to sort timbral information.
[64] Musical scales, functionalities, chord inversions, and so on, belong to taxonomies.

As mentioned under basket 2, timbre spaces are the taxonomies closest to our thesis. This literature, also called **differential timbre studies**, is given in basket 2 and in chapter 2.4.

Of our two main role models in timbral taxonomy, PEETERS (2014, 2011, and 2010) has worked numerically with computer analysis to extract timbral and morphological descriptors from sound, whereas THORESEN (2009 and 2015) developed a listening-based analysis of sound objects, with analytical verbalisations and shorthand notations for the sound phenomena described.

REID (2013) theorises the locations of instrumental sounds in timbral space, using selected timbral descriptors. Regardless of the lack of a standard conception of timbral space, timbral transformations (see SIEGEL 2014) and visualising of distances in timbral space have been discussed (see MÖRCHEN et al. 2005).

Studying the typology of musical motives, Olivier LARTILLOT (2009:25–26) notes that both "well-defined" and "ill-defined" categorisations exist although "well-defined" or classical, Aristotelian categorisations are easier to control. Lartillot uses a "taxonomy of subcategories forming a multi-levelled hierarchy" (LARTILLOT 2009:25) when classifying motive patterns in music and navigating between the classical view and the ill-defined models that the more complex situations and "adaptive matching in a multi-parametric space" (LARTILLOT 2009:30) would require[65]. Such ill-defined concepts can be differentiated from each other by laying out either "concrete instances" or a "prototype" (LARTILLOT 2009:26). **Our timbral taxonomy will consist of a set of prototypal questions, whereas the timbral strategies will be identified by concrete exemplary works.**

Descriptors [66] are what in our method quantify and describe what is being considered or modified about a sound. This term, as used by some writers on timbre, is the closest to our understanding of and goals with timbral analysis. **Criteria** are the individual states of those descriptors that can be either fulfilled or not. **Descriptor spaces** are often represented using two or three dimensions that are chosen to best represent the sound phenomenon and its typology. Even descriptor spaces cannot quite represent the connections between categories, since they have at least two dimensions: thickness, covering "many aspects of someone's [or an object's] identity", and scale, from local up to globality

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[65] Multi-parametric spaces and processes in general are an actively published field in computerised machine learning.

[66] The general literature may use the terms parameter, aspect, feature, attribute, and descriptor interchangeably. Attributes point closer to the verbal realm and to an upper level that does not operate with numbers. One established meaning of the term parameter would require an algorithm to be fixed and known; it is a "value input to an algorithm that is used in calculating the output. In computer music, a parameter in the score controls an attribute of the sound produced by a computer instrument." (DODGE 1997:435). Yet in most acoustic sounds, features depend on each other and cannot be steered separately without affecting other features. When changing parameters in computing, we might not be able to hear the change in the timbre, and there would not be a real equivalent sound outside sound synthesis.

(BOWKER & STAR 2002:315-316); one descriptor space of up to three dimensions typically makes only one strong categorisation at a holistic level. Other categorisations will use different descriptor spaces.

2.2. The acoustic basis of Froise, current literature summary

Timbre studies, music analysis, categorical perception and psychoacoustics relate differently to the question of Froise in its separate aspects of intermediariness, spectrotemporal nature and inclusion as a musical substance. Although this literature is lacking, this literature will be divided into baskets in chapter 2.3.1., and we can outline three stances in each of them.

Field of study	Concerns about being an intermediary category	Concerns about spectrotemporality	Concerns about being a musical substance
Timbre studies (basket 2 below)	Needs to establish Froise as an intermediary category and for that needs to loosen the rigidity of (numerically measured) boundary values.	Needs to expand to spectrotemporality. This far, mostly short slices of time have been studied in comparable detail.	Classification is conventional in timbre studies; Froise would constitute a third main category of sound and help orient all classified sounds
Music analysis (baskets 4 and 5 below)	present analytical methods would not accommodate Froise since even their accommodation of timbre is minimal. Intermediary categories are known to chordal analysis in modulation.	Is aimed at temporal progress of sounds yet needs to better address the spectral aspect of spectrotemporality.	Needs to adjust to noise as analysable material. Analysis might accommodate noises and Froises as musical substance, especially if Froise and timbre in general is shown to follow a hierarchy

Categorical perception and psychoacoustics (baskets 6 and 7 above)	Categorical perception needs to consider Froise as an intermediary category, as one level below the main categories pitch and noise. The phenomenon has not been studied in psychoacoustics.	Perception already considers spectrotemporality.	Has readily considered timbre yet needs to abandon old axioms; needs to establish noises and Froises as timbral and musical substance and research what is perceptually particular to it.

Pitch studies and noise studies within no specific field (found in several baskets below) do not address Froise, to our knowledge, while starting from the 1960's, some psychoacoustics studies have addressed concepts resembling Froise.

2.2.1. Literature on pitch, noise, timbre, spectrotemporality, and spectral analysis (Basket 2)

Our largest basket is made of five topics: **pitch, noise, timbre, spectrotemporality,** and **spectral analysis.** In each case, both the social and technical aspects are covered. We devote here due attention to topics fundamental to **noise and/or timbral composition** and analysis. Noise music in its non-sociological aspects cannot be understood without an understanding of the musical functionality of pitch that noise replaces and Froise extends, nor without timbre which becomes the main channel of listening to noisy sounds. Spectral analysis is shown as the common approach to questions of timbre locally, and spectrotemporality on the timescale of entire pieces. Readers who are already versed with the listed five topics will do well by proceeding to chapter 2.2.2.

Pitch literature

Far too many aspects of pitch perception are unknown, and in our case it would be subjected to the perception of Froise. Pitch still lacks an official definition and the phenomenon is still not entirely known (YEARY 2011:74), in addition to our basic definition from chapter 1.

Lyytikäinen defines pitch as "a sound with one perceivable pitch height level and that does not include an emphasised element of noise"; an "absolute pitchedness" is found in "the extremely soft sine tone in a reverbless space". (LYYTIKÄINEN 2009:89–90, our translation)

For Godøy, definite pitch is "more or less stationary throughout the sonic object" and complex pitch an "inharmonic or various noise band sound" which resembles a loose definition of a Froise sound, while "variable pitch" is "pitch changing in the course of the sonic object, for example by glissando" (GODØY 2017:16); these address inharmonicity, noise bands, and grades of stationarity found in the repertoire. YEARY (2011:89) uses the preferable term "harmonic complex tone" to discuss complex pitch content instead of noise, although this description may include multiphonic sounds.

Even when pitch is taken to not have any timbral features, musical pitch is acoustically carried by frequency, a continuum that has much more gradation than has been conventionally used in naming pitches. We speak of **pitch space** and "continuous frequency space" (KLINGBEIL 2009) synonymously. While the term register relative to an instrument's available range affects perception, pitch space consists of the whole audible range. Regardless of how we build our instruments, have historically notated music, tend to listen categorically, or conceptualise pitch Westernly on a visual low-to-high scale (ASHLEY 2004; TIMMERS & LI 2016; BROWER 2008), no inbuilt steps phenomenally exist in pitch space. A moving pitch that makes use of this fluidity of pitch space yet inhabits only one frequency at a time, is a **fluid pitch**.

Pitch space will be expanded to the more recent notion of spectral space (on this distinction, see KHOSRAVI 2012). Spectral aspects of pitch must be included and the common reliance on a pitch being equal to the fundamental (BRIXEN 2011:20) disbanded. The present widened understanding of pitch audition and options for the use of pitch within various stages of the compositional process has spurred the apt characterisation of a "post-pitch" or "post-tone" practice[67]. Much of this recent development has been led by advances in microtonality and microintervallic studies (see STIEBLER 2003:213ff.).

Pitch is often the last remnant that retains a linearity in an otherwise noise-based composers' practice. However, the entity of pitches can also be organised by independent use of pitch space as in **polysystemic composition**, a way of combining different tuning systems and pitch systems (see theorisation in ELIA 2017; examples in KLINKENBERG 2020).

Noise literature

The **noise** definitions and statements given in the basic definition in chapter 1 and in the literature below reflect a range of views that are mostly irreconcilable: our approach to noise as **musical material and the target of attentive listening** as well as the somewhat useful **technical measurement** approach, versus the for us less useful **sociological** approach. The latter two are the reigning written approaches to noise and their incorporation will be difficult to avoid.

[67] For this term, see MAJD 2019 and NOBLE & McADAMS 2020.

This distinction has many names, for instance Wallmark's *a-noise* (purely acoustic and measurable) and *p-noise* (auditory perception) (WALLMARK 2014).

Our method will need to apply some perspectives of **measurable noise** as well as listeners' judgments about noise, while steering clear of the societal conventions around noisy sounds.

Sociological viewpoints on noise are divided into *noise sounds* and *acceptable sounds* by any chosen group of listeners, which seldom connects to the artistic intentionality of noises (TREMBLAY 2013:77) as used in composition and improvisation. Although writers such as Sangild (2004) consider this as the **subjective** meanings of noise, such subjectivity is worth maintaining only when one is able to converse with a wider society that listens to and judges these sounds too. The social meanings of noises and the location of the **border between noise and (musically or contextually) acceptable sound** vary with culture, place, time, and life experience. Such preferentiality and familiarity also exists in music and thus the current meanings of (sociological) noises might have value in certain approaches of composing. A sociological strategy of listening to the current music repertoire will yield limited results and thus are omitted here. Likewise, we will forgo physical reactions to hearing noise.[68]

Noise is, in addition to the grounds already listed, often viewed as a nuisance (WITTJE 2016:207), chaotic or turbulent (KLETT & GERBER 2014; KAHN 2001:20), "extreme densities and complexities" (SUDO 2020), multiplicity (BYRNE 2017), extremely redundant (ABLINGER 2013), "the other" (TCHUMKAM 2019:192), unfamiliar and offensive (KLETT & GERBER 2014), disruptive, confusing, inconsistent and injurious (KAHN 2001:20), unhealthy EGGERMONT (2014), "as a sound other than music or speech" (WITTJE 2016:207), success through failure (HEGARTY 2001; ZAKIEWICZ 2020), unfair modification or hacking (EVANS 2016, JURKONYTĖ 2016), a rough manner of communication (CSÁKAYOVÁ 2012), the disturbances that a communication signal faces (SANGILD 2004), and as a welcome break to "instrumentality" and a "rejection of virtuosity" (KLETT & GERBER 2014). The general association is sounds that are to be attenuated or socially avoided. Many of these characterisations arise from politics – on the politics of noise see ATTALI 1985, TOTH 2009, and HALL 2016, and the role of noise in new materialism (PEETERS 2021) and a posthumanist aesthetic (FILIPOVIĆ 2013) – while some have merely sociological aspects. On the social history of noise see MIESZKOWSKI 2017, HONGLER et al. 2014, KAHN 1999, GINKEL 2017, FRIEDMAN 2013, KRAPP 2011, and KENNEDY 2018. Among the neutral associations, noise has been considered simply a signifier (BJØRNSTEN 2012). The signifier may however not carry any generally agreed signification: "interaction, not discourse, characterizes the central performance that constructs the meaning of Noise" (KLETT & GERBER 2014). "Even "awesome" music can be considered noise" (BRIXEN 2011:212), due to

[68] On the social meanings of noise, see further GINKEL 2017; CASSIDY & EINBOND 2013; RENAUD 2013; KOSKO 2006; KENNEDY 2018; BORSCHE 2014, THOMPSON 2017, MIESZKOWSKI 2017, NECHVATAL 2011; DENNING 2015; GOLDSMITH 2012; HENDY 2013; STRAUS 2007.

the social polarisation of the phenomenon. The English language fares badly at distinguishing these approaches whereas German distinguishes the connotations using *Lärm*, *Geräusch*, and *Rauschen* (BOLCSÓ 2006:4 and WITTJE 2016:17), all of which are standard translations of the English term noise [69]. It will be crucial that we consider noise not as an independent discourse seemingly without any connotations (because this would unfortunately return to the sociological discourse), but instead think of **noise as a timbral discourse**, which shows its connections to the musical tendencies during the last hundred years.

Technical viewpoints have measured noise for as long as the measurement devices have been available. Technical approaches to noise are paradoxically taken up by both those with sociological motivations (for attenuating unwanted noise) and those with a music or sound engineering background. Noise is technically "the antipode of a defined signal" (WITTJE 2016:207). Most signals cannot be neatly defined, and a noiseless world would be a paradox.

The phenomenon of noise is not restricted to the sonic arts [70]. Noise as a practice in all the concerned arts can mean going for the **fragile** (MATTIN 2009). Fragility in sounds may be intentional in some repertoire (see BELGIOJOSO 2014) and makes it be perceived as more noisy, due to being less predictable. Indeed, the psychology of noise sounds relies on **uncertainty** inflicted on the passive listener (VERHAGEN 2015:78–80), and here noise music practice may share the most with tonal practice, in which not each event and change is equally anticipated and thus part of tonal-functional form emerges from a structuring of expectation and uncertainty effects. SAARIAHO (1987) finds analogies between the concepts of noisiness and **dissonance**, yet this may have only been an early necessary tactic to make noisiness palatable to the wider theorist public of the 1980's. If noisiness takes many of the roles that dissonance has had earlier, the emancipation of noise would be able to profit from the analogy to the emancipation of dissonance. Apart from both dissonance and noisiness being relatively estimated within a musical context, these phenomena have little in common. Dissonance is a straightforwardly measurable phenomenon from dissonance curves [71], and is only moderately affected by individual audition and historical usage (TENNEY 1988), while measurements of noisiness nor which

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69 *Rauschen* is the most neutral and music-oriented, *Geräusch* conveys randomness and multiplicity, while Lärm portrays most of the sociological associations by an individual that are irrelative to volume, source, and qualities (SCHMICKING 2003: 316).
70 On the positioning of noise music in the arts, see STUEN (2017), and depictions of and literary use of noise in fiction see EPSTEIN (2014). One early predecessor for noise is found in Italy, already before the futurists, in *inquietùdine* literature with its focus on creating an uncomfortable and laborious state that is however gladly consumed by the perceiver: "Mit Spannung ist im Folgenden ein durch spezifisch literarische Verfahren induzierter kognitiv-emotioneller Komplex gemeint, der sich beim Rezipienten in Unruhe manifestiert. [...] Das kalkulierte Spiel mit der Ungeduld und den Ängsten des Lesers wird als typisches Kennzeichen einer Form von Literatur betrachtet, die nicht auf Erkenntnis, sondern auf Emotionalisierung abzielt, auf die schnelle Befriedigung der Gier nach Neuem." (ACKERMANN 2010:52–53).
71 see a psychoacoustic account on this in LACH LAU 2012:98.

factors should be measured, have not been agreed upon [72].

For musical practitioners of noise however, the discourse branches further – into **noise vs. music** (HEGARTY 2006, ARNÁEZ 2017, CASTANET 2008, CAMPESATO 2011, BRIEBA 2005)**, noise vs. sound, noise vs. timbre**, **noise vs. meaning** (HEGARTY 2006), and **noise vs. composition** (NONNENMANN 2021).

Numerous sources on **noise composition** cover its historical beginnings from some or all the sociological, technological, and aesthetic perspectives. Noises often result directly from an instrument's construction: "The noise that is attached as a part of the characteristic sound is common for almost all musical instruments. Examples of this are the sound of the air leakage on the mouthpiece, the sound of resin on the bowed string, and the sound of different instruments' moving mechanical parts." (BRIXEN 2011:28), and sometimes *ordinario* sounds are found topologically nearby, and can be physically easily accessed and build a visual connection in performance. Music also uses those noise sounds that are socially undesired [73] and of the glitch or error [74].

After the emancipation of noise [75] we are still in need of an "organisation of noise" which is still underway, especially since there is a widespread disconnect with many potential audiences that prevents an appreciation of noise repertoire. Noises have become, since their emancipation by the futurists at the latest, a common feature in certain stylistic branches of current acoustic music and almost indispensable in electronic music. Once noises are understood as musical material and also as members that constitute a category of noisy sounds in which some sounds are more noisy than others and in which noisiness can be achieved by several distinct features, we can speak of a **noise continuum as part of the timbral continuum**. K.Stockhausen's *Gesang der Jünglinge* was a crucial work for the noise continuum due to its various (at the time technical) sound types (BOLCSÓ 2006:19–20). This development took place with fixed (tape) media, and such rigorous timbral organisation only later moved to acoustic instruments. A prerequisite for this was to make the nature and context of individual noise timbres clear; each sound had to be defined as clearly as possible, and preferably standardised in notation, so that different timbres could be performed and perceived each time similarly. The spectral way of thinking which was able to balance between the associations from timbre and the added technical accuracy in modifying sound have since incited an extreme approach toward slicing sounds, "to look at each constituent part of the sound as being individual elements that, taken out of context, become more like glitches—they abandon their capacity to describe." (FLEMING 2014:46). Johannes Kreidler

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[72] For the history of the dissonance concept, see GURD 2016, for the emancipation of dissonance see WANDERER 1982, and the psychoacoustic explanation of dissonance also in the microintervallic (and xenharmonic) context see SETHARES 2005.
[73] See VAN ENIS 2014, MIESZKOWSKI 2017, GINKEL 2017.
[74] See BROMBOSZCZ 2010; MWAMBA 2020; PRIEST 2013; KRAPP 2011; KANE 2020.
[75] The intentional use of noise in composition has been covered in FUHRMANN (1966) who considered the emancipation of noise to have been a finished project ("vollzogen") already by then, and considered its main lasting efforts to be found in Edgar Varèse's oeuvre (FUHRMANN 1966:19).

describes such underlying and enabling aesthetics as *Klangfetischismus* (HIEKEL & MENDE 2018:24)[76] . If Kreidler intended this as a critique, it has to do especially with the ever-growing accuracy asked by composers in the production and notation of noisy sounds and the dwindling possibility of anymore discovering novel timbres.

Timbre literature

The more composers have become aware of timbre as an independent part of their toolbox, the more it has become an obstacle. Timbral thinking in composition developed first ahead of the proper technical means [77]. Early thinkers commonly made an inexact analogy between timbre and visible colour (KIENSCHERF 1996). Timbre has emotional correlates; many aspects of timbre can steer the emotions that music can raise (WEIHS et al. 2017:511ff.), and as rather a primitive skill, timbral hearing develops already in childhood (SCHELLBERG 1998).

There were developments until the first decades of the 1900s by which timbre was able to emerge from the musical *Satz* as a distinct phenomenon and to rocket itself to the compositional prestige it would enjoy in our times (see MÄKELÄ 2004; SOLOMOS 2020). The conventional division of sound into central (pitch) and peripheral (intensity, "colour") categories became more porous already from the 1800's onwards and subject to re-evaluations (JESSULAT et al. 2017:93). In tendencies towards what we could now call timbralisation already in late tonal repertoire, individual particularly dissonant chords (such as those labelled *Tristan, Eulenspiegel, Wanderer, and Mystical)* started to be considered outside their local context and even respective musical compositions (EICHHORN 1990:287; similarly CORNICELLO 2016 and SOLOMOS 2020.). This slow timbral revolution started with the addition of instruments to the standard orchestral setups, continuing with the indepence given to percussion instruments (DEVENISH 2015; SCHMUHL 2010) by composers such as E.Varése.

Much timbral study took place at the turn of the 1980s and 1990s [78]. Since then, research settings favouring Froise have not improved considerably nor have data sets become available. Thus this corpus merely answers our need for a timbre analysis method.

NIKOLSKY et al. (2020) sees "timbre-based music as a special system of musicking, communication, and psychological and social usage, which along with its corresponding beliefs constitutes a viable alternative to "frequency-based" music." People have timbral preferences as listeners and as active performers (DOBROWOHL et al. 2019), and these may also direct at non-instrumental,

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[76] Kreidler witnesses "eine interessante, superlativistische Endphase: Die Entdeckung, Erfindung, Übernahme und Enteignung von Klängen geht weiter, bis zur völligen Bemächtigung alles Klingenden." (KREIDLER 2009). On timbral fixations see also HOSOKAWA & MATSUOKA 2008 and STERNE 2019.

[77] For the 20th-century development of timbral thinking in composition, see SOLOMOS 2020.

[78] The history of timbral studies is extensively covered in many texts, see for instance MUZZULINI 2004, OPLIŠTILOVÁ 2007, REUTER & SIDDIQ 2017, REHDING 2018.

complex, or noisy sounds.

The numeric aspect to timbres was previously limited to amounts of instruments in orchestration, or doublings by organ stop partials (LOUGHRIDGE 2021), while verbalisation remained the more common approach. With the availability of electronics, much of what was metaphorical in timbres became rather concrete (BARRIÈRE 1991); after the first spectral visualisations of an instrument sound (see MOORER 1977; also including elementary descriptions in COGAN 1984), timbre was studied in electronic sounds, which allowed for easier modification. This finalised the division between the "Relational measures of timbre research", made of "two popular paradigms: **dissimilarity rating** and **verbal description**." (ZACHARAKIS et al. 2015:394, our formatting). Dissimilarity measurements lead to various degrees of **numerisation** of timbre, and this is the term we will use for this branch of studies. Even Schaeffer's (1966) proposed relating of "perceptually pertinent timbral features to gestural metaphors" as worded by HALMRAST et al. (2010: 193–194) or phenomenologies of timbre (DE CEUSTER 2016) may align more with verbalisation than constitute a veritable third (possibly bodily) way of conceptualising timbre.

Studies on the perception of spectral timbres (SCHNEIDER & WENGENROTH 2009; TOIVIAINEN 1996; TOIVIAINEN 1998) can serve spectral composition techniques. Systematicity in the modifications dictated that timbres also be categorised also for other features than the harmonics. Timbre typologies started to emerge after SCHAEFFER (1966) and were enabled by visualisations and other studies on specific timbres (see percussive timbre in BRENT 2010, impulse noise in JAROSZEWSKI & JAROSZEWSKA 2000, growl timbre in TSAI et al. 2010, chilling timbres in HALPERN et al. 1986, or distortion, roughness, and granularity in GENTILUCCI et al. (2018).

When temporal definition increased, distinctions between stationary and constantly transforming timbres (for instance in SCHMIDHOFER & JENA 2011) could be technically made, which gave rise to Denis Smalley's spectromorphology, a rough categorisation of changes in timbre through time.

Timbre in its present wide scope cannot be explained fully by one viewpoint (instruments and organology, signal processing, acoustics, psychoacoustic cognition, semantics, notation). Any comparisons of sounds for musical and technical purposes can be made when a timbre space is formed. Afterall, timbre has multiple dimensions which must be considered (WEIHS et al. 2017:146; HALMRAST et al. 2010: 193). Timbre spaces rely on the finding that some pairs of timbres are judged to be perceptually closer to each other than other pairs. This recognition of dissimilarities in a multi-feature phenomenon such as timbre however leads to the creation of several different timbral spaces, the auditory basis of each of which must be proven separately. Any differences that timbres have in audition are also the features that most successful timbral composers use, even if they cannot rely on any scientific knowledge when composing and if the specific feature cannot be labelled. Timbre space thus has no equivalent in notation nor quite in FFT visualisations. "Timbre space provides a model for relations among timbres. A *timbre space* is derived from dissimilarity ratings on all pairs of a set of sounds (usually equalized for pitch, duration, and loudness) to which a multidimensional scaling algorithm is applied to model the dissimilarities as distances in a Euclidean space [...] The dimensions are presumed to be perceptual." (McADAMS 2019:213).

Timbre taxonomy is the classification of timbres based on some distinguishing criteria, which can be chosen according to the analytical or compositional purpose. Timbre taxonomies will be central to our thesis and are introduced and further discussed under basket 7. Timbres can be compared between instruments and even within the timbral range of a single instrument (see DE PAULA et al. 2004 and TERASAWA et al. 2005). Any non-identical timbres are located differently in timbral space. Beside this notion however, no standardised method (verbal-semantic mapping or numeric methods) exists in which a timbral space should be built. Distances in timbral space show differences of timbres yet have rather abstract meaning – and thus the implications of a **timbral interval** are yet unclear. Dissimilarity matrices can be created by **multidimensional scaling** (MDS) which position timbres in timbre space (see PLOMP 1970, GREY 1977, IVERSON & KRUMHANSL 1993, McADAMS et al. 1995, CACLIN et al. 2005), yet even when perceptual dimensions in timbre are located, this method cannot reliably label them (ZACHARAKIS et al. 2015:394). If timbral intervals exist, this "extends the use of the timbre space as a perceptual model beyond the dissimilarity paradigm" (McADAMS & GIORDANO 2015:4 [and 2009:75]).

Timbre spaces can use low-level features of acoustic sounds (see GANGULI et al. 2020) or focus on temporal features of sound (see CREASEY 1998). Timbral data can be inputted to software such as CataRT to create timbre spaces that can be accessed by a computer interface. Electronically controllable timbre spaces can be then steered by anything that they are linked with, for instance by sensors for physical gestures (see ZBYSZYŃSKI et al. 2019). A minority of the timbral space theories, and composers, seem to be enchanted by spectrographs. This is understandable, since for a long time, spectrographs were the most easily available or the only abstraction of timbres: "Textbooks present many "typical" spectra of musical instruments. It should be emphasized, however, that sound spectra from a given instrument vary widely according to the way in which the instrument is played (soft, loud, high, low, or midrange) and how the sound is recorded (near field, far field, reverberant field, direction of microphone from the instrument, etc.)." (ROSSING et al. 2002:138).

In a widely influential text in the literature and a paragon for our study, McADAMS et al. (1995) uses three dimensions for instrument timbre determination: attack time, spectral centroid, and spectral flux. This observes *ordinario* playing and leaves out the effect of register, dynamic, and duration on the perception of timbre. Later McADAMS (2019:212–214) touches on the topics of **memory capacities for timbre** and for **timbral [exact] intervals** or **timbral [approximate] contours**, and mentions the existing research classics from the 1970's onwards. The **size, positioning, and direction of timbral intervals (vectors)** have been tested, and although "even professional composers have had almost no experience with music that systematically uses timbre intervals to build musical structures", the positive experience with such a timbral interval model "was stronger for electroacoustic composers than for nonmusicians, however, suggesting some effect of musical training and experience." (McADAMS 2019:215). McAdams expects "effects of the relative magnitude of a given vector and the distance between to-be-compared vectors: it may be difficult to compare with precision very large vectors or small vectors that are very far apart in the [timbral] space."(McADAMS 2019:216). Timbral vectoriality is also discussed in HÉROLD (2016).

Spectrotemporality literature

Whichever type of sound is concerned, fluctuations in musical sounds are the rule and stable sounds a rarity (WEIHS et al. 2017:36). This is intentional, and "skilled musicians have a rich and nuanced repertoire of timbral expression, acquired through years and years of practice" (HALMRAST et al. 2010: 209) – such **micromodulations** in the smallest sound aspects can be perceived in acoustic sounds (REUTER & OEHLER 2011). The progress of these features of sound is known as **spectrotemporality**, mostly in (psycho-)acoustic literature, and can be calculated and visualised [79] . Spectrotemporal receptive fields (STRF) track continuous changes of data, such as in an auditive field (ELHILALI 2019:346). As a special case of spectrotemporal study, SMALLEY (1986) defines **spectromorphology** for the first time and later refines the scope of spectromorphology for listening-based analysis yet does not apply it as a fully-fledged analytical or compositional tool in SMALLEY (1997) [80]. Spectromorphology is "the interaction between sound spectra (spectro-) and the ways they change and are shaped through time (-morphology)" (SMALLEY 1997:107). This definition however already addresses complex situations of two or more distinguishable sound sources with different spectra; the seeming source of the morphing alterations to a sound can emerge from outside the sound or from within. "Spectro-temporal cues" determine changes in spectrotemporality, which affects how we determine where a Froise timbre starts or ends [81].

Spectral analysis literature

Our method utilises a spectral approach only selectively [82] and rather focuses on those skills of spectral analysis, often acquired from exposure to the FFT

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[79] See CHI et al. 2005; VAN HENGEL & KRIJNDERS 2014; THORET et al. 2016; SADAGOPAN & WANG 2009; KHAN et al. 2016; KLEINSCHMIDT 2003; ABIDIN et al. 2018; BACH et al. 2017; SHAMMA & DUTTA 2019; KLEIN et al. 2003; in clinical phonology see KODRASI & BOURLARD 2020.

[80] This text is a widely known classic in literature and has served as inspiration to numerous composers, improvisers, and theorists. Smalley explicitly renounced the goal of a compositional theory, and instead aimed to give "words to diagnose and describe" (SMALLEY 1997:107). Paradoxically, neither Smalley nor anyone else has incorporated this spectromorphological terminology systematically to music analysis during the over 35 years that this term has existed. For a similar spectromorphological approach see COUPRIE 2003 and RICARD & HERRERA 2004.

[81] this literature is given in SIEDENBURG et al. (2016:32–33).

[82] The spectral approach to noisy sounds (FELIX 1988) might be among a few feasible approaches.

method[83], that are less pitch-based. We afterall aim to work without computer assistance and visualisation. We work past spectrograms which are a typical visualisation "pattern for sound analysis that provides a three-dimensional display plotting time on the horizontal axis, frequency on the vertical axis, and intensity on a color or gray scale" (WOLFE et al. 2009:283). Most of our findings remain spectral in that an attentive listener would be readily able to confirm them with the reference to an FFT analysis. Spectral analysis also differs in its application to time; either no morphology is observed (by selecting very short slices of time, under 1 second), morphology is observed, or morphology with auditory streams and voice-leading are observed (slices of several seconds). Short-time spectral analysis (see WEIHS et al. 2017:129ff.) is best suited to assigning identity to sounds, before they morph into other sounds.

We deal with sound-based repertoire, not repertoire of **spectralism** (the recognisable movement in composition by spectral methods that developed in the 1970's [84]) although the use of spectral methods is shared. Spectralism has very specific compositional applications (CHAHIN 2017), many of which were spearheaded by G.Grisey (TOPOLSKI 2012; HASELBÖCK 2013) [85]. It was with the spectral repertoire that visualisations of music and timbre became commonplace (TAKAKURA et al. 2018).

2.2.2. Froise literature proper (Basket 1)

The two main sources on Froise were written before 2018, both in the Finnish language. LYYTIKÄINEN (2009) mentioned a plan to study functions of noise in three works (by Lachenmann, Meriläinen, and Saariaho) yet eventually no music is analysed in this preliminary text. Lyytikäinen (2009:90) is interested in studying the grade of noisiness due to the width of the border region of pitch and noise, and mentions Froise in this context. The method was analysis based on scores and recordings. Lyytikäinen arrived at the topic of noise since it is found as a timbral side-effect of large dissonant chords, yet found noise also in wider contexts. Criteria for identifying noisiness in sounds are given (they form the inspiration for our set of descriptors). Lyytikäinen's focus on the noisiness grade is in keeping with many branches of timbre research and with Saariaho's timbral concept (McADAMS & SAARIAHO 1985). This approach however merits further development beyond verbalisation, such as in the form of a numeric analytical system. The article elegantly bypasses the question of the exact location of the

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[83] see LOY 2011b:459-501; WEISSTEIN (n.d./2019); the technical basis of Fourier transform in BRACEWELL 1986.

[84] See TEODORESCU-CIOCANEA 2003.Pitches at at certain intervallic combinations become perceived holistically as a chordal sonority, a timbre constructed on the principles of blending and actively in use at least since Debussy (GUIGUE 2009). THORESEN (2015:316-326) speaks of "chords as sound-objects". Only some spectralist repertoire operates with conventionally understood timbre or incorporates noise. The slightly earlier Poland-originating movement of **sonorism** put less focus on blend by pitch, and rather developed a wider set of methods to timbral questions; for perspectives on sonorism, see JANELIAUSKAS 2014, KOSTRZEWSKA 1994, SEEHABER 2016, and LITERSKA 2012.

[85] For the concepts and history of spectralism, see FINEBERG 2000 and HARVEY 2011.

noise–pitch border region, yet we will deal secondarily with that aspect.

In addition to the definition in the chapter 1, we can say that "a sound that clearly includes both noisy and pitched sound will be called Froise [Finnish: "sole"] (LYYTIKÄINEN 2009:90, our translation).

Although no encyclopaedic entries on the topic seem to exist, many theorists have hinted at the possibility of Froise sounds, by empirical observation with instruments or studio practice, or on a similar conceptual level; the earliest intentionally Froise instruments may be the *intonarumori* instruments built by Luigi Russolo (RUSSOLO & TIEKSO 1913/2018), and the term "quasi-periodic" waveforms, although not clearly defined, are mentioned as a third category between "completely aperiodic" and "completely periodic sounds" by WEIHS et al. (2017:40), or sounds about which a singular strong blanket statement cannot be made ("Klänge mit mehr als einer pauschalen Klangeigenschaft", BAYREUTHER 2019:34). As an early proponent and idiosyncratic writer, Horst-Peter Hesse also suggested determining pitch levels within noise (HESSE 1978:119)[86]. Hesse was perhaps aware of the recent progress in psychoacoustics, afterall, leading to the laboratory experiment by RAINBOLT & SCHUBERT (1968) mentioned in chapter 1, VON BÉKÉSY (1963:596) had entertained the concept of a perceived precise pitch without genuine periodicity in the sound signal, that is, a more abstracted concept of pitch that would consist of the negations or opposites to the factors that constitute noisiness. Von Békésy tested this using overlapping noise bands of different widths at the distance of an octave, which we should understand as imitating a sensation of harmonics.

LYYTIKÄINEN's article (2009) does not mention any source for the Finnish term "sole", yet we recollected during our phone call during Summer 2020 that the term originates in the theoretical work by professor Matti Antero Karjalainen [87]**.** The Finnish term "sole" might have circulated orally among and originated for the needs of Karjalainen's circle of students, and if an English translation ever existed, it has been difficult to locate in his vast theoretical output.

The oldest known source that mentions Froise, TOLONEN (1969), is a dissertation on the acoustic features of minor trichords and draws conclusions about the overtone structures of chords. As a musicologist and composer, Jouko P.K.Tolonen (1912–1986) casually in a half-sentence defines the phenomena of pitch and noise, and between them, Froise: "It is in Froise that we observe both

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86 "Auch die Höhenmerkmale von Geräuschen würden sich in derselben Ausdehnungsrichtung wie die von Tönen erstrecken, sie seien aber im Gegensatz zu diesen nicht punktuell zu lokalisieren, sondern erstrecken sich über ausgedehnte Bereiche. Die übrigen qualitativen Ton- bzw. Klangeigenschaften – darunter die dreidimensionale auditive Farbqualität, als deren eine Dimension die "Helligkeit" gilt, seien absolut unabhängig von der genannten Lokalisation, nämlich der "Tonhöhe""

87 As an acoustician, Karjalainen (1946–2010) wrote and lectured extensively while tenured at Helsinki University of Technology, pioneering many groundbreaking incentives in psychoacoustics (see Helsinki University of Technology 2010). Much of his interest in the inner life of musical sounds seemed to stem from a need to more accurately model the human auditory system, by using "well-behaving tones" (KARJALAINEN et al. 1993:5) in the aspects of stability and noisiness, and thus advance sound synthesis for all its everyday technical applications.

periodic and aperiodic numbers of vibration". (TOLONEN 1969:75, our translation[88]). Tolonen's work unfortunately does not return to define this term any further other than as sounds "related rather to human speech" (TOLONEN 1969:75) [89]. From this fleeting mention by Tolonen, the term Froise may have circulated to Karjalainen, if collaboration is excluded. In this case, whether Karjalainen restricted the applicability of the term is not known. This dissertation will be the first transmission and translation to the worldwide public of the general idea behind Tolonen's term with additions made by Lyytikäinen which transfer it from the psychoacoustic realm to composition and analysis, while developing and maintaining their connection. This work is for us methodologically unimportant. The most comprehensive conceptual definition of Froise this far is my unpublished essay (VESIKKALA 2018), although I have since greatly refined the concept of Froise during my research progress.

Froise can be approached both from the direction of noise and from pitch, whereas the former is more common in attempts to make Froise sounds more palatable to pitch-based listening: "Real noise signals such as traffic noise or ventilation noise can, in addition to broadband noise, also contain audible tones. The spectral distribution may show that the primary content is found in a specific part of the frequency spectrum. For example, ventilation noise contains a primary content of low frequencies, and compressed air noise has a primary content in the high frequencies. Noise signals can also be a part of the sound of musical instruments, for example the "resin sound" of the strings or the air noise of various wind instruments." (BRIXEN 2011:22). This is in keeping with the etymology of the term "noise with one or more **frequency cores** each wider than a critical bandwidth and that have inharmonic relations to the other frequency cores." (VESIKKALA 2018). The condition of inharmonicity was to initially exclude sounds that would be strongly perceived as harmony rather than Froise, yet after the **application of scalarity to Froise** that made it conceptually more flexible, such a restriction is no longer needed. Neither do we anymore need an exact balance, as in Froise as "a narrow category of sounds where pitched and noisy elements are balanced enough so that neither noise nor pitch prevails in perception." (VESIKKALA 2018). Froise is not only an in-between object, but also an in-between region with gradients on both sides, to pitchedness and to noisiness. In a strict understanding of Froise, we could concentrate on extremely local spectral analysis, with short spectral slices of 50 ms or less. In that case, we could require that "a state of *Froise* has to be sustained and continuous for a long enough time that its elements become discernible by ear. Thus it can be an intermediary state between two sounds. Normal speech does not constitute *Froise* because in undisturbed speech, the states of pitch and noise are separate" (VESIKKALA 2018) yet could not uphold Tolonen's starting point by which Froise was immanently present in speech. In this study, we instead take the perspective by which we listen with stretches of

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[88] "Solessa tavataan sekä periodisia että epäperiodisia värähdyslukuja"
[89] We should note that the term "quasiperiodic or virtually periodic signal" (YEDLA et al. 2015:1) is used in the case of speech or compromised sound recordings. WARREN & BASHFORD 1978 explored the intersection of whispering and Froise-seeming sounds.

at least 1 second, even though the state of the sound may change drastically during that time. We then take such changes to constitute an element of disorganisation that further contributes to noisiness and that do not detract from the sound’s identity and coherence.

Froise may also be seen as the next purely aural development in music, and follows the historical lineage that assigns increasing particularity to small combinations of instrumental sounds [90].

From the perception literature below, it will be clear that not everyone can discern complex auditive concepts, one of which is Froise. If one needs to possess **a perception so sensitive** to appreciate not just spectralism but the sound-based, non-stable kind of music, that must be taken for granted here, and is facilitated since the time audio recordings spread to the wide audience. Recordings have also uprooted non-intended artefacts in performances and made performance practise a common concern for any music. This observation about timbral music lies also behind Solomos’ conclusion that the path to timbral composition "has been about [...] also a question of sensitivity" (SOLOMOS 2020:242).

Some potent evidence for Froise comes from logical deduction, induction, and retroduction. In some cases, a flexible movement between two opposites is not sufficient since the values in between still do not adequately describe the object being described – the in-between object has properties that are simply foreign to the polarity. Especially in this case, the middle ground (or rather, an “outside ground”) has also been seen as an intermediate logical value: “[Jan] Łukasiewicz first introduced a third logical value – which can be called ½, in addition to 0 and 1 for falsehood and truth – as a result of philosophical investigation into ideas of freedom, indeterminism, future contingents, modality, and also the paradoxes of set theory.” (MALINOWSKI 2001:309). This is how we will also consider Froise numerically, as a falsehood in respect to both common extremities of noisiness and pitchedness.

To prove variability in Froise sounds, we will select a group of timbral descriptors big enough to address most microevents in Froise sounds. Froise however resembles conventional theory in that it does not address the role and origins of timbre that emerges from musical texture. Timbral texture from morphology (such as rapid iterations, or registral changes due to filter focus) will be addressed, yet “surface” texture that grows out novel timbres from a combination of instrumental sources will be as much a blind point as it has been for timbral studies before [91].

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[90] This proceeds from fixed tunings (at latest in the Greek antiquity) - fixed instrumentation (by 1600) - timbral combinations (1700s) - structure of the spectrum (1800s) - audio recordings in improving performance standards (late 1800s) - acousmatics and sound objects (1950s) - robust spectral analysis and synthesis (around 2000) –ANTOINE & MIRANDA’s (2017), LANGFELDT’s (2016), and PULKKIS’ (2021) instrumentation tools – to musicians who simultaneously plan and evoke timbre spaces (SEAGO et al. 2008, SCHWARZ & SCHNELL 2010, O'CONNELL 2011).
[91] See DIMINAKIS 2012 on the interaction of timbre and texture in auditory streams.

Based on this information, we strive to prove Froise with an analytical tool that applies best to pieces that are entirely auditive, are not pitch-driven nor based on extramusical associations (such as collage or field recordings). We hope to show Froise eventually as a device that is applicable to compositions, in addition to being an analytical device.

2.2.3. Music analysis literature (Basket 4)

This basket includes general methods for music analysis as solutions for compositions. This applies especially to literature on tonal and atonal analysis where we will have to adopt most of our methods from. For timbre-based music, considerably less literature exists for both general and particular purposes.

Much of the analytical literature does not answer our needs, yet for constructing an as effective method as possible, we need to know the dangers present in other analytical ideas and methods.

To save space, we will discuss this large basket in terms of **general analytical approaches** here, and will introduce **analytical literature on musical form and structure** and on **aural analysis** only directly in our discussions of analyses (chapter 5) as needed [92]. More specifically, **analyses of noise and timbral repertoire** make up basket 5, and of Froise repertoire will be developed further in chapter 2.4. We will now consider more general approaches in analysis.

Systematic music analysis is an indispensable tool for both the composer and performer. Mere verbal description is secondary to the predictive power of analysis which can also envision other possible courses for the music. Most analytical methods are reductions and include numerisation or the use of notation.

Music theorists's subjectivity (see POPLE 2004) cannot and need not be entirely avoided. There are differences between exact quantitative science and music analysis (see SAYRS & PROCTOR 2008), yet also shortcomings in music analysis by theorists both science-minded and not, that have ignored some aspects of music. In the presence of the noisy repertoire which works against many principles of tonal music or pitch-based music in general, we should leave much of what music analysis has considered important in the past. Susan McCLARY (2001:138) reminds us that common goals for most music analysis have been conditioned by the needs of tonal-functional music composed during a relatively short historical period. The shared goals for the analysis of noise repertoire include **reduction**, a compositional approach to learn from and improve a piece, as well as **determining segmentation**, **hierarchisation**, **functionality**, and **other auditive infrastructure** at work. While many criteria for the analysis of common-practice music may be questioned as obsolete remnants, at least no stricter requirements need be set for noise analysis keeping our study scope in mind. Segmentation, reduction, hierarchisation, and functionality as intertwined

[92] This literature is annotated with the number 4 in the bibliography.

and strongly loaded terms leave little room for incorporated perspectives from psychoacoustics and phenomenology. Our morphological focus can consider aspects of music that have come to be addressed by many composers and that cannot be directly seen in traditional notation, including "microstructure", including the effect of pulsation and articulation on amplitudes, the "appropriate placement" of the "amplitude envelope" in vibrato, "micropauses", and "variations of timbre within each note of the music" (CLYNES 1985:4). Such topics tend to be divorced from music analysis, allotted rather to performance practise.

Common methods for music analysis have been the use of charts, visuals [93], lists, notation, and numerisation [94]; in many cases this has assigned to music something abstracted that is arrived at very selectively or is not originally there. Analytical representations rooted in the analytical tradition while deeply integrated with sounding music remain rare.

2.2.4. Music analyses of noise, Froise, and timbral repertoire (Basket 5)

Music analysis literature tailored to noise, Froise, or timbre is the most consequential for all parts of our thesis. This literature is small, due to what Tomi Mäkelä criticises as theorists' and musicologists' untenable arguments and intellectual manoeuvring when encountered with the need of analysing timbral repertoire (MÄKELÄ 2004:60-63). The situation with noise repertoire is not better, and the common cause seems to be the lack of perception-based approaches that would bridge conventional music analysis with the perceptual devices already used by much of recent repertoire. Perception-based timbral studies is not a new field yet still very slowly evolving. Theorist Tobias Schick mentions as the main proponents for perception-based timbral studies ("wahrnehmungsbasierten Klangforschung") the texts by P.Schaeffer (1966), M.Chion (1983), and D.Smalley (1986); most such methods evolved for the needs of acousmatic music and were only later transferred to the instrumental medium (SCHICK 2018:17). This far, we have seen that very few studies have sought to analyse recent acoustic noisy repertoire with the necessary analytical rigidity. None of the existing sources provide for all our analytical needs. This literature lacks not in methodology, but relative to our goals, due to their limiting axioms chosen.

The main division is between **descriptive versus analytical explanatory texts**. The former includes general works on noise sounds, timbres, and their perception, including instrumentation guidebooks as well as descriptive literature about the repertoire and composers studied. These are however seldom focused on the noisy repertoire. Some of the analytical texts use methods that are for us not applicable, by analysing particular noisy or timbral compositions from viewpoints other than noise or timbre. The rarest case are the analytical, hypothetical general texts often with a self-developed method that provided

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[93] Yet visual evidence cannot prove a theory, see AMANN & KNORR-CETINA 1988.
[94] On some numeric analysis methods relative to sound see COUPRIE 2018.

analytical tools without having applied them to any piece in practice. They are fertile ground for further developments (from chapter 2.3. onward). Analytical methodical texts are our preference when they conduct analysis of noise and timbre in particular compositions. This literature has the widest range of methods, often developed by individuals from various historical subjective lineages in thinking about music. Compared to basket 4, these texts tend to address a small number of pieces from one of the timbral viewpoints and do not attempt general theory formation (of the kind which would be urgently needed).

Our method in chapter 3 will make graphic presentations of timbre in several ways [95], as well as verbalisation [96], identification, classification, taxonomy [97], and computational numerisation of timbre [98]. Although our method deals with noise-based repertoire, only a minority of our referential methods [99] attempt this. Our method's outlook on timbral transitions is by trajectories [100]. As a side product, our method can be used to suggest segmentation or formal divisions, which for

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[95] A similar method is found in SAARIAHO's (1987) noise-pitch axis, while different methods and premises to graphic representation are taken by MINTZ 2007, SORAGHAN et al. 2018, SORAGHAN et al. 2016 (3-dimensionally), McADAMS et al. 1995, WALLMARK 2014, FERNÁNDEZ HERRERO 2017, ROSSETTI 2017 (no compound descriptors), GILLIES 2012, ZACHARAKIS et al. 2015, DRIBUS 2010, DOLAN 2021 (as instrumental mass in time), GOODCHILD 2016, SINERVO 1997 (intensity, noisiness and dynamic), SIEGEL 2014 (rough contours), MIRKA 1997 and 2001, REID 2013 (by cubes), M.Spahlinger's three sonic features in REID 2013:17, and THORESEN 2015 using symbols for timbres.
[96] Similarly dealt with by PEETERS 2004, differently by SORAGHAN et al. 2018, McADAMS et al. 1995, WALLMARK 2014, RAASAKKA 2010, SCHAEFFER 1966, SMALLEY 1997, REID 2013, M.Spahlinger's three sonic features in REID 2013:17, and SCHICK 2018 who lightly uses timbre typologies of Chion and Smalley. SASSOON (2017) also uses verbal trait inventories and introduces further concepts such as "prototype theory", "additive similarity", "multiplicative similarity", and "family-resemblance score".
[97] Familiar methods are found in MAJD 2019, McADAMS et al. 1995, and ROSSETTI & MANZOLLI 2018; different ones in SYNYTSIN 2012, ROSSETTI et al. 2020, CENDO 2014 focusing on types of saturation, SIEGEL 2014 (brightness, "noise, airiness, and vibrato"), MIRKA 1997 & 2001 referring to organology and the instrument materials, RAASAKKA 2010 using Lachenmannian sound type categories, SCHAEFFER 1966, POLZHOFER 2014:36 defining "non-protected and transparent families and sound types", and McCONVILLE (2011:37) who identifies two types of airy (essentially) Froise sound and four basic registral contours of four notes each.
[98] Our numerisation method was developed without influences yet was later seen to be close to the methods of MAJD 2019, McADAMS et al. 1995, and ROSSETTI & MANZOLLI 2018. Different numerisation methods are found in MINTZ 2007, SORAGHAN et al. 2018, WALLMARK 2014 (by fMRI study), FERNÁNDEZ HERRERO 2017 (partials only), ROSSETTI 2017 (using the Orchids software), GILLIES 2012 (algorithms for roughness), ZACHARAKIS et al. 2015, DRIBUS 2010 ("noisiness" dimension), GOODCHILD 2016, SIEGEL 2014:34 (although "inherently subjective"), PEETERS 2004, REID 2013 (very roughly), use of three sonic features (MAURO & VALLE 2019) or in M.Spahlinger's 3-dimensional space (REID 2013:17), as well as in music information retrieval (MIR).
[99] MAJD 2019, SYNYTSIN 2012, ROSSETTI et al. 2020, RAASAKKA 2010, and THORESEN 2015.
[100] Trajectory approaches for timbre are only taken by the study of instrumental attacks by the harmonic tristimulus. Differing methods are found in CENDO 2014, GILLIES 2012 (in roughness), ZACHARAKIS et al. 2015, SINERVO 1997, MIRKA 1997 & 2001, RAASAKKA 2010, SMALLEY 1997, REID 2013 (by trajectories), CASTRILLÓN 2019:26–58 ("timbral modulations" on the cello), and THORESEN 2015.

some sources [101] is a much more central goal.

As to the **principles of timbre perception and cognition** [102], we can apply very limited literature, whereas those sources that analyse tonal, atonal, or spectral repertoire or skip psychoacoustics considerations altogether have a wider base in this respect [103]. In addition, associative or affective effects of timbre are addressed in WALLMARK 2014 and somewhat in SMALLEY 1997, which our scope does not allow.

Timbral music analysis poses several questions to conventional music theory, only some of which have been answered. As with noise, no systematic method exists. The few texts that address noisy repertoire analytically often have a musicological orientation in that they concentrate either on the sounds only yet not on their connections in the chronology of a piece, or the implications and semantics of the sounds.

With much of recent music, a valid yet limited analysis can be made without any focus on timbral elements, by identifying motivic processes ("motivische Arbeit") and Gestaltic entities ("Gestalttypen") [104]. Motivic processes are still well presented in timbral music yet purely motivic works are rare. The balance of motivicity with the timbral focus may vary. After an identification of the timbres used, there is no accepted way to classify timbres (which our method in chapter 3 will help), nor to address how the timbres are used for the dramaturgy of the piece, and the role of timbres to any non-timbre materials that are made salient by the music.

The search for a syntax for timbre has been criticised by TOUIZRAR & SIEDENBURG (2020); we also consider unification an impossible quest and rather speak of **separate strategies with sounds** and let the studied objects themselves "generate their own terms of analytical engagement" (HOLBRAAD

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[101] SYNYTSIN 2012 (by cluster-based timbres), ROSSETTI & FERRAZ 2016 (by morphology), ROSSETTI & MANZOLLI 2018 (at large shifts in the selected descriptors), McADAMS 2019, GILLIES 2012 (shifts in roughness, spectrographs, activity charts), DRIBUS 2010 (by dissimilarities), GOODCHILD 2016, SINERVO 1997 ("timbral pulsation" in intensity, noisiness and dynamic), KANKAANPÄÄ 1996 (purity of sound, texture of sound, and source recognizability), SIEGEL 2014 (changes in averaged or added values), MIRKA 1997 & 2001, RAASAKKA 2010, Schenkerian analysis of tonal-functional music in PREDA-ULIŢĂ 2013, FORTE 1973 (based on pitch set classes), MUNGAN et al. 2017, McCONVILLE 2011:37 (continuity and interruption), and THORESEN 2015.

[102] As do the closest similar methods McADAMS et al. 1995 who study distance in a predefined timbral space and DRIBUS 2010 who focuses on noise trajectories.

[103] These include SORAGHAN et al. 2018 (by semantic features), WALLMARK 2014 (who considers embodied perception and cognitive linguistics), CENDO 2014 (saturation grade), ROSSETTI 2017 (blending), KANKAANPÄÄ 1996 (purity of sound, texture of sound, source recognizability and spatialisation), SIEGEL 2014 (descriptor contours as set classes), RAASAKKA 2010:52 (by Lachenmannian sound types and one novel type), POLZHOFER 2014 (blocks of "Klangtypus"), MCMULLAN-GLOSSOP 2018 (contextualisation, connection, reduction, and expansion), SCHICK 2018 (timbral constellation "Klanggestalt", temporal characteristics, instrumental-technical aetiology, sonogram, way of conveying "Vermittlungsgrad"), and McCONVILLE (2011:37) who identifies mottos, two types of airy Froise sounds, and the alternation of extremely pitched material and silence.

[104] Example analyses include BATCHELOR 2015, MAINKA 2017, and UTRIAINEN 2005.

2014:228) **[105]**. There is however much room for systematisation, since most analyses have tended to remain on the musicological, verbalising and non-explanatory level **[106]**. We will call the specific type of strategies of timbral dramaturgy by the term **timbral trajectory [107]**.

2.3. Most relevant similar studies

Under the studies that are most relevant to our approach, we must consider sources that either **succeed in analysing timbral repertoire**, in **classifying timbres**, or in **addressing situations of Froise and noise**.

2.3.1. Differential timbre studies, timbre space revisited, timbral vectors

"it is not uncommon to posit models for sound, music and noise that exceed direct human experience and presence" (HEGARTY 2021:11)

A modest yet crucial corner of timbre literature in basket 2 considers differences between timbres, the placement of timbres in timbre space, and vectors in such timbre spaces. Differences between timbres are most often observed by utilising descriptors. Such descriptors are listed in literature including GREY & GORDON (1978), KRIMPHOFF et al. (1994), McADAMS et al. (1995), KENDALL et al. (1999). Semantic (verbal and non-numeric) descriptors are used by VON BISMARCK (1974), PRATT & DOAK (1976), SEAGO et al. (2004), DARKE (2005), and SEAGO (2013). The reverse approach is taken with "acoustic correlates of timbral semantic dimensions" in Zacharakis et al. (2015:406).

Listeners verbalise timbre using everyday parlance from the physical world, tangible materials, and textures (see PRATT & DOAK 1976; DISLEY et al. 2006), and descriptions of timbre can be made even in the absence of identifiable sound sources (SEAGO 2013), proving the independence of timbre from a particular instrument. Some call them timbre lexicons, such as ROMA et al. (2012). There however is a "semantic differential" in verbalising timbre (VON BISMARCK 1974; LICHTE 1941). Its variant, verbal attribute magnitude estimation (VAME) evaluates perceptual objects to position them on a semantic scale (KENDALL & CARTERETTE 1993a and 1993b).

PEETERS et al. (2011) rely on information redundancy analysis for timbral descriptors to refine the collection of descriptors, yet even after the procedure, **the resulting collection of descriptors is far too large and lacking internal hierarchy** to be practically useful for music analysis. Since no reduced set of

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[105] For instance, in the absence of a wide range of different timbres, HÉROLD 2012 devised a timbral analysis of piano repertoire.
[106] For instance, Pustijanac notes that the use of the inharmonic sound type in Grisey's three works *Partiels, Périodes*, and *Prologue* plays a different formal role in each; in *Périodes*, as an outlier block of maximal saturation, in *Prologue* as the result of a transformation from three earlier not-as-inharmonic substances, and at the end of *Partiels* diverse types of noise are used without a clear system. (PUSTIJANAC 2017:105–108)
[107] In a similar meaning as LEYDON 2012.

descriptors is given, the reader is also left without a simplified and non-computerised version of the method. Most importantly, **Peeters' descriptors were not designed to answer the noisiness–pitchedness axis**, and thus no subset of descriptors are given that would particularly apply to its continuum. The answer however is likely to be found within Peeters' numerous descriptors.

Within verbalisation of sounds, different approaches can be taken. SEAGO et al. (2004:2) make a distinction between terms of **task language**, which typically "cannot be captured well by conventional musical notation" and may carry analogies from other sensations than sound, whereas **core language** transfers technical sound signal terminology, "objective and measurable quantities associated with sound", as such for use in verbalization [108]. It will be crucial for our method to combine technical core language whenever it can be expected to be discernible by the practitioners of analysis, with task language such as in our case "soft" vs. "loud", "recoil", "competed", "present", "following", "control", "balance", "extreme".

When we add spectromorphological parlance, already noted for its features that diverge both from quantitative features of sound and from the verbalisations that the literature has derived from multidimensional scaling, we can bridge these core and task languages [109].

This combination will also facilitate the learning curve for users who embrace our analytical method from various fields of music composition, theory, performance, and sound technology.

> *"Unfortunately, as with most perceptual properties, timbral dimensions are difficult to quantify (Elliott, Hamilton, & Theunissen, 2013), much less label (Grey, 1977). With the vast array of dimensions that fall under the blanket definition of "timbre," it is no surprise that there are countless ways to manipulate and measure this attribute. [...] the dimensions of timbre can be divided in many ways–the challenge lies in pairing these dimensions with unique, separable, percepts." (ALLEN 2018:5).*

One such (inevitably subjective) pairing of timbral verbalisations can be seen in our method, and the list below connects the attributes from the literature and relates them to our pairings. Our method in its simple form will use 15 percepts (descriptors) that are unique and mostly separable from each other. Since the values within these descriptors are also defined verbally, there will be some perceptual overlap between certain values of some descriptors.

ALLEN (2018:6) introduces multi-dimensional scaling via the need "to measure and quantify timbral percepts, [by which] we must link these perceptual attributes to physical variables that can be manipulated when generating sounds.". For our method to also become an electronic composition method that

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[108] This perceptual divide corresponds with the previously introduced difference between phenotypes (cf. task language) and genotypes (cf. core language). Of them, only task language accesses sound's hyletic features. See WILLIFORD 2013 and WHITEHEAD 2015.
[109] As well as possibly cover some hyletic features.

steers the **generation and modification of timbres is not necessary**. This also means that exact multi-dimensional scaling need not be done, yet the ways in which resultant multi-dimensionally scaled data in a timbral space would be eventually operated, will be applicable here too.

One further point of friction between noise studies and timbre studies is that many of the empirical tests during the 20th century have been only conducted in the context of pitch material. This has led to occasional blanket statements, which regardless of their not having considered noise as musical material and this lack being left unsaid, have been then taken over to corrupt later timbre studies literature. Such is, for instance, the case of "short-term amplitude fluctuations" which were said to have an "aurally irrelevant" role by RISSET & WESSEL (1999:119). When in noise and Froise the perceptually prevailing phenomenon of pitch is downplayed or removed, **we cannot be quite sure which spectrotemporal features will genuinely take the place of pitch** in the auditive percept, due to the contextually compromised and even biassed statements in the historical timbre literature. We may expect this to lead to overcompensation in our method in the percussive and fluctuating aspects of timbre. The existing mainly pitch-based methods may still be used yet their weighting will be off for distinguishing timbres within the noisy repertoire, even when they are able to distinguish noisy material from pitched material.

One finding that affects the feasibility of noise intervals is that noises themselves have differing amounts of tension, resulting quite simply from their perceived frequency height [spectral centroid] by COSTA & NESE (2020). The writers studied "standard noises (brown, pink, white, blue, purple)" and probably did not realise that such simply built and predictable, yet multi-component, sounds will encourage approximative listening. The comparisons were made by moving from one wide-band noise to another, and that way very few other features of noisiness in the sounds became perceived – some of them, such as percussivity, were not even present in this set of sounds. Because the research setup provided audible differences in spectral centroid so easily, this became the prime medium of comparison. Yet, by the primacy of pitch-based hearing as formulated earlier, **Froise and noise require an accommodating and beneficial framing in order to be perceived above any pitch features**. Due to their origins in rough filtering, the wide-band noise sounds are already tuned much like pitches are, and when the research setting presents them together, listeners can hear them as in a scale formation – which is a correct observation. However, for noise music and Froise music particularly, such framings will make a difference. Froises also have a considerable pitch component (or several), yet they also have features that make them noisy and cannot be perceived similarly as pitches are perceived. To play tonal melodic or chordal music with Froises is entirely possible yet the perception of that music would not be Froise. It would be pitched, and no more a genuine question of timbre space, since human audition is able to adapt to the presence of "extra" noisiness in such music (especially so if the Froise sounds are unchanged expect for the pitch core feature, which here makes most of the audible percept). Such a framing would be countereffective and not conducive to the presentation of Froise music.

Most of the studies done and timbral spaces presented have functioned perfectly for the mechanical needs of timbral analysis (in tonal as well as early spectralist repertoire), since they are **primed for the presence of pitch in timbres**, yet it does not make the needed accommodations to the noisy repertoire in cases where 1) pitch is not present in all of the sounds (some types of noise) or 2) the pitch feature or a wider pitch centroid is not used as a main musical signifier (Froise and wide-band noise); that is, timbres are chosen not only based on their centroid, and the centroid is not the feature that creates the main differences between timbres.

We need an analytical method that **makes these accommodations that noise and Froise require, by strongly bypassing the effects of pitch**, and especially of the audition of pitch levels as mutually comparable and scalar. This will also best answer the needs of the noisy repertoire where this perceptual accommodation that restricts the salience of pitch material has been intuitively made by composers already. The pitch aspects of those timbres can be then separately addressed when the theorist considers that the accommodation is not complete and there remain some avenues for pitch-based listening.

"It may be difficult to use timbre intervals as an element of musical discourse in a general way in instrumental music given that the timbre spaces of acoustical instruments also tend to be unevenly distributed" (McADAMS 2019:216) addresses the fact that the collection of timbres available from a given instrument will not be distributed evenly or similarly as in another instrument, and that there may be regions of timbral space in which timbres are more recognisable because no playing modes of any other instruments are located in the nearby regions.

"If timbre intervals are to be used, in the long run they will most likely need to be limited to synthesized sounds or blended sounds created through the combination of several instruments. Whether or not specific intervals are precisely perceived and memorized, work in progress shows that perception of the direction of change along the various dimensions is fairly robust, which would allow for the perception of similar contours (patterns of relative change along the different dimensions) in **trajectories through timbre space**." (McADAMS 2019:216, our formatting)

Even if **three descriptors** could ever be enough to grasp timbre, the three-dimensional approach taken by many is difficult to produce rapidly in contexts of composition or analysis, or to interpret on 2-dimensional paper. On the other hand, one **compound total descriptor** such as noisiness by DRIBUS (2010) draws a linear trajectory and is unable to create a timbre space. What lies between these solutions is the two-dimensional presentation (an Euclidean plane) with the use of not simple but compound total descriptors in which several timbral features are **embedded**. Some complementarity (such as used by Rossetti's method) will be also welcome. This will be our solution, which is of a similar kind as many of the best practices from the studies cited, yet aims to address the complexity of the phenomenon and higher degree of timbral difference.

Whichever small **amount of descriptors** is chosen in the literature, the exclusion of the other descriptors often goes unmentioned. Although hundreds of descriptors have been listed in PEETERS (2004), different writers consider a different majority of them irrelevant for their study. The following solutions are found:

A set of three descriptors is used by CIOCCA (2008:153) who makes a reduction into ‘brightness’, ‘spectral fluctuation’, and ‘attack quality’, while “three independent semantic components, namely, brightness, roughness, and fullness” (ZACHARAKIS et al. 2015:394) are present in LICHTE (1941). Factor analysis by Zacharakis et al. (2014) gave the three most relevant verbalisations for timbres in both the English and Greek languages as *luminance*, *texture*, and *mass*. This "luminance texture mass" model is “Three salient clusters relating to: volume/wealth; brightness and density; and texture and temperature” recognised by Zacharakis’ study groups in several of their studies (SORAGHAN et al. 2016:54). Analysing a work by Mark Andre, JESCHKE (2019) classifies timbres into harmonic, inharmonic, and noisy (without stricter definition)**[110]**. Yet another common analysis method is based on the three lowest harmonics components, the tri-stimulus of harmonic timbres (see BARTHET et al. 2010; SIEDENBURG 2016a:31) and can be used to bridge pitch-based and timbral analysis where pitched harmonic sounds are present. Of the more metaphorical descriptors, PUSTIJANAC (2017) makes the three steps of the breathing process in G.Grisey’s music into structural descriptors. To Pustijanac, Grisey’s sketches evidence an understanding of noise as an exceptional material that is subjected to different structuring and perception than the spectral [harmonic] processes, which led Grisey to treat the inharmonic passages sometimes as inserts, and to this effect made exceptions and breaks to a global pre-compositional scheme (PUSTIJANAC 2017:113). Establishing this threefold grouping of sounds as intentional may have to be done very gradually or with large aggregates of different instruments. Three classes of timbral metaphors are “Density, complexity, homogeneity”, “Adjectival”, and “Nominal” by NOBLE et al. (2020) who have grouped the verbal semantic associations that arose from recent repertoire. However, there is no indication that that repertoire is solely influenced by timbre, and the level of associations remains far from systematic music analysis and composers’ needs. The three sound-producing categories of **sustained, impulsive, and iterative** sounds “could form the basis for a taxonomy of timbre based on gestures, given that the gestures are biomechanically quite distinct, and produce acoustically quite distinct sounds.” (HALMRAST et al. 2010: 194)

◆ **A set of four descriptors** is used in OTČENÁŠEK (2014), studying roughness perception, as well as in Sudo’s analysis (SUDO 2020) of a piece by P.Ablinger:

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[110] “Ein wichtiges Thema aller drei Teile von [Mark Andres] *auf* ist das Verhältnis verschiedener Gruppen oder Typen von Klängen zueinander. Es geht um verschiedene Klangqualitäten, um „Klangfamilien”, würde der Komponist und Lachenmann-Schüler sagen. **Harmonische, unharmonische und geräuschhafte Klänge** stehen einander in drei grundsätzlichen Gruppen gegenüber; in einem nächsten Schritt geht es um Verbindungen und Übergänge zwischen ihnen.” (JESCHKE 2019:128)

the descriptors are “Stability/variability”, “Register”, “The degree of pitchedness”, and “Fricative intensity”.

◆ **A set of five descriptors** as most relevant by ŠTĚPÁNEK (2006) is given as “brightness”, “clarity”, “harshness”, “fullness”, and “noisiness”.

◆ **A set of six descriptors**: Descriptors follow a logical divide into six categories in ZACHARAKIS et al. (2015:412): Spectral Content, Energy distribution of harmonic partials, Spectrotemporal, Spectral fine structure, Harmonic series, Temporal. This reflects the conventional focus on harmonic sounds and exact frequency content in general. The ones relevant for our study of noise and Froise sounds are Spectral content, Spectrotemporal, and Temporal. When the sound is harmonic yet is Froise, the remaining features of harmonicity tend to be overruled by features of noisiness, and thus study of harmonicity in Froise may not need to be as thorough as it is in pitch.

◆ **A set of seven descriptors** is used by MAJD (2019) who also assigns simple numeric vectorisation (1…9) to the descriptors, with their simple visualisation on a graph respective to time, without deriving any timbre-space findings from them. A total timbral saturation value is derived when the seven numbers in the vector are added together (MAJD 2019:24). Majd’s vector carries the name “Timbral Icv” which is left unexplained in the study. One possible source of the name may be interval count vectors as known from set class analysis, in which case Majd’s vector label is misleading [111].

◆ **A set of ten descriptors:** The ten descriptors [of PEETERS 2003 listing] that best differentiate in tasks of instrument recognition are, for the harmonic components of a sound: rel.specific loudness, temporal increase, temporal centroid, spec.spread, Bark-band tristimulus, temporal decrease, spec.skewness, harmonic spec.roll-off, fluctuation strength, and Bark-band tristimulus. For the remaining (non-harmonic) part of a sound: rel.specific loudness, temporal centroid, spec.kurtosis, spec.variation, MFCC, perceptual spec.kurtosis, fluctuation strength, Bark-band tristimulus, Delta-Delta MFCC, and spec.kurtosis. For a sound with its components unfiltered: rel.specific loudness, temporal increase, spec.kurtosis, temporal centroid, MFCC, Delta-Delta MFCC, Spec.spread, temporal decrease, roughness, and Bark-Band Tristimulus. (LIVSHIN & RODET 2006)

◆ **A set of 14 descriptors** as well as defined regions of spectral energy: HERRERA et al. (2002) in classifying percussion instruments.

◆ **23 descriptors** (FAURE et al. 1996) and **34 descriptors** (LE BEL 2017).

With theorists and composers who create timbral systems for their personal use, we can distinguish either mono-dimensionality or a fixation on a maximum of three features at a time, and in many cases even in these limited dimensions a

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111 Until the publication of Majd’s work, our systems have developed this feature of the added total value similarly yet independently and without knowledge of each other. For Majd, the total value resembles saturation while in our method it is noisiness, yet the practical applicability may also be very similar.

smooth scale is not provided. Apart from the writers who theorise a composer's method, no particular schools of thought can be discerned. It is notable that the highly influential texts by Schaeffer and Smalley have still not attracted practical applications in the analysis of pieces.

Our method in some ways compares with the aforementioned yet should serve noise and Froise repertoire equally. However, Froise sounds will also include pitch – thus after the timbral focus, we will return to the role of pitch, since "it is difficult to ignore either parameter (pitch or timbre) when both are changing and indicates a tight relation between timbral brightness (change in the spectral centroid) and pitch height." (McADAMS 2019:217).

2.3.2. Conventional spectrotemporal descriptors and their refutations

Our positioning between Thoresen's (2015) and Peeters' (2004) method was presented in chapter 1.3. Here we consider further literature that addressed possible timbral descriptors.

How to address a sound's timbral (temporal, micro-level) variety, the kind that does not break the identity of a single timbre or timbral aggregate? Philosopher Dexippus elaborated on this using Aristotelian categories: "in so far as accidents are relative to and present in substance, and are conjoined to it in an organised fashion, to this extent we must assimilate them to those things derived from and centred on a single focal entity […] by employing always more basic conceptual distinctions." (DEXIPPUS 1990:73). We will prefer simplicity, the Dexippean "basic conceptuality", in analyses even today; many of our descriptors distinguishing between timbres will be common words and words that will be intuitively clear to musicians who have visually studied FFT graphs.

Our analysis method can address jointly three considerations that have remained open: of the pitch-noise spectrum as voiced by Lyytikäinen and by Saariaho's texts and compositions, of "timbral dissonance" (LERDAHL 1987), as well as of spectromorphological features (inspired by Smalley's texts). Our timbral descriptors are chosen to reflect these considerations in a balanced manner. Thus it is crucial to show the accumulated knowledge of timbral features from which our timbral taxonomy (in chapter 3) will make a selection.

> *"Although a more sufficient definition of timbre has not been proposed [even with recent technological advances], there is a growing body of research that suggests that it is better understood in relation to a large set of audio descriptors that capture different aspects of the temporal, spectral and spectrotemporal qualities of the sound."* (SORAGHAN et al. 2016:53)

Our table 2.3.2.-1 takes a look at timbral descriptors in the literature, for the timbral phenomena that our method addresses. The descriptor abbreviations point to our coming descriptors in chapter 3 and Appendix 1.

Table 2.3.2.-1. The descriptors commonly cited as central to timbre analysis.

Timbral criterion or descriptor	Mentioned by or included in an analytical apparatus	Addressed by our descriptor

	by	(abbreviation)
“inharmonicity” “The departure of the frequencies of partials from those of a harmonic series.” (ROSSING et al. 2002:332)	Zacharakis, Pastiadis & Reiss 2015:412; MANOURY 1991:299	Inh.
“pitches” with inharmonic spectra have increased timbral dissonance	LERDAHL 1987:142	Inh, Di.
inharmonicity	SORAGHAN et al. 2016:54; PEETERS 2004:23	Inh, Wb, Di.
Inharmonicity relates to repetitiveness in textures	GIANNAKIS (2001)	Pa, Ca.
(in)harmonicity of the peaks that are not part of the (perceived) frequencies	MANOURY 1991:299	Inh, Di, Wb, Br.
attack time	SIEDENBURG 2016a:32; logarithm of attack time in ZACHARAKIS et al. 2015:412	Ca, Ed, Idc.
spectral brightness (see WEIHS et al. 2017:150) increases timbral dissonance	LERDAHL 1987:141	Br.
an extreme vibrato (frequency modulation) or no vibrato both increase timbral dissonance	LERDAHL 1987:142; MANOURY 1991:299	Fr, Di, Afr, Br.
amplitude vibratos	MANOURY 1991:299	Dsb, Pa, Ihc, Fr.
an extreme tremolo (amplitude modulation) or no change in dynamic both increase timbral dissonance	LERDAHL 1987:142	Dsb, Er, Inh, Pa.
a sharp onset (attack) increases timbral dissonance	LERDAHL 1987:142	Ca, Pa, Ed, Lm.
a sharp release (decay) increases timbral dissonance	LERDAHL 1987:142	We only consider sharpness of

		release for percussive sounds, not when the sound has lasted for long enough that a first impression has been made.
Grouping of frequencies	MANOURY 1991:299	Idc, Ifc
[harmonic] spectral flux (or variation)	ZACHARAKIS et al. 2015:412; WEIHS et al. 2017:150; KNEES & SCHEDL 2016:43	Br, Afr, Fr, Ifc, Ihc; somewhat: Dsb.
spectral flux and irregularity	SIEDENBURG 2016a:31	Br, Di, Afr, Wb, Fr, Ifc, Dsb, Pa, Ed, Ihc.
spectral skewness [position of the majority of frequency power]	WEIHS et al. 2017:148-14	Ihc, Br, Di, Afr, Inh, Er.
[harmonic] spectral kurtosis	WEIHS et al. 2017:149-150; PEETERS 2004:23	Ca, Pa, Fr, Ifc, Dsb, Idc, Ed, Di.
the relations of dynamic envelopes in the same spectral content	MANOURY 1991:299	Idc, Ihc, Fr, Dsb.
control as to the emergence and fading of partials	MANOURY 1991:299	Ihc, Idc, Dsb, Afr, Br
grouping of (spectral components) based on amplitude	MANOURY 1991:299	Ihc, Di, Fr, Dsb.
(de)synchronisation of the dynamic envelopes	MANOURY 1991:299	Fr, Dsb, Ihc.
aleatoric microvariations, (in)stability of the spectral envelopes	MANOURY 1991:299	Afr, Ifc, Br, Ca, Fr, Ihc.

grave vs. acute	COGAN 1984	Br, Er.
centered vs. extreme	COGAN 1984	Er.
narrow vs. wide	COGAN 1984	Wb, Afr, Di, Er.
“compact vs. diffuse” (COGAN 1984); spectral density (MANOURY 1991:299)	Note that sensed density might result from low frequency content (SORAGHAN et al. 2016:57)	Afr, Di.
non-spaced vs. spaced	COGAN 1984	Wb, Di.
sparse vs. rich	COGAN 1984	Di, Afr, Ifc, Idc.
soft vs. loud (COGAN 1984; PEETERS 2004:23); “noisiness resulting from volume” affects noisiness grade (LYYTIKÄINEN 2009:90, our translation)		Ed, Dsb, Fr, Idc.
level vs. oblique [probably about pitch levels]	COGAN 1984	Di, Afr, Fr.
“steady vs. wavering” (COGAN 1984); stability or instability (MANOURY 1991:299)		Ifc, Dsb, Idc, Ca, Pa, Br.
no-attack vs. attack	COGAN 1984	Ca, Ed.
“percussivity” affects noisiness grade	LYYTIKÄINEN 2009:90 (our translation) percussivity: TACHIBANA et al. 2014	Fr, Ifc, Dsb, Idc, Lm.
sustained vs. clipped	COGAN 1984	Lm, Ed, Ca, Idc, Dsb, Ifc, Fr.
beatless vs. beating	COGAN 1984	Inh, Ihc, Pa, Idc.
slow-beats vs. fast-beats	COGAN 1984	Ihc.

"negative and positive sonic characters"	COGAN 1984	meaning unclear
temporal control and variation of frequency band sizes	MANOURY 1991:299	Wb; somewhat Inh.
(registral) distribution of the (frequency) peaks by the spectral envelope	MANOURY 1991:299	Di, Wb, Inh.
total noise energy	PEETERS 2004:23	Inh, Er.
noisiness	PEETERS 2004:23	calculated as the total of values.
spectral shape (PEETERS 2004:23) and temporal distribution of the spectral envelope (MANOURY 1991:299)		Di, Ed, Fr, Dsb, Pa, Lm.
total energy of the signal	PEETERS 2004:23	Ed.
fundamental frequency	PEETERS 2004:23	Br, Er, mostly excluded.
spectral crest [protruding spectral peaks]	PEETERS 2004:23	Di, Br, Ihc.
interference-derived roughness values near the maximum increase timbral dissonance	LERDAHL 1987:142, implicitly formulated	Inh, Ihc, Idc, Pa.
required rise time of a timbre	LAKATOS 2000	Ca, Ed, Idc, Afr.
temporal/spectrotemporal variation (T/STV).	ZACHARAKIS et al. 2015:408	addressed by most of our descriptors.
spectral centroid	LAKATOS 2000; SORAGHAN et al. 2016:54; WEIHS et al. 2017:147; KNEES & SCHEDL 2016:43	Br, Afr, Er.
spectral spread	also called bandwidth by KNEES & SCHEDL 2016:41	Di, Afr.

	and “derived from the spectral centroid”; SORAGHAN et al. 2016:54; WEIHS et al. 2017:147-148 cf. texture contrast in Giannakis and Smith (2000b)	
spectral flatness (SFM)	SORAGHAN et al. 2016:54; PEETERS 2004:23; WEIHS et al. 2017:150 cf. texture granularity in GIANNAKIS (2001) & BERTHAUT et al. 2010	Di, Wb, Ihc.
harmonic energy ratio (HER)	SORAGHAN et al. 2016:54	Br, Inh, Ihc.
Harmonic Spectral Irregularity	ZACHARAKIS et al. 2015:412	Di.
energy distribution of harmonic partials (EDHP)	ZACHARAKIS et al. 2015:406	Ihc, Afr, Dsb, Inh.
“the amount and noisiness of attacks” affect noisiness grade	LYYTIKÄINEN 2009:90 (our translation)	Ca, Pa.
“noisiness resulting from register” affects noisiness grade	LYYTIKÄINEN 2009:90 (our translation)	Er, Br.
“noisiness resulting from [room] acoustics” affects noisiness grade	LYYTIKÄINEN 2009:90 (our translation)	Ra.
“noisiness resulting from deviations from the harmonic series, or from volume differences between the harmonics” affects noisiness grade	LYYTIKÄINEN 2009:90 (our translation)	Ihc.
“noisiness resulting from a dissonant harmony” affects noisiness grade	LYYTIKÄINEN 2009:90 (our translation)	Cbb.
“noisiness resulting from the tuning setup [or technique]”	LYYTIKÄINEN 2009:90 (our translation)	Cbb.

affects noisiness grade		
"A factor analysis of the ratings suggested three perceptual dimensions: Activity, Brightness, and Fullness" for polyphonic timbre.	ALLURI & TOIVIAINEN 2010:223	Activity: Afr, Fr, Ifc, Dsb, Idc, Ca, Pa, Ihc, Cbb. Brightness: Br, Er. Fullness: Di, Wb, Inh, (somewhat also Ed, Lm).
spectral detail (SDT) as a perceptual (verbalised) dimension	ZACHARAKIS et al. 2015:408	addressed by all our descriptors.

2.3.3. Excluded irrelevant descriptors
The literature also has commonly used descriptors that we will exclude. They and their definitions can be found irrelevant for four reasons:

1) Due to an **interval-based focus and over-reliance on pitch and/or harmonicity**: spectral rolloff (see WEIHS et al. 2017:150) requires a set frequency point in the spectrum, yet such a unanimous point in frequency space cannot be set with most repertoire; spectral centroid (in the loudness model) as the "SC of the specific loudness (Moore et al., 1997)" (ZACHARAKIS et al. 2015:412). Spectral centroid is also already related to brightness (BEAUCHAMP 1982; SCHUBERT et al. 2004; SCHUBERT & WOLFE 2006); normalized Harmonic Spectral Centroid (SC_norm) as the "Normalized barycenter of the harmonic spectrum" (ZACHARAKIS et al. 2015:412) and [harmonic] Tristimulus 1, 2, and 3 (T1, T2, T3) as the "Relative amplitudes of the 1st, the 2nd to the 4th and the 5th to the rest of the harmonics (Pollard & Jansson, 1982)" (ZACHARAKIS et al. 2015:412; see also PEETERS (2004:23). In many Froise sounds, these harmonic components are not even discernible and thus do not render proportion information; "SC standard deviation", "SC variation", "SC (loudness model) corrected", and "SC variation (loudness)" (see Zacharakis, Pastiadis & Reiss 2015:412) all address the harmonic spectral centroid and are better addressed by other measures of instability or deviation; "Harmonic Spectral Spread" (see Zacharakis, Pastiadis & Reiss 2015:412); "zero-crossing rate" as a time-domain feature (WEIHS et al. 2017:146) and a "low-level feature in music retrieval" (KNEES 2016:41) achieves measurements of percussiveness, which can be however addressed by the missing of data in descriptors whose values remain undecided when the sound is too short. Our method will separate sounds based on whether they are stopped early, cannot be held long, or are held long, yet not using such a signal processing based term that is likely indiscernible to musicians; odd-even ratio of harmonics (ZACHARAKIS et al. 2015:412; BARTHET et al. 2010; SIEDENBURG 2016a:31); analysis based on octave bands (FRITZ et al. 2012) is irrelevant since our frequency ranges are not defined as exactly. Octave equivalence is obsolete and probably does not lend acoustic support in noisy contexts.

2) Due to **inadequacy**: **"Noisiness"** (ZACHARAKIS et al. 2015:412) is given as one feature, which from our perspective is a gross simplification; **Jitter and shimmer** (see OPLIŠTILOVÁ 2007:39) as features that only occur with electronic sound processing.

3) Due to irrelevance for the noisiness–pitchedness continuum: thinness and thickness of sound (MAJD 2019); temporal centroid and normalized temporal centroid (ZACHARAKIS et al. 2015:412); instrument recognition, which LIVSHIN & RODET (2006) say is more effective based on the harmonic content than on the non-harmonic content, when the instrument is playing a pitch; MFCC [mel-frequency cepstral coefficients] (and its derivatives in speech processing). (SIEDENBURG et al. 2016:29). The cepstrum discourse and its derived descriptors, although possibly fruitful for differentiation between noises, rely on a logarithmic operation which renders it unusable for our computer-free method. Additionally, in WEIHS et al. (2017:40) "Noises can be classified according to their power spectral density [PSD]" which derives from the theorem of Wiener–Khintchine. This approach would create a different yet possibly useful taxonomy of timbres; for example, with about 20 spectral bins as octave bands (each corresponding to one octave in the audible range). Timbres would have their own spectral "fingerprint". It would however be unable to distinguish between harmony and noise or to address any morphology. This would be a place of application for the calculation of Relative Specific Loudness, across a chosen frequency band. According to LIVSHIN & RODET (2006), it is the most important descriptor [from the PEETERS 2003 listing] for all aspects of instrument recognition – holistic, harmonics-based and non-harmonics-based.

4) Due to being of **negligible effect**, a "low-level feature in music retrieval" (KNEES & SCHEDL 2016:41) and thus of too little relevance also for our method: Amplitude envelope (AE); Root-mean-square energy (RMS); Zero-crossing rate (ZCR); Band energy ratio (BER); and number of frequency bins, i.e., the number of the highest frequency band. KNEES & SCHEDL (2016:43–46) gives the corresponding definitions, alongside their calculation formulas. Conversely, some of the features disregarded by Knees are reflected in our method.

Now, by the end of this literature overview, the reader who finds it convenient would be able to develop error theories about musical functionality, segmentation, auditory streams, and voice-leading, such that Froise is taken into account in these fields after removing the original formational assumptions of these fields. Many of the errors emerged in an era when Froise as well as noise were not understood as even potentially musical material.

2.4. Literature related to our thesis

Here we shortly review how the fields of literature relate to the parts of our thesis.

2.4.1. Review of conditions for the existence of Froise

This review of literature has been to supply research for proving our thesis, to introduce a novel type of sound, as well as to provide ways of contextualising Froise within the realm of all acoustic sounds (by taxonomy) and analysing its roles in the repertoire.

Our review of literature has shown several possibilities for further study (to be touched upon in chapter 5), restrictions for the use of our methods, and methods that will not be applied.

We have given an overview of further comparable methods, some of which however are intended for use with a computer and outside acoustic repertoire or otherwise include aspects that cannot be applied in our method [112].

Another question considers the place of Froise sounds in the general taxonomy of sounds. Thus proof for the existence of Froise will be (at least) perceptual, spectral, visual, notational, and organological, and taxonomical. We will proceed in this order.

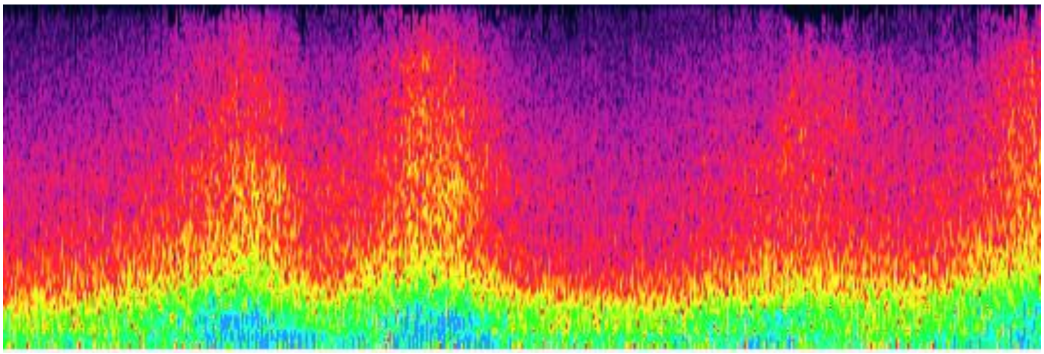
1) Possibility for perception studies: Our limitations do not allow us to conduct listener testing as pertains to basket 6, since we continue to focus on WALLMARK's (2014:63) perspective of *a-noise*, "the physical qualities associated with" noise timbre, rather than *p-noise* (the noise "percept itself"). A test in any case should consist of numerous individuals, both with and without musicianly and studio experience. We should expect to derive hardly any definitive answer and that individual answers about noisiness and pitchedness perceptions will range according to the elliptically bordered and evasive feature of the Froise phenomenon.

2) Spectral FFT proof: In spectral listening or FFT visualisation, we can see (Figure 2.4.1.-1) that Froise spectra differ from the spectra of pitches (which tend to have a harmonic setup of partials with a diminishing loudness towards the higher components, and almost no other content) and of noises (which tend to have spectral energy in a large uniform stretch of spectral space distributed equally or with a logic of no clear dynamic dips or peaks).

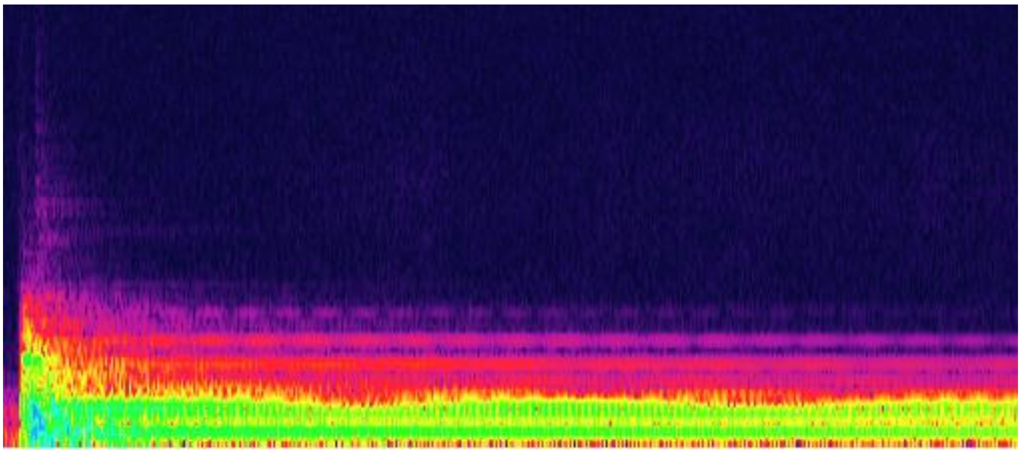
Tables 2.4.1.-1a, b, c, d. Examples of four instrumental aetiologies for Froise and their FFT visualisations.

A Froise sound as holes in an otherwise wide or full spectrum (example: a wide-band pitch core from traffic noise and passing vehicles)

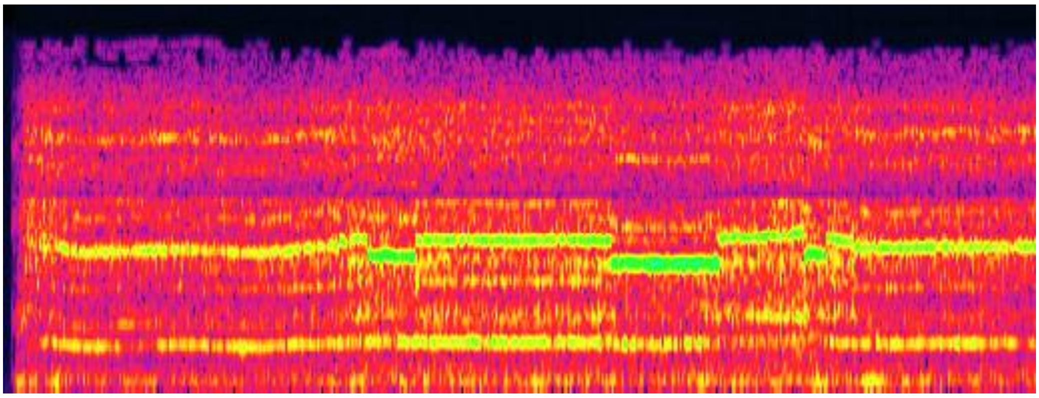
[112] For instance, the frequency bin method in SORAGHAN et al. (2016:54-55) would take us back to computer-assisted analysis, which is in opposition to our need to have a method on based on paper, so that it remains accessible and streamlined enough to the everyday and occasional use by a theorist or composer.



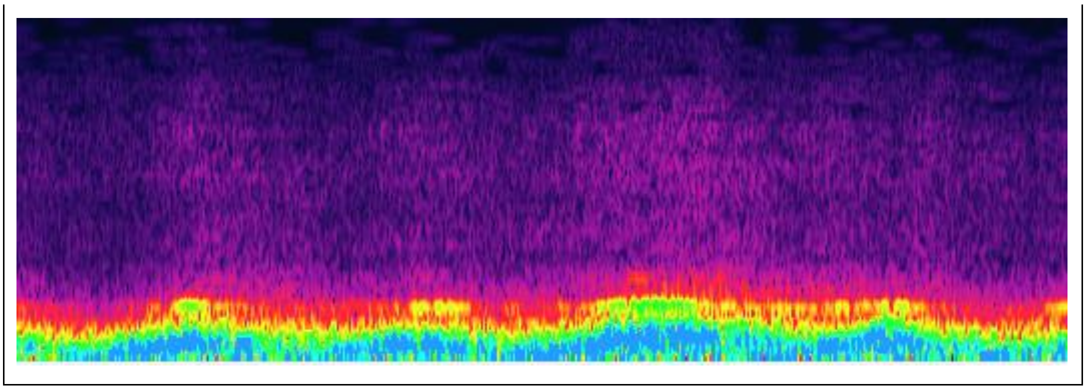
A Froise sound as two or more perceptually competing strong elements. (example: the attack and decay of a grand piano multiphonic)



A Froise sound as strong peaks in an otherwise wide or full spectrum (example: an airy tin whistle noise that occasionally breaks into pitch)



A Froise sound as an unstable pitch collection and auditory scene (example: the wobbling noise of a thunder sheet)



3) Notational proof: Almost all Froise sounds require some symbolic or verbal adjustment to conventional notation. Several works have used an intermediate manner of notation by the use of conventional 5 lines for pitch level and unconventional noteheads, square, triangular, or otherwise, to mark a "compromised" quality for the pitch to which more noisiness is "added". In other cases, the pitch level in the Froise cannot be modified (or is not considered) and thus only one percussive stave may be chosen.

4) Proof in physical means of sound production: we can often approach Froise sounds as pitches that have obstacles applied to them so that they become more noisy – seldom the other way around. It is afterall conceptually more difficult for humans to understand noises, especially when we do not identify the aetiology of their obstacles, and to remove their obstacles one by one to imagine a more pitched sound. In the case of acoustic sounds, Froise has to be executed with even more precision than in the electronic realm.

From our grounding from the literature, several types of sound land in the Froise category:

◆ all timbres that have no dominating core pitch, instead several [113]. This includes many types of multiphonics.
◆ many timbres that have tremolo, fluctuation, or other rapid alternation
◆ many timbres that have distortion, leakage, friction, or strong resonance and/or feedback
◆ many timbres that cannot be held long so that their inner organisation as pitched or noisy could be appreciated

This evidence proves the existence of the Froise range. Yet it will be impossible to accurately prove or even reflect the point of perceptual equilibrium between noise and pitch due to the variation in individuals' hearing; the differences in the outcome of the playing, as well as the musical context and acoustics of the space

[113] Note that clusters on the piano for example were considered a special technique in the early 1900s, even though the timbre or the technical mode of playing the instrument did not change with the addition of more pitches and timbral mass. This also leads to the realisation (along the lines of LYYTIKÄINEN 2009) that even pitched chords with more and more pitches and increasing blending tend towards Froise. Our following method will be simplified enough to not address all aspects of multiplicity, instrumental doubling, and mass and how they affect, if not the individual timbres, the holistic perception of the timbral mass.

also have some effect that make blanket statements about this phenomenon unavailable.

2.4.2. Froise within the taxonomy of sounds

From our basket 7 and the category studies and taxonomy literature related to Froise, we know that "objects can inhabit multiple contexts at once, and have both local and shared meaning" (BOWKER & STAR 2002:293). We have posited Froise as such a boundary object.

Taxonomy literature does not directly address, yet can be applied well to, the question of Froise. The theories about categorical ambiguity address the noise-pitch continuum. "The classical view [of concepts by SMITH & MEDIN 1981] argues that every object is either in or not in the category, with no in-between cases." (MURPHY 2004:15). We may not need to define hundreds of narrow sub-classes of noise, pitch, and Froise, since this scientific programme is obsolete. **Classical taxonomy** does not bide well with even the conventional dichotomy that consists of pitch and noise only – this line has been porous since at least the early 1960's when it for a while became psychoacoustics *fascinosum* for VON BÉKÉSY and consequent researchers. This line of study seems to have been abandoned as the paradigm changed to a more accurate yet complex one: "The groundbreaking work of Eleanor Rosch in the 1970s essentially killed the classical view [of concepts] [...] In part it happened [...] by the discovery of data that could not be easily explained by the classical view." (MURPHY 2004:16). If the same Froise sound is heard as pitched by one listener and as noise by the next, or as noise in a certain musical context and as pitch in another, this percept cannot fit the classical view in taxonomy. However, "the neatness envisioned by the classical view does not seem to be a characteristic of human concepts. [...] the notion of a definition implies that category membership can be discretely determined: The definition will pick out all the category members and none of the non-members. Furthermore, there is no need to make further distinctions among the members or among the nonmembers." (MURPHY 2004:19).

Froise is outside the **classical logic of sound types**: "Classical logic is based on the *principle of bivalence,* that every proposition has exactly one of the two logical values *truth* or *falsity.* This finds expression in the two laws: the *law of the excluded middle* [...] and the law of *non-contradiction*" (MALINOWSKI 2001:309). "According to the *law of the excluded middle*, a rule of logic, every statement is either true or false, so long as it is not ambiguous." (MURPHY 2004:15). Froise combats the exclusion of middle concepts, being ambiguous sounds in the middle of noise and pitch. Yet a middle value can result from a coming together of attributes, when a phenomenon is described by several true-or-false statements, as long as not all of them have the same value. This follows the logic of a cumulative effect. Whatever "logic" of timbral listening Froise projects, this wider logic, according to Malinowski, either requires more values than two, or it requires delicate combination operations beyond the simple AND and OR: "The most natural and straightforward step beyond two-valued logic is to introduce more logical values, thereby rejecting the principle of bivalence.

Another, indirect, way consists in challenging the classical laws concerning the sentence connectives and introducing other non-two-valued connectives into the [logical operator based] language." (MALINOWSKI 2001:309). Based on how many timbrally distinguishing attributes we would like to be reflected in our terminology, the necessary vocabulary would increase from each added attribute by a corresponding multiplier factor (MURPHY 2004:21); we would not speak only of noise or Froise, we would also be able to designate specific labels for noises that have a high frequency core or a low one, for instance. The attributes "neutralising" or "balancing" serve a good fit here. Froise is a neutralised pitch and a neutralised noise, concepts which also land close to each other (exact matching is not required since Froise is a region, and its abstraction to a pointlike state would be even less relevant than with the polar extremes). By this neutralisation, any extremity and polarity has been removed, at least in the holistic evaluation of the sound. Froise is made possible through changes made to either noise or pitch; "What is in general possible is the same as what can in general come about through change." (WATERLOW 1982:148).

The simplest case of taxonomy are **phylogenies**, unfolding tree branches that line out a group of features or choices. If we follow traditional writers on timbral verbalisation such as Schaeffer or Smalley, we land with distinct timbres by a series of branching questions, which bears a helpful resemblance to the field of phylogeny[114] . When we understood the perception of sounds as a set of branching questions (most ideally of the yes/no type) that are taken by auditive cognition at lightning speed, and from which we could derive a typology of sound types, we would be using a traditional form of phylogeny (see Fig. 2.4.2.-1). Many events of branching also secretly take place in instruments such as the human voice. A base vibration from the vocal folds is transformed by obstacles to the course of the wave before it leaves our head, and each obstacle can be considered to be another branching. Phylogeny is one way of conceptualising timbre at least from the acoustic perspective (cf. Wallmark's a-noise and p-noise) – perception has a heavily classifying tendency yet might not have a phylogeny-finding tendency [115].

From the acoustic point of view, we see two ways in which sounds can be classified as a phylogeny, a series of branching logical eliminations. The first, **motoric or physical-topological instrumental origin (aetiology)** of a timbre was considered by early futurists, which is logical especially in cases where the sound wave faces genuine physical obstacles or filters. The second, used especially by acousmatic composers classifies timbres according to the **spectral content** and gives precedence to sound only, as we have done. Froise differs from noise and pitch in both the questions of aetiology and spectral content.

The audible "obstacles" (or branching) in human cognition that contribute to the

[114] On the general field of phylogeny, as primarily developed in biology and hereditary genetics, see HOWARD & BERLOCHER 1998, WILEY & LIEBERMAN 2011, STEEL & PENNY 2005 and BAUM & SMITH 2013.
[115] However, HÉROLD (2019:28-29) applies phylogeny on the level of musical dramaturgical structure, namely Lerdahl's tree method (that was developed to show formal divisions) to a spectrogram of Schumann's *Eusebius*.

perception of noisiness are unknown as shown with basket 6. Thus below, we take the approach of branching based on perceived acoustic content.

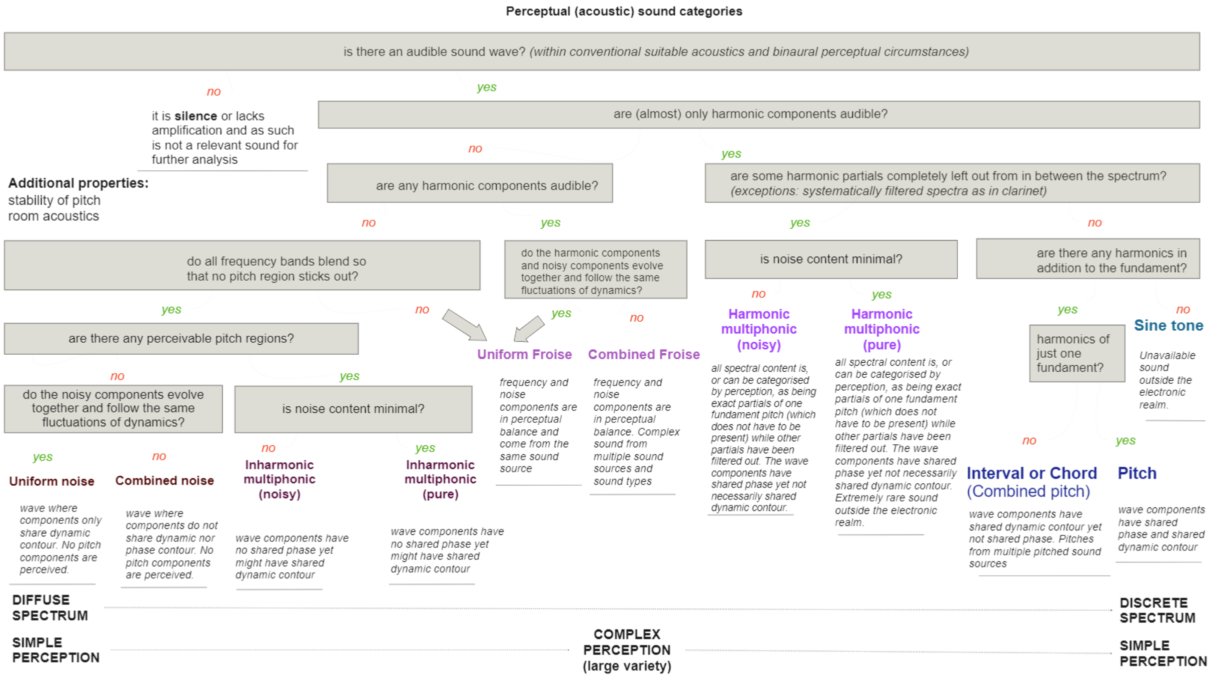


Fig. 2.4.2.-1 A dendrogram, branching view, or phylogeny of sounds. This rough aetiology of 11 types of sounds pays tribute to the Schaefferian tradition and might be even considered a genealogy (see BISWAS & ROY 2014 and VILLEGAS VÉLEZ 2018). This phylogenetic chart is a classification based on binary divisions which gives very few different combinations, and has limited distinguishing power. It is enough to show the taxonomic necessity of Froise yet is an unrefined prototype before the timbral analysis method that we will develop in chapter 3.

The existence of Froise as a human cognitive category may be conditional on the existence and perceptions about other human cognitive concepts: “What is possible/impossible at a given time is restricted to what is possible etc. relative to the way things are at that time.” (WATERLOW 1982:141). At this stage in which noise music and pitch-based music are spoken as separate approaches to musical sound yet both can be considered timbrally, the perception of Froise as a timbre between noise and pitch is not restricted by conceptualisations at least.

2.5. Addressing Froise with an analytical method

“*Data* means “given” in Latin and, as such, it is usually treated as a trace and a representation of what has been observed” (PIRRÒ 2018:142). The observations in our case are in active listening. “Data is the collection of information produced by the application of a reiterated function, the experiment.” (PIRRÒ 2018:142)

The **main reasons for music analysis** are, in outline, the same grounds why any degree of analytical understanding of the workings of a piece will enhance listening, performance, and composition; our study will especially benefit the former and the latter. Analysis is available whenever there is the possibility and intention to replicate or simulate that musical experience. Fundamentally, **music**

analysis aims at replicability of a pleasurable experience, either by enhancing repeated listenings to the analysed piece, pointing out previously latent yet particularly focusable and enjoyable aspects of it, or by mimicking its most functional effects in future compositions. This replicability is often achieved by identification of the functional elements and by their subsequent decoding via reduction, by some procedure to invade under the surface of the music, or even by its deconstruction. Our spectral descriptors will mostly fulfil this purpose.

We intend to establish Froise and a numeric timbral analysis method that recognises Froise as an intermediate state between the numeric states that noise and pitch receive. Any field of the human sciences that attempts to establish itself will look forward to quantifying its data. While we have seen that most musicology about the noise repertoire only attempts to verbalise and at times compare sounds, for our purposes information has to be numeric in order to make queries, find patterns, and develop educated guesses about musical chronology, even theories.

While we lay out the formal functionings of Froise as analysts who face a new kind of repertoire, we have to steer clear of the limitations of present formal analysis since many Froise and noise compositions make use of formal solutions that follow an **inner logic based on the sounds themselves**, something that cannot be yet found extensively in music analysis manuals[116]. It is a revolution that Solomos calls "the substitution of the composition *of* sound for composition *with* sounds" (SOLOMOS 2020:237) and Thoresen (2015) calls sound-based music. Froise can be found fulfilling many more formal contexts and functions in the repertoire than conventional (pitched or spectral) sounds can. In the words of H.H.Eggebrecht: "Historically and theoretically it is impossible to ignore how innovation within the realm of what is musically applicable and valid has had consequences at the fundamental level of musical material" (EGGEBRECHT 2010 [1999]:49). Froise sounds have had this material legitimacy among listeners, performers, and composers for decades and are awaiting their decoding method in music theory as well. It is likely that **many theorists have long acknowledged this shift in musical substance** yet have lacked either hands-on methods of immersion with the Froise and noise repertoire (comparable to the role of keyboards in the analytical access to intervallic repertoire), thorough knowledge of the noisy modes of playing on instruments, or versatility in listening strategies which many composers develop in studio practice.

[116] One such approach is found in VLITAKIS 2008.

3. The analytical method

3.1. Module 1: Numeric classification of noisiness in Froise and other timbres

"Timbre, loudness, perceived location and pitch are perceptual attributes of sounds that are generated for each auditory event, whether the event can be recognized as familiar sounds or not. The auditory processes that generate these perceptual attributes are perceptual schemas that are specific to each attribute." (CIOCCA 2008:153). With our method, we approximate these unknown perceptual schemas that affect Froise perception and reduce them to a practical number of descriptors.

Froise analysis differs from established analysis methods. At each stage of the methodology, we must bear in mind the lack of the necessary psychoacoustics research and the differences in the audition of one-dimensional scalar linear phenomena (such as pitch and tone perception) and multiscalar (noise and Froise). Likewise, by nonlinear phenomena in sound sequences, competing timbral features feed back to the perception of neighbouring timbres (Froise and to a lesser extent noise).

In this chapter, we introduce the first module of a spectrotemporal analytical method for timbres. By it all acoustic timbres can be distinguished from each other by morphology and on the basis of noisiness [117]. The non-pitched aspects will be addressed by our method's three modules followingly: module 1 undertakes timbral reduction and categorisation to understand the basic musical substance with which the Froise repertoire operates, and presents a local or absolute approach; module 2 places the timbres and temporal progressions between them into a timbral space, reflecting a contextual approach; module 3 finally interprets the constellations, groupings, and trajectories that constitute voice-leading between the Froise timbres. This is the logical order of these prototypal modules so that each of them can be replaced with a more refined module when psychoacoustics research progresses.

This method is portable (non-computer assisted) and introduces timbral descriptors, in keeping with earlier developments in timbral analysis, with the difference that the values of our descriptors can be determined by human listening. The method then presents all the timbres used in a passage of music in their interrelation using one 2-dimensional graph at a time. This lays out a timbral space, a basis with which the following chapters will be able to analyse noise-based repertoire, assess composers' choices of timbres as well as appreciate designs that help create dramaturgical progressions, grammars, and forms based on timbres. A discussion of problematisation follows in chapters 4.5 and 5.

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[117] We again understand noisiness as the presence of one or more noise features that can be quantised. Based on how many and which features accumulate, noisiness has gradations.

3.1.1. Quantitative descriptors corresponding to auditory criteria

"the proclivity to categorize is innate, develops early,
and is susceptible to training and other experiences." (WALKER 1990:56)

Froise analysis is different from the verbalising or numeric branches that our study of literature indicated. A categorisation is the content of the first module of our analytical method, yet it merely is not enough. We will also need to do analysis from real pieces of music as to how music with Froise proceeds; the descriptors must be of use when we analyse timbres numerically, yet with a different inventory than other studies have done. Numerisation or categorisation of the basic musical substance (in our case Froise and noise timbres) is the preferred way that we have seen in the existing literature. Differently to other approaches until now, we will attempt to **cross from descriptive to explanatory analytical territory**. Description thus has to be done, and not only verbally, since we hope it to serve rather as a device to explain the Froise repertoire.

Derived from the previous comparison of timbre taxonomy literature, we will have a **verbalisation-based set of 15 spectrotemporal descriptors** (see Appendix 1) that we consider the most representative while also practical amount. Each descriptor receives one of **five possible values**. It will be a sufficient compromise between the large amount of mostly nonlinearity phenomena that affect noise and timbral perception, the usability of the method manually, and a minimum realistic dataset size that not only individualises the timbral profiles but also begins to display differences between timbres. Our method treats the verbalisations of a sound as a trait inventory of noisiness; thus **each descriptor can potentially contribute to noisiness or to pitchedness. When it contributes to neither, it counts toward Froise**.

We have to combine both verbalisation and categorisation [118], and have thus made our selection of descriptors. Some inspiration for our classification comes from LYYTIKÄINEN (2009). As an introductory essay it however does not give detailed or spectrum-based criteria. Lyytikäinen is concerned with the outlines of noisiness on the level of labels and looks for the general factors of noisiness, and foregoes discussing anything related to numerisation or the intermediate stepwise grading that we use here.

Appendix 1 shows our **spectral descriptors of noisiness**. In this list of descriptor definitions (**the reader should refer to Appendix 1 from now on**), the 15 descriptors are verbalised. The descriptors and their abbreviations in this crucial appendix will be frequently referred to since these 15 descriptors form the basis of our spectrotemporal analysis method. The various **criteria in creating the descriptors** were that the described features are perceivable by a listener

[118] Verbalisations are done on the level on which an individual feature of a sound is judged as to five given options. This transforms the feature from words to a numeric value. This is part of the categorisation process, which is finalised when all 15 numeric values of a sound are observed.

familiar with spectral listening, they address features that display a noisiness continuum, and that the set is made of the features held most relevant by the literature (in chapters 2.3.2 and 2.3.3) while being compact, uniform in its principle, without complicated numeric weighting factors, and portable for use without computer assistance.

The five definitions should be read in each case before selecting the most accurate one. Each set of definitions assigns one numeric value. Many descriptors' definitions for our five classes on the pitchedness–noisiness continuum include words that are not numerically accurate; as befits music as a nonexact field, some terminology lacks a mathematical definition, and we have to refine this part of quantisation. We want to be able to always choose the most accurate one out of five value options, without having to computerise the method. The **meanings of these imprecise words** used in the descriptions are explained below in Table 3.1.1.-1. This also shows the possible calculation operations, if the method ever were to be computerised.

Table 3.1.1.-1. Discussion of the verbally defined approximate quantities.

competed / uncompeted	Uncompeted: only one strong component is found and has no competition; no spectral components of about 80% of its amplitude or stronger are present. Components at 80…120% amplitude relative to each other are competed.
high / low	This relates to the instrument's range or to the registral span that is principally used in the particular piece, either as pitches or as spectral harmonic components. Such a range (typically less than 7 octaves) is then divided in three equal regions in terms of octaves: high–middle–low, such that the middle register would not trigger this condition.
extreme high / extreme low	The last third of the respective high or low region, as defined above. Alternatively, the edge region where the main means of sound production starts to produce glitches or instability.
long / short	Determined by the point during the course of the sound after which the sound source has been identified or has been deemed as unknowable, the constancy of its morphology has been evaluated, an adequate guess of the sound's continuation has been made, and the sound has been roughly categorised relative to the musical context and prior familiarity. The time during this process does not trigger this condition, while the time before this process counts as short and after as long.
small / moderate / large amount	Relative to the competing spectral spikes of the sounds that are principally used in the particular piece. This can again be divided into three equal regions: small–moderate–large.

weak / strong	Weak: less than about 10%, strong: 50…100% of the entire sound’s spectral energy (calculated for instance in dB).
narrow / wide frequency band	The critical bandwidth (or JND) in any given register separately is divided into three equally large regions: narrow–medium–wide (calculated in cents). The medium width region would not trigger this condition.

In chapter 2, we mentioned the importance of **categorical typicality judgements (CTJ) in timbre perception**. Thus, a basic sound from an acoustic instrument, before it is more carefully evaluated by auditory cognition, would receive a categorical typicality judgement that corresponds with the more pitched values −1 or −2, certainly not with the Froise value 0 nor the noisy values +1 or +2. We should exclusively expect the value −2 for the descriptors Br, Di, Afr, Wb, Fr, Ifc, Idc, Pa, Ihc, and Er to be the typicality norm. Thus the only exceptions are Dsb, Ca, Ed, Lm, and Inh where instead of the value −2, the −1 is permissible and likely, perhaps since it is common to the everyday human voice. In the lack of contrary statistical evidence, and if CTJ indeed similarly affects all the 15 descriptors, no modifications to the descriptions would be needed since CTJ would pose an equal bias on all of them throughout. Well-differentiated listening conditions and longer duration of a sound make its features easier to determine.

3.1.2. Calculation of noisiness and its variance

Noisiness total is a holistic approximation of a sound’s noisiness and can be calculated as a simple addition of all 15 values that a sound receives. Noisiness total is a composite value made of the sum of all 15 descriptors and thus receives a value ranging from −30 to +30. This correlates directly with calculating an average of the descriptors. We, however, refrain from using a scaled-down version of these numbers since integer values are easier to memorise than decimals. The extreme values are theoretical in that even our two ideal polarities, sine tones and white noise (or any of the possible variants to it to make it have even more obstacles to auditory cognition) do not receive those extreme noisiness total values because some of our descriptor criteria are very exclusive.

This collection of descriptors is a simple first prototype that will later need adjustments to the features addressed, as well as mutual weighting of the individual descriptors. Even the most studied descriptors (by Peeters and others discussed earlier) have not been weighed. It is too early to tell by which factors the features affect emergent timbre perception and whether the presence of Froise should change such weightings.

In addition to counting totals of noisiness which composers such as Saariaho (1987) deemed central to musical dramaturgy, we should be able to count the sensed tension and release from timbre also in a different way; the more so if we do not believe that noisiness solely affects the sensation of tension in noise-based music [119]. Tension will be approached with a slightly more mathematical operation: we count to what degree the descriptor values of a sound are mutually distinct, by employing **variance**. This variance accounts for the added cognitive obstacles in determining whether a sound is noisy or pitched, and it is calculated from the values of the 15 descriptors of one timbre at a time. Variance here is not to be understood such that there would be any errors in how the timbral descriptors' values were numerised, rather that such internal discrepancy is typical and even characteristic to each timbre [120]. We take the mathematical operation of variance, which makes all differences inside the group of values stand out and more visible to evaluation. Each timbre thus has one **timbral internal variance (TIV)** value that reflects how much the noisiness counted from some descriptors conflicts with the pitchedness present in other descriptors. This value can only be changed by changing the descriptor values of the timbre, which, as we will see, has musical implications. Below, a simplified mathematical explanation of timbral internal variance [121]:

$$\text{TIV} = \frac{\sum(\text{ each descriptor value individually one by one}^{2})}{15} - \frac{\text{noisiness total}^{2}}{225}$$

The symbol ∑ means summation of the values, the subtracted later fraction indicates the mean (μ) of the descriptor values, where 225 is 15 squared [122]. Our method results in TIV values between 0 (not tense) and 4 (tense).

Any features of any timbre can contribute to noisiness but some of the descriptors' values are also in seeming conflict with each other, for example with the values +2 and +1, some more noisy than others. The very evaluation of noisiness becomes more difficult – this internal cognitive challenge or the difficulty of processing the often ambivalent percept is what is addressed by TIV, and ambivalence is central to timbral perception (GRIMSHAW-AAGAARD 2019).

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119 Lyytikäinen (2009) states that harmonic tension also cooperates in noisiness. Tension is analysed in tonal music in FARBOOD 2008 and by timbre in FARBOOD & PRICE 2017, and preference rule scores for musical tension are given by TEMPERLEY 2004:307ff.

120 Most timbres carry features from both noisiness and pitchedness, yet these features occur in each timbre more or less extremely and located in different descriptors.

121 The detailed steps to calculating variance are to calculate the mean value by adding up all the values from the 15 descriptors, and dividing that sum by 15. Then using subtraction, each value's deviation from this mean value is determined, and separately multiplied by itself. Finally, the sum of each 15 values obtained this way are added up and this sum is divided by the square of 15 which is 225.

122 Since we take the descriptors to be a representative population, an entity that is not missing any members to sample (unlike the world of instrumental timbres which is infinite), we do not use the variant of this mathematical formula known as Bessel's correction. In our platform on Google Sheets, this means using the function VARP instead of VAR. Note that the operation of variance is closely related to standard variation, which the noise-pitch continuum also materialises; in any randomly generated combination of descriptor values, the majority of such constructed timbres will present noisiness total values that are in the Froise region which is the statistically likely middle.

3.1.3. Specific dimensions of noisiness from the descriptors

We now expand on numerisation, to add another way of considering Froise as the effect of all the 15 descriptors – the possibility to use subsets of the descriptors. One common subdivision follows the spectral dimensions found in an FFT analysis, namely time (in the case of an instrument, this dimension is called durative), frequency, and loudness[123]. The descriptors can be added all together in four different ways: the total of 15 descriptors as done above, and three ways of **comparing two complementary subsets (subtotals) at a time**. This way each complementary pair will maintain a balance by including each descriptor exactly once.

Such **subtotals** of descriptors could rely on the role that they play in spectrotemporal dimensions. Thus:

spectral descriptors with negligible time dimension (abbreviated **NTemp**):

Wb, Br, Er, Inh, Di, Ihc. These descriptors can be observed even in short temporal slices of the spectrum and do not require a proper time dimension.

The rest, **spectrotemporal**, or rather, **durative** descriptors (abbreviated **Temp**):

Afr, Dsb, Ifc, Ca, Lm, Pa, Fr, Idc, Ed. These descriptors require duration to be evaluated accurately [124]. This corresponds with PEETERS' (2004:1) division into "Global descriptors: descriptors computed for the whole signal" and "Instantaneous descriptors: descriptors computed for each time frame". We see that these two groupings (6 + 9 descriptors) are complementary and add up to the 15. This also addresses short sounds that end before they manage to convey much of their spectromorphology; as listeners, we tend to classify them as noisier than they would be when their continuous morphology is laid out in a long sound.

In the other subtotals, only some descriptors had features of change (marked Δ).

Those descriptors that include **frequency**: (this addresses descriptors that have Δ values of frequencies, Δ amount of frequencies, and frequency generally; abbreviated **Freq**):

Wb, Br, Er, Inh, Di, Dsb, Ihc, Afr, Ifc, Ca, Pa, Fr.

Entirely **non-frequency-based** (this excludes the components Δ values of

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[123] The musical dimensions of coherence listed by THORESEN (2015:303) parallel this: pitch, duration, (dynamic) energy, timbre (or *Klang*), and spatiality, in this order.

[124] Time is the dimension of timbres that we should verbalise with most caution because its scalarity or axis is the least available of the three to human perception: "Wenn wir auf die Individualität von Klängen referieren, wenn wir also die Was-Frage in einer Klangwahrnehmung beantworten, steht die zeitliche Ausgedehntheit der Klänge nicht im Zentrum einer solchen Bezugnahme. Üblicherweise antworten wir auf die Was-ist-das-Frage mit einer pauschalen Eigenschaft. […] Wie in anderen Phänomenbereichen auch haben wir bei Klängen kein explizites Zeitbewusstsein. Die Zeit liegt unter unserem phänomenalen Radar." (BAYREUTHER 2019 : 89–90)

frequencies, Δ amount of frequencies, and frequency generally; abbreviated **NFreq**):

Lm, Idc, Ed.

Those descriptors that include **amplitude** (this addresses Δ amplitude, amount of different amplitudes, and amplitude generally; abbreviated **Amp**):

Di, Ihc, Pa, Dsb, Fr, Idc, Ed.

Entirely non-amplitude based descriptors can be marked with **NAmp** and include:

Wb, Br, Er, Inh, Afr, Ifc, Ca, Lm.

Our subtotals have a rationale in spectral analysis, since they show internal aspects of a sound [125]. In the subtotals of the "non" type, an explicit connection to that spectral dimension is lacking. We do not however consider that dimension as crucial to the descriptor, that is, there have to be certain values or there has to be a change of value, in order for the descriptor to be defined. The temporal dimension enjoys a special place since although sound perception requires all three dimensions, frequency and amplitude features are technically carried on waves through time.

All the subtotals are also known to statistics under the term **summated scales**, an operation of "combining several variables that measure the same concept into a single variable in an attempt to increase the *reliability* of the measurement. In most instances, the separate variables are summed and then their total or average score is used in the analysis." (HAIR 2010:93) [126]. To delve more accurately into the Froise phenomenon, be it from the aspect of frequency, loudness or time, our analyses should also use the subtotals. Summated scales avoid some of the measurement errors, especially since our scale only has five steps, and they require a prior theoretical basis and clear conceptual definition for the desired multivariate aspect (HAIR 2010:124), as has been introduced above. Thus our subtotals should be a compromise between conducting too detailed analyses on the movements of individual descriptors, and not observing the Froise repertoire closely enough.

3.1.4. Smooth timbral continua in the bowed strings

The instruments of the bowed string family present the largest timbral variety, and thus the most complex timbral canvases can be found in string instrument repertoire. In many such cases, it is necessary to reduce the number of individual timbres to not overcrowd the presentation. This reduction could focus on the mode of playing by smoothing out those timbral differences that result

[125] The frequency-based features come from changes in the value of frequencies (Br, Ifc, Ca, Fr), the amount of frequencies and its change (Wb, Afr, Ca, Pa), and the presence of frequency generally (Wb, Er, Inh, Di, Ihc, Afr, Dsb). The amplitude-based features come from changes in amplitude (Idc, Dsb, Pa, Fr, Ed), the amount of different amplitudes (Ihc), and the notion of amplitude generally (Di, Ihc, Fr, Ed). The time-based features reflect the course of a sound in time, which is relevant only for the Temp descriptors as listed above, and irrelevant for the descriptors of the NTemp subtotal.

[126] This statistical operation is synonymous to composite measures.

from the size differences from the violin to the double bass. This size difference mostly affects the descriptors which are based on register, that is Br and Er, and on the presence of high harmonics, that is Inh. With this reduction, it is possible to give abbreviated labels to all string modes of playing, in all their different combinations, with an in these contexts negligible loss of precision.

Some of these modes of playing cannot physically coexist, or they depend heavily on pitch and dynamic, yet even then we speak of hundreds of possible combinations.

In our examination, we start with an *ordinario* sound on a "generalised bowed string instrument", played ord., for a bow duration, at *mf*, in the middle register, with almost no vibrato, which receives the descriptor values in Table 3.1.4.-1,

Table 3.1.4.-1. Descriptor values for ordinario on a generalised bowed string instrument.

Br	Di	Afr	Wb	Fr	Ifc	Dsb	Idc	Ca	Pa	Ed	Lm	Inh	Ihc	Er
-1	-1	-2	-1	-1	-1	-2	-2	-2	-2	-2	-1	-2	-2	-2

and a noisiness of -24 and TIV of 0.240. All perceivable changes to the mode of playing will alter one or more of these values. Not all modes of playing can be smoothly varied; rather, many aspects are binary, either on or off.

The possible transitions can happen smoothly in the following (in brackets, the aspect of playing that is changed, and the affected descriptors):

◆ bow pressure, in about three stages: none, pitched soft pressure, noisy heavy pressure (Inh and most descriptors except Lm, Idc and Ifc)
◆ figures played (such as contour or free figure, or two strings alternating) (Ifc, Afr, Br, Di, Dsb, Idc, Ca, Pa, Inh, Er)
◆ pausing and perforation during playing (Fr, Dsb, Ca, Pa, Lm)
◆ (ir)regularity or rhythmicity of repetition (Fr, Dsb)
◆ accentuation (presence and strength) (Br, Di, Afr, Fr, Dsb, Idc, Ca, Pa, Ed, Ihc)
◆ choice of register or string, when stable (Br, Er; with smooth changes also Di, Afr, Fr)
◆ flageolet trill (speed or no presence) (Br, Di, Afr, Fr, Pa, Ed, Inh, Ihc; somewhat also Ifc, Idc, Ca)
◆ trill or tremolo (speed or no presence) (Br, Di, Afr, Fr, Pa, Ed, Inh, Ihc; somewhat also Ifc, Idc, Ca)
◆ the continuum between bowing material: arco, ½ legno, legno (Br, Di, Afr, Fr, Ifc, Dsb, Idc, Ca, Ed, Inh, Ihc)
◆ the continuum of bow contact point: tallone, ord., punta (Br, Di, Ifc, Ca, Ed, Inh)
◆ the continuum of bow speed: fast, ord., slow (Br, Fr, Idc, Ca, Pa, Ed, Ihc)
◆ contact point on on string: tasto, ord., pont. (Br, Di, Fr, Dsb, Ca, Inh, Ihc)
◆ the amount of string instruments used for the timbre (Idc and Ihc, and somewhat Ca, Pa, Di, Afr, Dsb)
◆ the presence of vibrato (not addressed by the abbreviation system)

Transitions cannot be smooth in the following:
◆ flageolet status: present or not (Br, Di, Inh)
◆ repetition: present or not (Ca, Pa, Lm, Br, Afr, Fr, Dsb)
◆ arco vs. pizzicato (most descriptors)
◆ which one of the four strings is used (Br, Er)
◆ how many strings are used for playing (Br, Di, Ifc, Ca, Pa, Ihc)
◆ the stages of string damping: damped, flageolet pressure, half-flageolet pressure, normal pressure, open string (Br, Di, Wb, Fr, Dsb, Ed, Inh, Ihc, Er)
◆ contact point behind bridge: at bridge, behind bridge pont., behind bridge (Br, Di, Wb, Fr, Inh, Ihc)
◆ the use of sordinos (not addressed by this system)
◆ bowing from beneath the strings IV and I (not addressed by this system)
◆ bowing on other parts than the string (not addressed by this system)

The most efficient way in which string timbres can be addressed is an **abbreviated bowing label system** that consists of the following "digits" (Table 3.1.4.-2):

Table 3.1.4.-2. Combined string playing modes on a generalised bowed string instrument, with their explanations and abbreviation codes. The optional digits particularly address timbres from advanced playing mode combinations.

Digit 1.	**2.**	**3.**	**4.**	**5.**	**6.**
Descriptive question					
EITHER bow pressure OR flageolet ?	figures played?	pausing or perforation present?	(fast) repetition present?	accentuation present?	which register
Options					
YES bow pressure: 1 NO bow pressure nor flageolet: 0 NO bow pressure, YES flageolet: f ; bow pressure on flageolet: F; under-pressured with flageolet: u, without: uu.	YES contour or free figure: 1 YES, two strings alternating: 2 NO: 0	YES: 1; by battuto with bow hair: b; by battuto legno: B; by pizzicato: p. NO: 0	YES, regular and rhythmic: r YES, irregular (and when perforation is present regularity is lost): i MORE STAGES THAN ONE: insert number of stages (counts as in the case of i) NO: 0	YES: 1 NO: 0	MORE PITCHES THAN ONE, OR UNISON ON MANY STRINGS (simultaneous) : insert number of pitches. HIGH PITCH: 1 LOW PITCH: 0
Other notions					

smooth processes between the yes/no conditions can be marked by an ordered string of letters, such as yn, ny, nf, fn, fny					
Affects the descriptors (compared to standard timbre)					
bow pressure affects Inh and most descriptors *except Lm, Idc and Ifc*. flageolet affects Br, Afr, Inh, Fr, Er, Ifc, Idc, Dsb, Ca, Ed, Inh, Ihc.	figure or alternation: Ifc, Afr, Br, Di, Dsb, Idc, Ca, Pa, Inh, Er.	Fr, Dsb, Ca, Pa, Lm	presence: Ca, Pa, Lm, Br, Afr, Fr, Dsb. regularity: Fr, Dsb.	Br, Di, Afr, Fr, Dsb, Idc, Ca, Pa, Ed, Ihc.	Br, Er. With smooth changes also Di, Afr, Fr. Number of pitches: Br, Di, Fr, Idc, Inh, Ihc.

Optional digits: 7.	**8.**	**9.**	**10.**
Descriptive question			
nonstandard bow position?	nonstandard bowing speed?	nonstandard bow part (longitudinal and perpendicular)?	nonstandard finger pressure?
Options			
normal position: [empty digit] molto sul tasto: TT sul tasto: T verso il ponte / sul ponticello: P molto sul pont.: PP	fast / molto veloce: VVV ordinario: VV [or no marking]. slow / lentissimo: V	punta (at the tip): pn metà (middle): m [or no marking] tallone (near the handle): tl <u>as well as</u> arco: A [or no marking] arco & legno: L legno: LL	ordinario: o [or no marking]. flageolet pressure: f. half-flageolet pressure: h. Not needed if flageolet bow pressure is used (“f” in digit 1) and finger pressure is that of a flageolet.

Affects the descriptors (compared to standard timbre)			
Br, Di, Fr, Dsb, Ca, Inh, Ihc	Br, Di, Afr, Dsb, Lm	Br, Di, Afr, Fr, Ifc, Dsb, Idc, Ca, Ed, Inh, Ihc	Br, Di, Afr, Wb, Fr, Ifc, Dsb, Ed, Inh

The standard *ordinario* string timbre thus receives the label 000000. To save space, the appendix also uses these labels. The string instrument-driven repertoire that we analyse in chapter 4 with this notation are the Furrer and Rădulescu pieces. In other pieces, this shorthand notation is occasionally useful.

The verbalisation and numerisation parts of the method are now covered, and next we discuss visualisation. Both parts help us hear, analyse, and compose with Froise sounds.

3.2. Module 2: Visualisation on the timbral canvas

Now that we have put together 15 values from descriptors to receive noisiness and TIV values, we have two dimensions of timbre. Timbres can be positioned in a timbral space (**timbral canvas**), which visually shows how timbres are different from each other, not only due to their aetiology. Our timbral canvas shows **pitchedness to noisiness from left to right**, as a sum of 15 descriptor values. Here neutral values (Froise) sounds are found in the middle region, at around −7…+7. **The vertical axis shows increasing TIV values.** This corresponds to the internal complexity of a sound's descriptors, as reflected in the previous mathematical operation of variance calculated from the 15 descriptors.

In our following analyses of **spectrotemporal dramaturgy** and onwards, we will move past the individual spectrotemporal descriptors and may focus on any two of the listed two upper-level features at a time to form the axes of a two-dimensional **timbral canvas** [127]. This canvas will help visualise the chronology of timbres moving and being evoked and deactivated throughout the piece. This kind of representation always shows a reduced version of the dramaturgy since some processes still take place in the individual descriptors or in the other upper-level features than the two axes shown at a given time.

The most typical type of timbral canvas will carry the noisiness value as its X axis and the internal variance of the descriptors as its Y axis. Each separate timbre will be shown, regardless of its temporal occurrence(s) in the course of the piece, as a point with two coordinates. For easy readability, the analytical charts will be presented in two dimensions only, and several versions of the charts can follow each other at different times in the piece, to represent the time dimension. Temporal information can also be shown using lines and arrows, groupings,

[127] If a three-dimensional representation would be used, the third dimension typically would be time (on an extra axis difficult to read on paper, or by a colour dimension), to avoid a too abstract constellation.

colours or shading of the points. If two or more timbres share the exact same coordinate, their texts can be italicised or coloured with the same colour, to distinguish them from the other timbres written in the default black font. Since we have the noisiness–TIV comparison as well as three spectral dimensions that each have a complementary set of subtotals, this results in four feasible canvas versions.

We have analysed according to our taxonomy (the first step in our method) all instrument sounds found in our repertoire selection, and some more. The activity of categorising timbres should not be an end in itself. **Our entire timbral taxonomy is shown in Appendix 2 and it should be referred to from now on for timbres**. It is for us only a lexicon in the service of a musical grammar or syntax, to the extent that music and language have analogies.[128]

We give as our first visualisation example the timbres of the grand piano, a timbral canvas that can serve as a basis for composition or improvisation (Fig. 3.2.-1). It presents the familiar notion of plentiful noisy sound as physical obstacles to a most regular pitched sound and obstacles that can combine and branch out. All the available sounds originating from different combinations of the sounds made by playing on inner parts of the piano have been likewise classified in the Appendix 2. A cursory look serves to show that the location of a sound's physical origin on the instrument does not correspond with any of the numeral quantities received, whereas we expect spectral classification to correspond with perception and thus with the positioning on our timbral canvas.

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[128] If we were to neglect categorising and learning the timbral "vocabulary" of sound-based music, we would not be able to distinguish between sounds and assign them functions – difficulties akin to misunderstanding a child's speech during the "acategorial stage" which undergoes lexical acquisition yet fails to modify word stems into their correct syntactic class such as verbs and nouns (MALMKJÆR 2010: 294).

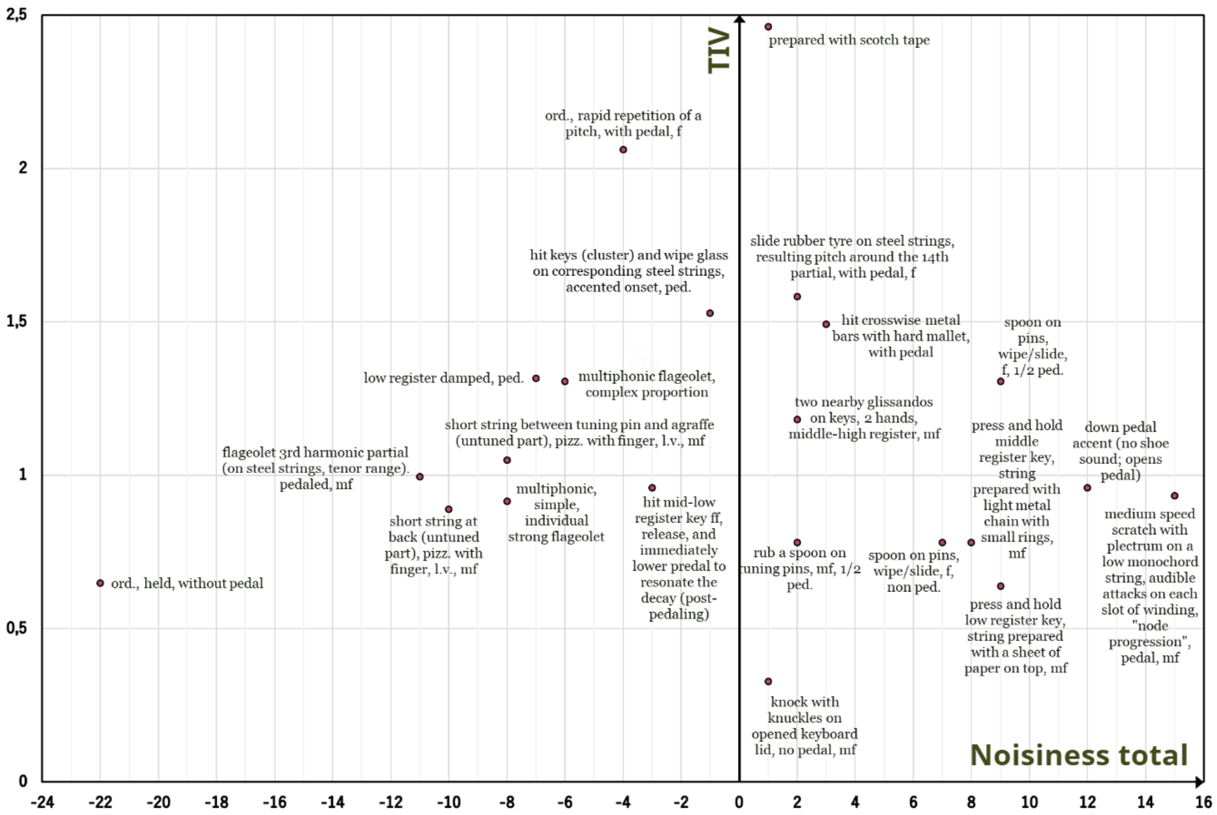


Fig. 3.2.-1. Grand piano timbres, shown on the timbral canvas in its basic version, noisiness–TIV. Noisiness increases from left to right, TIV increases upwards. The grand piano timbres have perceivable differences that reflect into their placement in this presentation of timbral space. For instance, the leftmost timbre, ordinario playing, is the most pitched sound available on the instrument and has low tension associated with it (TIV value).

3.2.1. Further types of timbral canvases

In our four standard canvas versions, the graph will have the X and Y axes as follows:

- ◆ noisiness total – TIV
- ◆ Temp – NTemp (marked with yellow dots in our charts)
- ◆ Freq – NFreq (green dots)
- ◆ Amp – NAmp (blue dots).

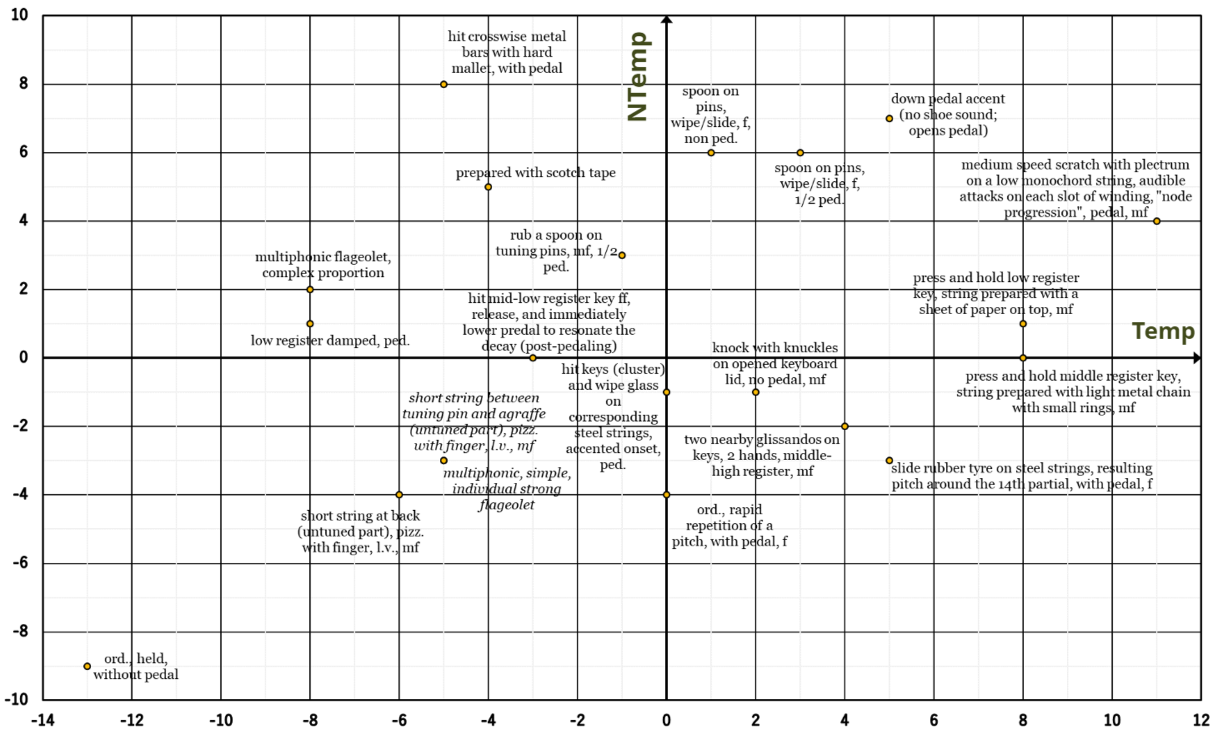
These presentations have the advantage that **each one of the 15 descriptors is included exactly once**. All other imaginable combinations of two dimensions or subsets would not have such balance. The mutual order of the axes does not matter nor alter the results, and thus we have standardised their order. The two axes are only a reflection of the possibilities of the timbral collection and should not be seen as representing a mathematical function.

It would be tempting to try several different timbral spaces too [129] yet we will

[129] And timbral set vectors, a topic which Arash MAJD (2020) is approaching.

not. This selection of four (time, frequency, amplitude, and one possible calculation of noise-based tension) is logically the minimum for understanding all the three dimensions that would be shown in a typical FFT analysis, and on the other hand, there is no evidence of the centrality of any further feature. Although (noisy) timbre as a nonlinear phenomenon can never be represented entirely by any of these canvas variants alone, a small number of approaches should be enough to show consistency in a piece of music. The approaches that we choose are the closest to the FFT, since we base our approaches on the spectral notions of noise.

We now show the latter three versions of the timbral canvas, again with the grand piano sounds, in the order temporal, frequency, amplitude (Fig. 3.2.1.-1). In each case the *ordinario* piano sound is distinct from other modes of playing.



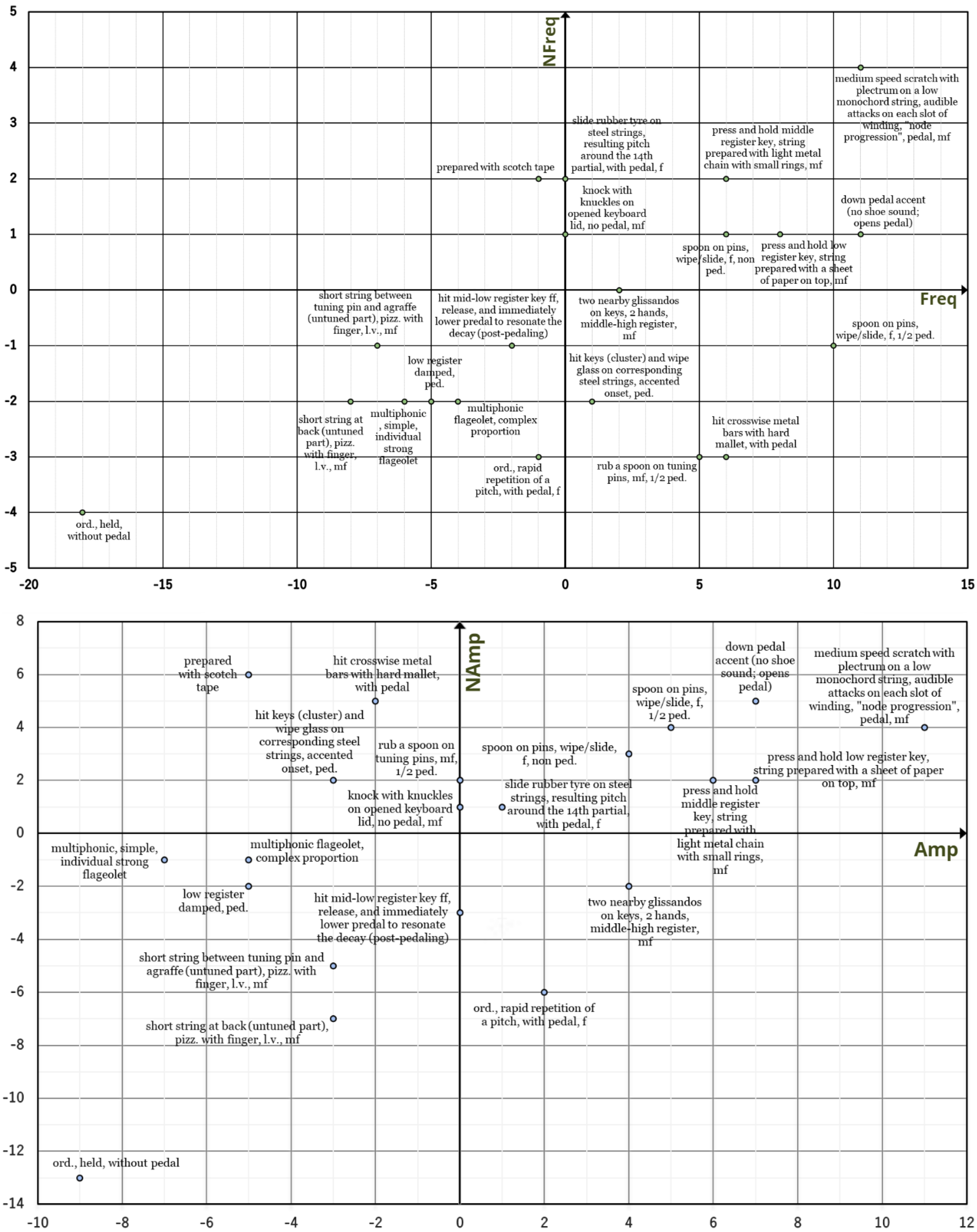


Fig. 3.2.1.-1. The three further different canvas versions of the grand piano timbres are shown: Temp – NTemp (marked with yellow dots in our charts), Freq – NFreq (green dots), and Amp – NAmp (blue dots). Each canvas version reveals different aspects of spectral or spectrotemporal phenomena and can group this set of sounds differently.

In formatting most charts, we will prefer to scale the distances on both axes similarly and to keep the canvas generally close to a square shape. However, the NFreq–Freq charts have a wider range of values on the Freq axis than on the

NFreq axis. This does reflect the fact that the Freq subtotal consists of a large majority of the descriptors, yet this large number of descriptors do not capture much of that differentiation in the pitch realm (both absolute and relative) that is addressed by existing analytical methods of interval-based music.

Hypothetically, when only one morphological axis is selected, and the other selected axis is not its complement, this means that the descriptors are presented at unequal weighting, and one could rather consider using an axis that shows which of the axis variants (for instance Freq or NFreq) differs more from the noisiness total. In any case, such axis choices are not encouraged.

For the rest of this subchapter, we will define the central terms for our analysis method.

A constellation is the collection of timbres presented in timbral space and the identifiable shape or shapes that they constitute. All timbres used in a piece or passage are equally members of a constellation – only a timbral (temporal) trajectory can give differentiation and meaning to them.

Constellations are shapes of timbral collection such as:

- sequence or chain
- circular (hollow inside)
- heap (high and even density, few outliers)
- one block (no outliers)
- set of blocks (each of them with solid borders and no outliers).

Cardinality of a timbre collection is the number of distinct timbres in the passage. Also timbres that are different yet share the exact same coordinate are counted towards cardinality.

Timbral habitat evokes a continuous area of timbral space that is used by a passage of music. Unlike constellation, timbral habitat considers area, not shape. Non-habitated areas are **gaps**.

In two-dimensional timbre spaces, it is possible to divide the timbral habitat of a piece into four large sectors (quadrants), either by building the sectors based on the axes, which may lead to different amounts of timbres in sectors (equal distances from an average value), or the borders of the sectors are adapted such that a same or similar amount of timbres are included in each sector.

Although this can help rough categorisation of timbres, this far no studied composition is built on such a division [130]. In the case of noisiness–TIV this division means

pitched intense	noisy intense
pitched non-intense	noisy non-intense

[130] If it were not for the quadrants, some other number of sectors than four would be available, or closed sectors that do not continue towards the extremes.

The timbre taxonomy and its related database, if it could ever be visualised in all its 15 dimensions, might cluster around some of the previously existing timbral taxonomies such as that by Pierre Schaeffer (1966), yet since that system attempted no scientific verification, **a listening test** with verbalisations of the degree of timbral similarity would be the only valid reference.

Some analyses of the compositions might evidence specific **timbral (temporal movement) trajectories** by which timbres move in timbral space respective to each other[131]. A timbral trajectory indicates the accessing order of the timbres used in a piece (Fig. 3.2.1.-2). It is reductive in that it does not intend to show the ends or durations of the individual timbres nor the overlaps between them. Returns and frequent repetitions can however be shown using arrows. To the two-dimensional timbral space one can add a third axis to show the temporal progress – a complicating mode of presentation which for the short passages we observe is not necessary. The term trajectory differs from voice-leading in that it **denotes strict chronology only and not necessarily smoothness of progression**; it does not claim a common instrumental source for the timbres traversed nor even that they are part of a particular listening strategy or thus part of the same auditory stream. In an analysis, potential ambiguous situations would have to be verbalised or the amount of parallel auditory streams studied with the score. For instance, sequences can be marked differently from simultaneous sounds, by numbers, arrows, and colours. Apart from the time aspect, timbral trajectories and constellations overlap conceptually and should be verbally defined by what is distinctive about them [132]. In this respect, the timbral descriptor criteria and the timbral trajectory strategies (in chapter 4) will follow a strikingly different logic and are only in a mutual hierarchical relation.

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131 A strong contribution in favour of accurate timbral descriptors and representations of timbral space would be if a listening study would yield positively correlating results, for example, after processing that data with principal component analysis (PCA). PCA cannot be conducted on paper and did not bring satisfactory results when applied to an early dataset. Other available statistics methods must be considered inaccessible for regular musicians, theorists, and composers to use in analysis. A test would yet not validate any theorisation about timbral trajectories. Any theory about timbral processes in any composition, using timbral descriptors, goes beyond the concept of timbral space itself.

132 After the initial stage that analyses timbres verbally and numerically, we should be cautious of a second step of numerising.

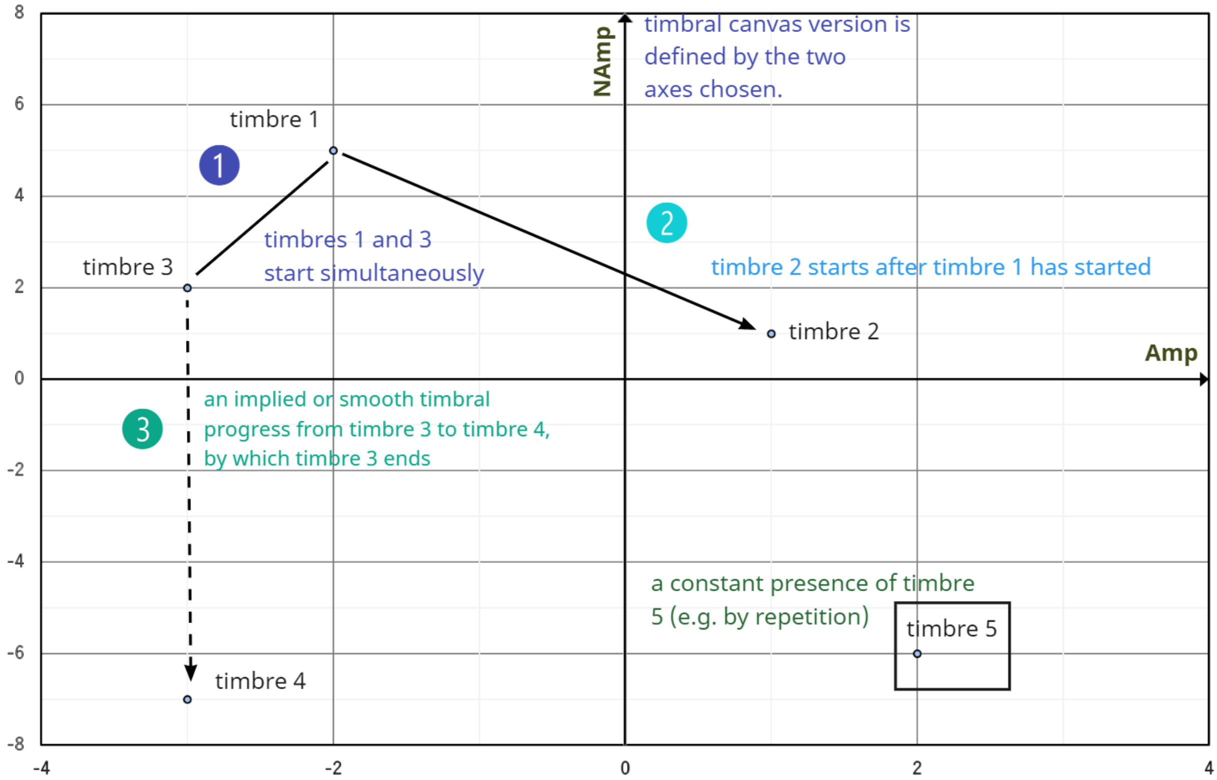

Fig. 3.2.1.-2. Timbral progressions 1 to 3 in an imaginary piece shown as trajectories on the timbral canvas, and their annotation. The points can be shown with their value, chronology, instrument, or timbre.

Our main 15 spectrotemporal descriptors can be **illustrated and reproduced quite faithfully in FFT space**, since the descriptors have very few features that do not correspond to time, frequency, or amplitude.

For the reader who needs to bridge the textual descriptions and conditions to the visual realm of FFT, in Appendix 3 we provide a visual representation of the 15 descriptors. It is necessary to understand their implications in listening and the sound signal, since these descriptors will find most use in our analysis. As was shown by the subtotals, some of the descriptors need all three dimensions while some can be understood in the spectral segments or snapshots without time information.

3.2.2. The noisiness–TIV canvas

Since TIV is calculated using the mathematical operation of variance, here we make the disclaimer that the range of possible TIV values is not entirely linear. Thus, TIV values do not have even meaning throughout the range of noisiness. Variance cannot yield large values on the extremities of the noisiness value range – in our case, when there are large values of noisiness or pitchedness. The widest range of different TIV values is found around the 0 value of noisiness. This resembles a Gaussian curve. These values are illustrated in Fig. 3.2.2.-1 below. The same minimum and maximum values also mirror for the negative noisiness values. The dips and peaks in the possible values are due to the non-even (15) number of descriptors.

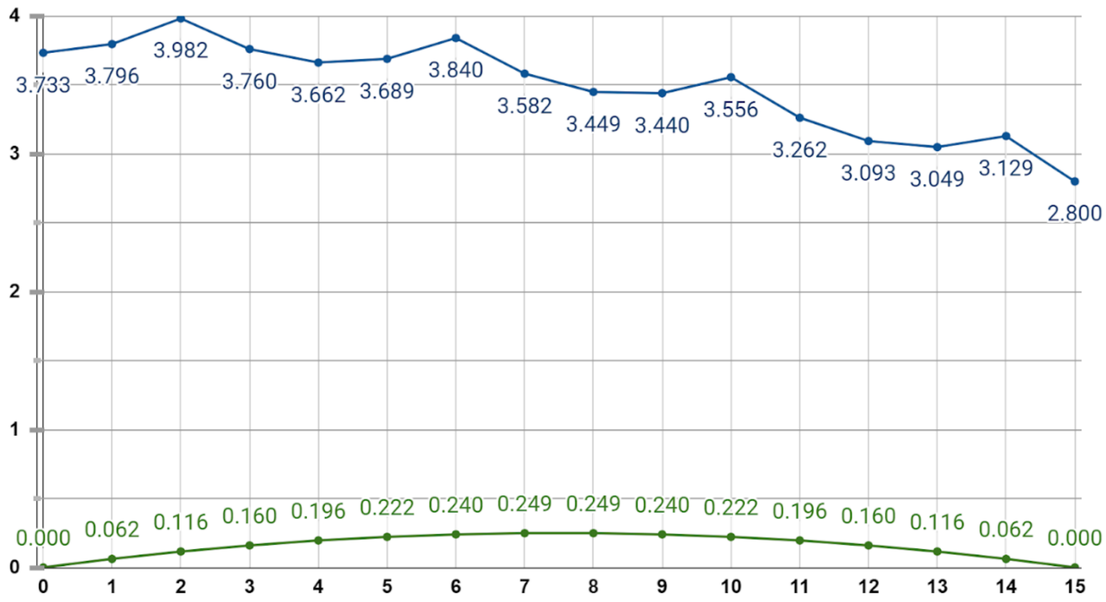

Fig. 3.2.2.-1. The largest and smallest possible TIV values (vertical axis) relative to noisiness value (horizontal). The same values also mirror for the negative noisiness values and for the values up to 30 and –30.

If we would like to counteract this inaccuracy, we could draw supporting "intensity" curves to denote different regions that are between the minimum and maximum possible TIV values at any point, for example at 25, 50, and 75 % of these values.

Inner timbral organisation of noisiness can be colloquially addressed as tension; **loosely tense timbres** display a great diversity among their descriptor values (TIV values 1.5 or more). **Neutrally tense timbres** display medium variance (TIV values between 1.0 and up to but not including 1.5) whereas **very tense timbres** have a value less than 1.0. The unevenness of the range of values that TIV can receive at different noisiness values is not taken into account, since a large region around the boundary values 1.0 and 1.5 is available throughout the noisiness scale.

To summarise, a large TIV value in a timbre means that the listener will need more cognitive categorical work to determine whether that sound is indeed pitched or noisy, since many descriptor values would seem to reject either interpretation at a time (this model also allows a Froise sound to receive a low TIV value). This effort translates to a timbral intensity that the sound has regardless of how loudly it is performed or whether it is brought into a dissonant interval for instance.

The TIV–noisiness canvas, of our four canvas versions, provides the technically most limited interpretations of timbral location and movement.

3.3. Approaching the analyses

The above reductive modules 1 and 2 of our analytical method aim to classify noisy sounds by reducing out the effects of exact pitch, which in our repertoire selection is not a highly salient feature. What essentially remains are the chaotic and non-linear features of noisy timbre perception and a straightforward effort to describe them in a linear numeric logic. We see this as an intermediate stage before further psychoacoustics study is conducted. We also want to keep the analytical system adequately open so that the third module of our method (in chapter 4) is able to depict constellations and movements timbral space [133] and explain the dramaturgy of Froise in this repertoire. This is done by allowing four different timbral canvas versions and not preferring on one of them only. The third module will be introduced as we systematically analyse the repertoire. We now address our selection of works.

From the composers who often compose noise-based music, we select for analysis in chapter 4 representative pieces from several categories, since there are limitations as to the available space. The chosen repertoire has been introduced as our basket 3 (in chapter 2). As the axioms underlying our selection, we require the following:

▪ at least one Froise sound must be present, and preferably long, repeated, or otherwise salient
▪ the passage can include pitches as long as it does not prefer pitch-based voice-leading (which is readily explained by other theoretical models) above sound-based
▪ Froise sounds must be used for their timbral features, not only for their pitched features
▪ the composer's sound intention is reflected in the notation and/or on the recording
▪ all timbres that do not merge or merge only partly are taken to be separate timbres (the effect of blend on the verbalization or numerisation of timbre has apparently not been studied and thus cannot affect timbral coordinates)
▪ timbral constellations, gaps, tensions, and trajectories in the timbral canvas are identified
▪ timbres will be analysed for their timbral descriptors instead of subjective associations
▪ two applicable totals or subsets of descriptors are selected as axes for a two-dimensional timbral canvas (space) that hopefully brings out characteristic differences between pieces.

The next subchapters prepare us for the analyses and for identifying (at an archetypal level) several possible trajectories for moving in timbral space.

3.3.1. Noticing timbral trajectories

The minimum requirement that allows us to annotate timbral trajectories on the timbral canvas is that timbres are moving to other timbres, and not only in a manner of alternation. The possibility of making routes in timbral space drastically increases along with the number of timbres used in a piece. However, our markings **adhere strictly to the order of sounds in the piece** and do not

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[133] Only after our analyses in chapter 4 can we find what determines the analytically most robust canvas version.

expect any implied connections. In our method, the duration of timbres can be only indicated as text. The way in which the timbres proceed determines the lines, distances and angles, yet the interpretative work as to which trajectory type(s) the passage constitutes is left to the theorist. Thus for analytical purposes, **four timbres should be set as a lower limit**, while pieces with hundreds of different timbres, of which most do not occur simultaneously, should be analysed in shorter sections. Only this way can we ensure that the trajectories we notice have a true basis in the listening experience.

The neural-cognitive, perhaps learned circuitry that we know from tonal functional degrees could be taken up for noise and timbral music, if we follow **the tension–release principle** as a line of inquiry. Crucially to this approach, the timbres need to have **different degrees of intensity**, either by their own **absolute** merit (read: TIV, noisiness value, subjectively strong associations, or pitch interference structures) or within the **contextual** entity of the steps used by the music (read: differences in a certain descriptor, intervallic distance from a centre, identifiable shapes, repetitions and so forth). Lacking evidence to the contrary, we should expect both absolute and contextual aspects to affect Froise listening, as they affect interval-based listening. The difference between **absolute and contextual is the difference between our modules 2 and 3**. Of the absolute features, we focus on the information that can be shown on one of the four timbral canvases; of the contextual features, we look for timbral centralisation, shapes, repetitions, and distances. When we observe the change of TIV values in time, we see both **static and dynamic** features of timbral tension and the difference-based domain of tension (difference in TIV); a large tension appears between one timbre of high TIV value and another of low TIV value, and this is static when both timbres are present, and dynamic when the presence of the two timbres changes in any way. Likewise, tension exists within a TIV value itself since variance is understood as tension, which here cannot be dynamic, only static.

Much more than in the absolute meaning of the timbres (module 2), only in the contextual way (module 3) could individual timbres in a timbral canvas bear stronger dramaturgy that is repeatable and where each trajectory can instil musical meaning. Much of tonal music consists of **hierarchically recurring** functional scale steps (as well as alterations of steps and chord qualities, prolongations, and permutations). Even much of atonal non-noise-based music for most part of the 20th century followed some principles of recurrence, gradation, and "rejuvenation", even though a general theory for this large and various repertoire is yet to be developed. Our analyses will show whether such variety can be witnessed also in the trajectories made by Froise sounds.

The visualisations are already filled by labels next to dots of the timbres. To be able to show such repetitive movement effectively by adding lines, the timbral canvases we use should not be overcrowded with timbres [134]. Timbres can be

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[134] We can compare that for a basic analysis of common practice tonal music, seven scale steps suffice before modulations, chromatisations and chordal settings are taken into account.

also abbreviated or marked with numbers corresponding to their chronology to keep the analytical visualisation clear. All audible sounds should be included[135].

Our analytical interpretations look for special cases in which the compositional organisation of the piece either supports or rejects (or is seemingly uninformed of) notions of timbral trajectory, including:

▪ one timbre is an outlier in two or more canvas versions. What does this mean for the voice-leading if the piece does not particularly underline that timbre?
▪ one timbre has an exact mediator/average value of all other timbres' values. Will this automatically mean a centralisation of that timbre, or can this be overridden by how the piece organises the sounds?
▪ two timbres mediate between two sides of timbral space (an alternation which is not simply between noise vs. pitch). How strongly is traversing supported by events on the musical surface? What do such shifts spell for musical structure?
▪ one timbral region has a much larger density of timbres, everything else being the same. How strong is such a grouping if the timbres in the dense region however behave differently and are not sequentially linked with each other in the piece?
▪ in the piece, only timbres of a certain timbral region vary (by value, number, articulation, duration, frequency). Is the tension from the behaviour of such a timbral group even larger than from the other absolute and contextual means of tension?
▪ the trajectory gradually becomes smaller or larger, thus locally the timbral habitat diminishes or expands. For how long is the identity of a trajectory still identifiable after modifications? What is the role of trajectories in defining temporary habitats and vacuums in timbral space?

We will also observe these special cases when our analyses identify and formulate standard **trajectory strategies**.

3.3.2. A timbral analysis checklist in module 3 of the analysis

For any analysed timbral passage, we can maintain a checklist (Table 3.3.2.-1) about its functioning.

Table 3.3.2.-1. Checklist for module 3, for interpreting timbral movements in noise-based works.

> ▪ number of distinct timbres (**cardinality**) and of smooth processes between timbres
>
> ▪ how evenly the timbres are distributed among the instruments
>
> ▪ what first remarks can be said of the share and behaviour of Froise sounds
>
> ▪ which identifiable shapes emerge within the timbres (**constellation**)
>
> ▪ in what relation are the positions of the timbres to the temporal

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[135] This also concerns any sounds that can be expected to ring from earlier.

segmentation in the passage (**trajectory**)

■ how many occurrences each timbre has, and if exact chronology is concerned, how long are these occurrences (**trajectory**)

■ if order is concerned, which moves in timbral space happen repeatedly (**timbral centricity and pivoting**)

■ the extreme timbres (edge points) in timbral space (for each timbral canvas used) (**timbral habitat)**

■ the distribution density of timbres in timbral space (for each timbral canvas used)

■ which timbre is closest to the canvases' visual average or weighted average coordinate (for each timbral canvas used)

■ which of the timbres are varied only slightly without affecting their descriptor values

■ which canvas versions have more explanatory power and why (as explained above)

■ how (little) the timbral distances on the canvas are related to instrumental aetiology of the sounds

■ timbral consistency and stability

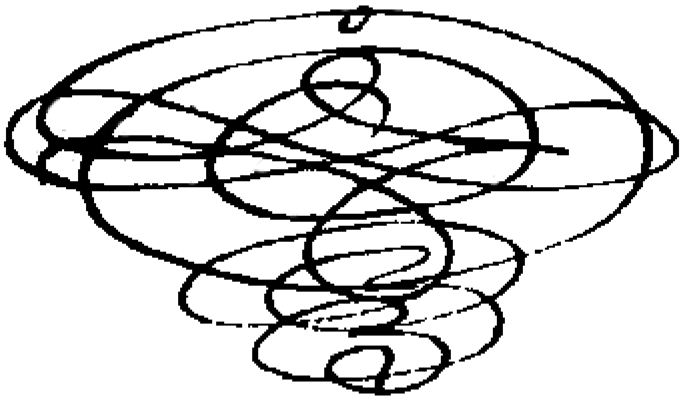
■ not strictly timbral organisation by means of texture and articulation, attacks, dynamics, and the frequency domain

■ inner organisation by means of spectral components' saturation, independence, and movement

We now refine the scope of analysis. We consider what the scope of our analyses should be, and how much our method can be generalised. By distinction to previous merely **descriptive analyses**, our numeric and visual method allows **explanatory analyses** to works of Froise music, as long as we think that "explanations can [...] trace development, analyse mechanics, compare, or assign causality." (MASON 2018:248). This follows conventional requirements in music analysis. Module 1 helps compare sounds, module 2 traces the movements between sounds from the mechanic viewpoint, and with module 3 we will strive to show causality. For us this means **showing that a piece displays an identifiable compositional strategy with timbral trajectories of noisiness, and that Froise sounds participate in that strategy with their unique mediating quality**. Chapter 4 will complete module 3 of our analytical method and identify such **timbral trajectory strategies** in the studied repertoire.

Since the concept of Froise is novel, we must be ready for honest criticism from any similarly not yet established fields, or eclectic combinations of fields. Eclectic criticism could include "any approach that seeks to extricate, translate, and selectively integrate analytic elements – concepts, logics, mechanisms, and interpretations – of theories or narratives that have been developed within separate paradigms but that address related aspects of substantive problems that have both scholarly and practical significance". (SIL & KATZENSTEIN 2010:10). Our transparent exposition of the method here and its relations to other fields (in chapter 2) will hopefully help us address points of criticism toward the method in chapters 4.5 and 5, after the analyses.

The next chapter corresponds to module 3 and is devoted to the analyses of our repertoire, using the freshly introduced two first modules of our analytical method.



4. Analyses of Froise repertoire passages

The previous chapter laid out two modules of our spectrotemporal analysis method. With the introduction of the **third module** in this chapter, we hope to show on any version of the timbral canvas that it can be technically used to reveal **voice-leading features of Froise and** new perspectives to the pieces. These are timbral features and strategies that can be found even in works that do not have Froise as their main material. The third module is first shown in outline, applied on the repertoire directly, and finally discussed.

4.1. Module 3: Analysis of movements on the timbral canvas

The third module of our method interprets in musical contexts the constellations, groupings, and trajectories that form between timbres. This is the deepest structural level in our analysis that addresses transformations and form-bearing by voice-leading, yet by difference to Thoresen's (2015) third level of analysis, does not attempt to link the timbral strategies to events in other simultaneous possibly supporting features of music such as rhythm, dynamics, motivisation, or pitch organisation [136].

Any movement on the timbral canvas will be considered as **timbral trajectories**. Regardless of the timbral canvas representation chosen, timbres will have distances to each other and their progressions have to be interpreted. We will consider at least the following eight movement and trajectory types that we can locate on any of the timbral canvas versions:

▪ **exact parsimony**: movement to the closest available neighbour timbre [137].
▪ **parenthetical**: different routes are taken, starting and ending with one and the same timbre. This timbre is not however used as often as to evolve into a centre in its own right, as would be in the centric type.
▪ **centric** (as a variant of the parenthetical type): repeatedly returns to one or two common timbres every now and then for "grounding" or pivoting; the centric timbres need not be close to the timbral average. Compared to the parenthetical type, arrivals to the centre in the centric type bear more sense of closure)
▪ **quasi-parsimony**: close enough neighbours yet not closest; contextually further than the closest possible timbre yet within the closest 40% of the timbres.
▪ **vectorial**: movement proceeds to one direction or along a line into either direction.
▪ **radial**: movement proceeds several ways to nearby timbres; often movement creates a circle clockwise or counterclockwise, other logics also possible. The route need not return to the original timbre.
▪ **grouping-based**: movement to timbres in the group or outside the group specifically.

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[136] Our scope will permit this only superficially, in chapter 5.
[137] calculations on the graph using Euclidean distance rather than city-block distance or Chebyshev distance. On parsimony as a principle, see SOBER 2005.

■ **non-parsimony**: movement to timbres that are not among the three parsimoniously closest options; any movement not explained by another trajectory type.

The identification of most sequential trajectories requires more than two timbral points to be included in the movement. These archetypal trajectories are eventually used to evidence trajectories that reflect some compositional strategy with Froise and/or gradations of noisiness. Using spectrotemporal analysis taxonomy by itself will not suffice, as is shown by Lyytikäinen as a writer about Froise:

"One could measure the concrete amount of noise in a sound, yet this will crucially not inform us about the function of noise in music. Thus our efforts should direct to relating noise and noisiness to the surrounding musical context" (LYYTIKÄINEN 2009:91, our translation).

We thus hope that the trajectories with noisy sounds, the constellations that timbres form in timbral space, and the more general strategies formed by all of this will reveal some of the functions.

4.2. Timbral trajectory strategies in timbral space

Our study of 12 composers' 18 passages of music resulted in timbral canvases four times that amount (72 charts), and a large taxonomic list of timbres. On applying the first and second modules of the method we identified trajectories on these canvases and found certain timbral trajectory strategies to be the most common. Some temporal progressions between the timbres can be difficult to show – for this reason, some of our analyses can maintain a linear approach in which one timbre unambiguously follows only one other timbre, and each timbre leads maximally only one timbre.

Since the five timbral trajectory strategies can be readily understood with a smaller number of examples, we give about three detailed timbral charts for each strategy. Here we present the data from our analyses and include only the most successful timbral canvases (we discuss reasons for the less successful analyses in chapter 4.5.). We then name the remaining canvases that also displayed that strategy. The reader is able to replicate with chart-formatting software all the results shown here (and more) on by referring to a score and/or recording, the numeric values of the used timbres in our timbral catalogue, and our analysis modules 1 and 2. Each timbre that you will see in the analysed passages is included in our timbral catalogue (Appendix 2), and thus the reader is able to map the timbres in any of the four canvas versions independently. For reasons of space, we will here include only those timbral canvases that bring the clearest results for voice-leading.

Some pieces only allowed the study of one line of timbre at a time, while some pieces progressed based on simultaneous combinations of timbres. Those pieces could be studied for both their features (which on a score or FFT visualisation are the vertical and horizontal). Their blending combination, an aggregate[138], allowed the vertical approach yet complicated the interpretation of chronology, since that point in the piece's chronology had several timbres. When we started each timbral analysis, we thus had to choose between two common approaches in analysis: **aggregate-based** (vertical or on the larger scale also segmentational) analysis or horizontal analysis of sequences of sounds, which we call **sequential**. We will abbreviate the first case as A since it deals with **identifying the groupings of sounds** that characterise a segment, block, topos, or trope, and thus occur close to each other [139]. The second, **sequential** approach (abbreviated S) observes **which sequences of timbres are formed**, typically based on the onsets of sounds. This is also the only approach for monotimbral solo instrument repertoire, while non-solo repertoire poses the most questions as to the most appropriate combination of these two approaches.

With each piece, we will mention whether its timbres can be analysed either as unambiguous sequences of timbres or as groups of timbres. The selections included works of different analytical difficulty levels. All initially selected pieces were analysed (see Table 4.2.-2) and did result in at least one clear result.

Table 4.2.-2. Works studied for this subchapter, the timbral chronology approaches used, and timbral trajectory strategies found. The explanation of TTS is given after the table.

Composer, work, instrumentation, passage(s) analysed [140]	Timbral chronology analysis approach; sequences-based (S) or aggregate-based (A) analysis; any reductions made	Which timbral trajectory strategies (TTS) were found most clearly, and in which versions of the canvas
Mark **Andre**: *auf...II* (2007) for orchestra; the final passage, m. 307– 427.	S. Our segmentation into four was confirmed by the composer: Segment 1: m. 307–342; 2: 343–368; 3: 369–411; 4: 412–427.	segment 1, noisiness–TIV: Grouped, with features of Merged

[138] Here, the term timbral aggregate is used solely to mean a combination of different instrumental timbres that has at least a shared onset and is massive and spectrally and spectromorphologically merging enough that individual instruments in it cannot be distinguished by the ear only. This term had its theorist proponents in the German term *Klangaggregat* in the writings of Christian Utz, including in Lexikon Neue Musik (HIEKEL & UTZ 2016). The term has a perceptual focus and makes no implications as to the nature of the sounds, their duration, or structurality. SKÖLD's (2017) "Harmony of Noise" is a similar concept.
[139] We will trace the segmentation again in chapter 5.
[140] For the compositional focus in chapter 5, an integration with my own compositions was planned since my most relevant Froise-based compositions were finished simultaneously as this analytical method took shape (particularly *Plainte* (2020) for vocalists, *Riss* (2021) for ensemble and clarinet solo, and *into these worldless houses* (2019–2020) for sextet). Although these works did not explicitly use the entire method, they may intuitively follow the timbral taxonomy and thus a comparison with these compositions might unequally skew the results with the repertoire.

Antti **Auvinen**: *Autuus* (2015) multimedia opera for amplified singers and amplified quintet; three segments from the second act: m. 858-882 (choir), 882-906 (bfl. and cb-cl.), and m. 907-916 (choir).	S. Acoustic elements, electronics presence is negligible.	segment 1, noisiness–TIV: Linear. segment 1, Amp–NAmp: Nuclear with outliers. segment 2, noisiness–TIV: Linear. segment 3, noisiness–TIV: Nuclear with outliers. segment 3, Freq–NFreq: Nuclear with outliers, with features of Solar with groups.
Carola **Bauckholt**: *Atempause* (2000–2001) for orchestra; m. 1–56.	A. Clearly defined timbral stations are evident and their particular texturation plays a negligible role.	noisiness–TIV: Merged, with features of Nuclear. Freq–NFreq: Merged. Amp–NAmp: Merged.
Chaya **Czernowin:** *Sahaf* (2008) for saxophone (or clarinet), electric guitar, piano and percussion; m. 88–114.	S (and A, some attacks are simultaneous without blending). Part of the piece's instrumentation is free – we take it to have a tenor saxophone.	noisiness–TIV: Merged, with features of Nuclear. Temp–NTemp: Linear, with features of Nuclear with outliers. Freq–NFreq: Nuclear with outliers, with features of the Solar system. Amp–NAmp: Nuclear with outliers.
Beat **Furrer**: *Wüstenbuch* (2010) for ensemble and stage performers; mvt. 5, the repeated cycles 1 and 2 (m. 1–12), and 6 (m. 69–96) of the string corpus.	S. The string instrument body has several simultaneous layers; only changes of timbre are shown.	cycles 1 and 2, Amp–NAmp: Linear.
Helmut **Lachenmann**: *Schreiben* (2003) for orchestra; m. 136–155, marked	S. The considerable amount of doublings is not taken into account.	noisiness–TIV: Merged. Temp–NTemp: Grouped. Freq–NFreq : Merged, with features of Grouped.

"deutlich hörbar".		Amp–NAmp: Grouped.
Gérard **Pesson**: *Catch Sonata* (2016) for clarinet, piano, and cello; m. 184–211, at ca. 10:20…11:14 on the recording.	A.	Pesson Amp–NAmp: Linear.
Horațiu **Rădulescu**: *Thirteen dreams ago* (1978), for 11 strings and two tapes; three consequent aggregates 0:00 to 5:50 (manuscript pages 1–6).	A. The electronics is not taken into account. Since the results of individual parts are highly unpredictable, we analyse only the changes at each new aggregate.	Temp–NTemp: Nuclear with outliers. Amp–NAmp: Nuclear with outliers.
Fausto **Romitelli**: *Seascape* (1994) for Paetzold recorder; a prominent timbral cycle at top of page 2 of the manuscript, from about 2:25 on the recording.	S. The piece realises a continuous variation of cycles of timbres and creates a myriad of timbres; we analyse some of the most identifiable timbral cycles	noisiness–TIV: Solar system with groups, with features of Grouped. Temp–NTemp: Grouped with features of Linear. Freq–NFreq: Grouped. Amp–NAmp: Grouped.
Kaija **Saariaho**: *Six Japanese Gardens* (1993–1995) for percussionist and electronics, mvt 6 “Stone Bridges”; percussionist passages.	S (globally) and A (locally), since we will not address the rapid texturation that reorders timbres that are already sounding. We analyse all five passages in which the percussionist plays. Electronics and percussion hardly ever overlap and the electronics part is not analysed.	noisiness–TIV: Nuclear with outliers. Temp–NTemp: Merged. Freq–NFreq: Nuclear with outliers, with features of Merged. Amp–NAmp: Nuclear with outliers.
Salvatore **Sciarrino**: *Quaderno di strada* (2003) for baritone and ensemble, mvt. 13.	A, since segmentation is clear throughout.	noisiness–TIV: Merged.
Agata **Zubel**:	S. This kaleidoscopic canon	noisiness–TIV: Solar

Cascando (2007) for quintet (fl., cl., voice, vl., vc.), mvt. 3.	touches upon most available timbral combinations. It is unclear which combinations are intended as structurally central or if aggregation grades are the main question. The instrumental parts abide by a logic which we analyse.	system with groups (without sun). Temp–NTemp: Merged. Freq–NFreq: Nuclear with outliers. Amp–NAmp: Merged.

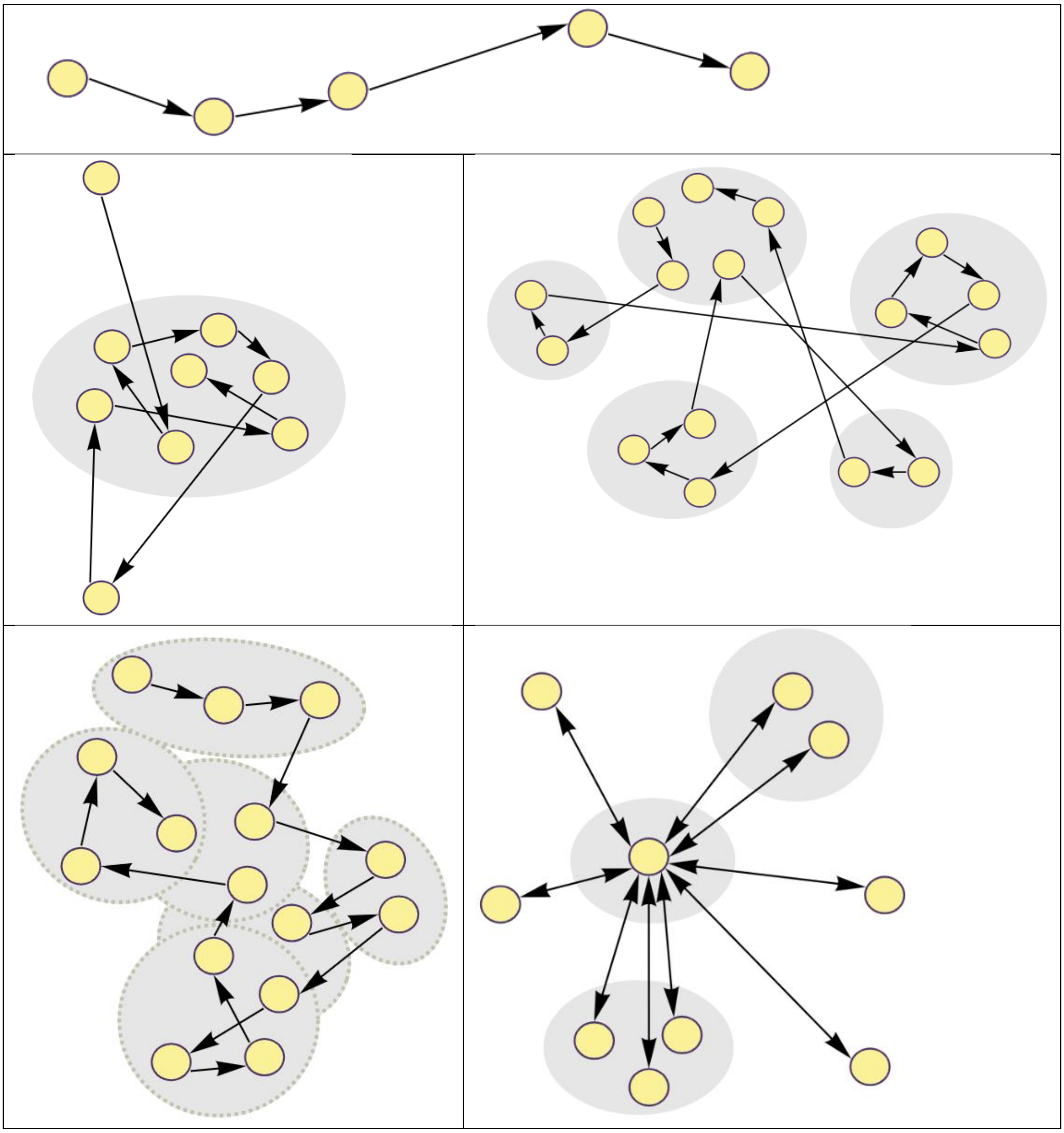
This chapter lays out the results of the analyses, by roughly grouping these works from several styles of Froise composition into more general strategies with timbre space. This is akin to the first steps taken by a music theorist. Chapter 5 opens the discussion for problematisation, questioning, and speculation related to the analyses. This addresses the prospects for composers and listeners.

We present our five found strategies **Linear, Nuclear with outliers, Grouped, Merged,** and **Solar system with groups**. Each timbral trajectory strategy depends on which constellation is observed, and which types of trajectories are taken the most often. Which of the timbres are accessed most often will also affect categorisation of the strategy. Since timbral constellations are seldom geometrically pure and our analytical method has its known irregularities, the strategies should be primarily based on which trajectory types are used the most. The eight trajectory types are (ideally) found at different proportions. For example, a strategy that we call Linear will mostly consist of the trajectory types "exact parsimony" and "vectorial", and while "parenthetical" is also occasionally present, the other five trajectory types are not used at all by the Linear strategy. For the needs of theorists, we visualise these strategies in Figure 4.2.-3 and discuss the variants they can have in real music with the analysed passages.

Similar understandings of music proceeding in abstract timbral space are rare, yet one similar concept can be found illustrated in a chart for "Five improvisational structures'' by MERMIKIDES & FEYGELSON (2017:190) [141]. Our set of five strategies more accurately describe pieces that can be analysed in the sequential approach, since the aggregate-based approach creates several movements at a time and does not indicate hierarchy between the movements.

[141] The writers speak on an even more abstract level, about improvised musical material that has yet to exist. The chart shows movement types in space: "1) 'Nuclear': phrases, with only occasional small anomalies, fall within one close field with only minor variances. 2) 'Field Series': close phrases are played a few times with variances before repeating the process at a different point in M-Space. 3) 'Pivot': one particular narrow field is played often, acting as a springboard to various satellite fields. 4) 'Merged': fields are merged by the use of a transitional phrase of otherwise distinct phrase fields. 5) 'Unbounded': a series of phrases with little proximity of one phrase to any other" (MERMIKIDES & FEYGELSON 2017:190). While these movements can be transferred to timbral space, only four of their movements were found in our analyses. To these options, we have added the more rarely found "Linear" strategy, and we rename some strategies.

Figure 4.2.-3. The timbral trajectory strategies in idealised form, from above to below, left to right: Linear, Nuclear with outliers, Grouped, Merged, and Solar system with groups.



The visual idealisations of the strategies derive from MERMIKIDES & FEYGELSON (2017:190), and some of the strategy labels are indebted to them. A detailed generalisation of these five trajectory strategies will be given in chapter 4.2.6.

From these generalisations, we can see that each trajectory strategy prefers certain trajectory types to others and can occur on any timbral canvas version.

We displayed all four types of canvases in chapter 3.2.1., and saw that the same set of timbres would position slightly differently in each canvas, and would create a different constellation, and some trajectories would be interpreted differently. The order of the timbres however always follows the composed chronology, in all the studied pieces.

It is only necessary to show for each piece those canvases whose results most clearly reproduce one of the strategies, show a compositional dialectic typically based on the noisiness grade, and give insights into the use of any timbres on the Froise region. We can make exceptions to only the first condition of the three, when a canvas displays features of two strategies simultaneously. Each piece's each canvas produced a combination of the eight trajectory types and a constellation, yet not each canvas gave otherwise satisfactory results on the three conditions. We lack the space or the need to show full sets of four canvases for any piece.

Here we must note that the canvas for intensity by timbral internal variance (TIV–noisiness) shows noisiness gradations most clearly, as horizontal movements, while the three spectrotemporal canvases (Freq–NFreq for frequency, Temp–NTemp for durative, Amp–NAmp for amplitude) show noisiness diagonally in a way which may seem at first unintuitive. All four canvas presentations capture different aspects of the changes in noisiness and about accessing, departing, and linking the Froise region.

The five following subchapters proceed to list the **five timbral trajectory strategies** in **generalised form with supporting analyses** and compositional implications. We will then return to refine these strategies' definitions.

The collection of timbres found in the analyses is large and listing the eight numeric values for each would be irrelevant here. With the notation (part of the editions are reproduced in Appendix 4), the exact timbres can be matched to items in our instrumental taxonomy (Appendix 2).

4.2.1. Strategy 1: Linear

a) Furrer, cycles 1 and 2: Amp–NAmp

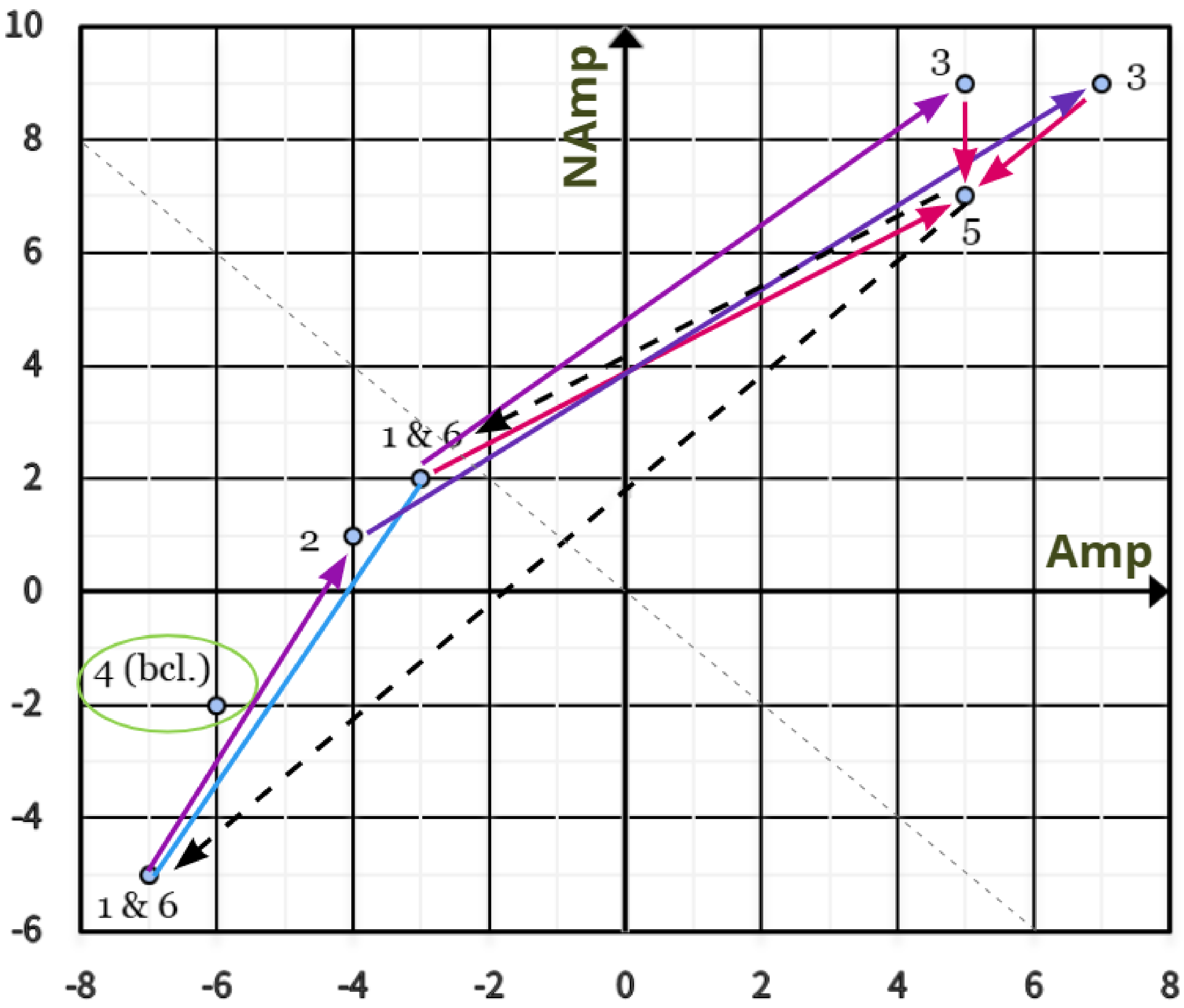


Fig. 4.2.1.-a. Furrer's cycle 1 and 2 on the amplitude canvas. Note that stage 3 has two distinct instrumental lines.

In pieces of the timbral trajectory strategy Linear, vectorial movement and exact parsimony are most common. In this passage by Furrer, all vectors except the one from point 3 to 5 that is implied (since it is interrupted by point 4) can be counted under one vector that is rather diagonal and similar to the noisiness grade diagonal. Indeed, the movement from 5 to 1 aligns exactly with the noisiness diagonal. We could mark even the contextual outlier (point 4) that overlaps on the audible surface, and it would align with these vectors. In that case, all movements would traverse the Froise region. The points occupy a unified timbral space that in itself is of a linear shape and shows two noise and Froise sounds each and three noise timbres. The general grouping of timbres however is twofold, on both sides of the Froise divide. This canvas version may be the most accurate to indicate the timbral implications from this piece's great dynamic range and nuanced changes that happen in a short time (both on the musical and morphological level). Since this canvas shows two cycles, the general trajectory is also parenthetical. The other five trajectory types should be absent in the Linear strategy and indeed are.

In an optimal **listening** that most adapts to this strategy, these trajectories may be heard as an association of four distinct locations of sounds, with mostly imperceptible seams in between, and with the largest location being the furthest from the starting location.

b) Auvinen, segment 1: noisiness–TIV

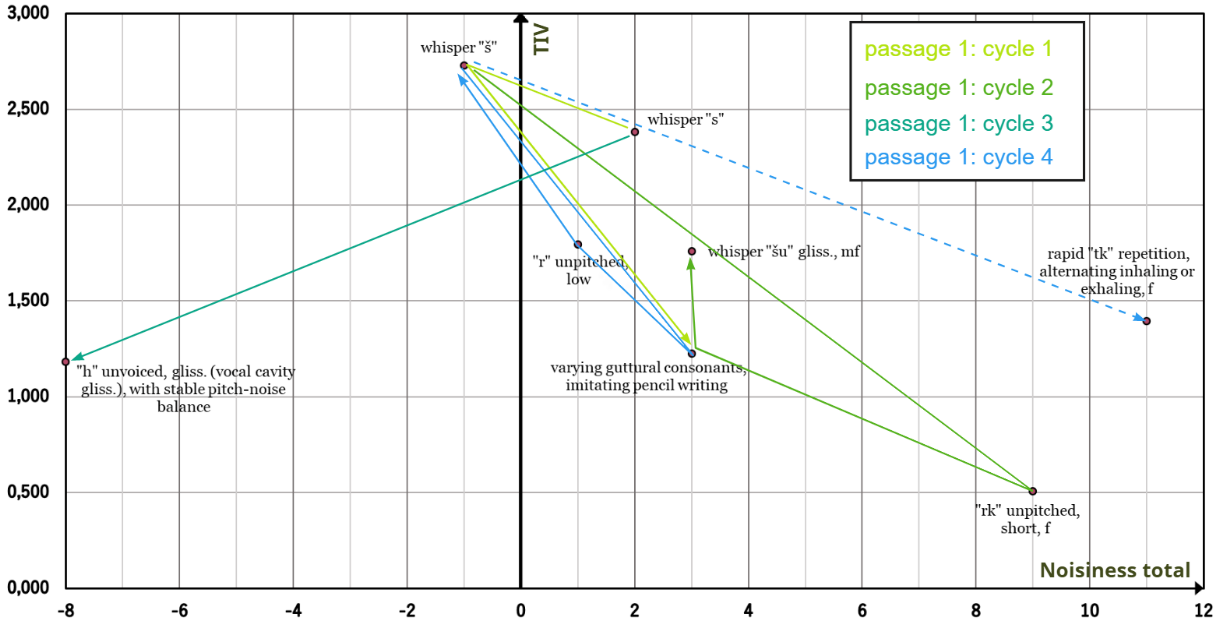


Fig. 4.2.1.-b. The timbral intensity and noisiness canvas of Auvinen's first segment for choir.

Another example of the Linear strategy comes from the first segment of the multimedia opera by Auvinen. The first cycle introduces three diagonal vectors. Two of them have almost opposite angles (cycle 3 versus cycles 1, 2, and 4). As to the vectors within the cycles 1, 2, and 4, one of them mostly changes the TIV count while the other affects the noisiness count more. While cycle 3 mirrors the movement of the vector that proceeds more in noisiness. As an exception yet not an outlier, the last movement of cycle 2 only changes the TIV component, and may be a variant of how the same timbre will proceed in cycle 4. All cycles combine a noisiness grade dialectic with timbral tension (TIV), and the most accessed timbre is a Froise sound with the largest tension. While most sounds are Froise, the one pitched sound (in cycle 3) is introduced close to the two noisy sounds (cycles 2 and 4).

The noisiness–TIV canvas excels here since the timbres proceed unlayered, clearly segmented, and the passage uses most timbres only once.

Akin to the Linear strategy's typical constellations, there is no strong grouping, and the trajectories realise the exact parsimony as well as vectorial types. The cycles (apart from for the third cycle) are themselves parenthetical yet not hierarchical enough to be centric. The other five trajectory strategies are missing, as expected.

In very concentrated **listening**, any movements that start from the whispered "š" sound could come across as the most striking and the unvoiced "h" sound could form a turning point that can be the least related to the preceding sounds.

c) Auvinen, segment 2: noisiness–TIV

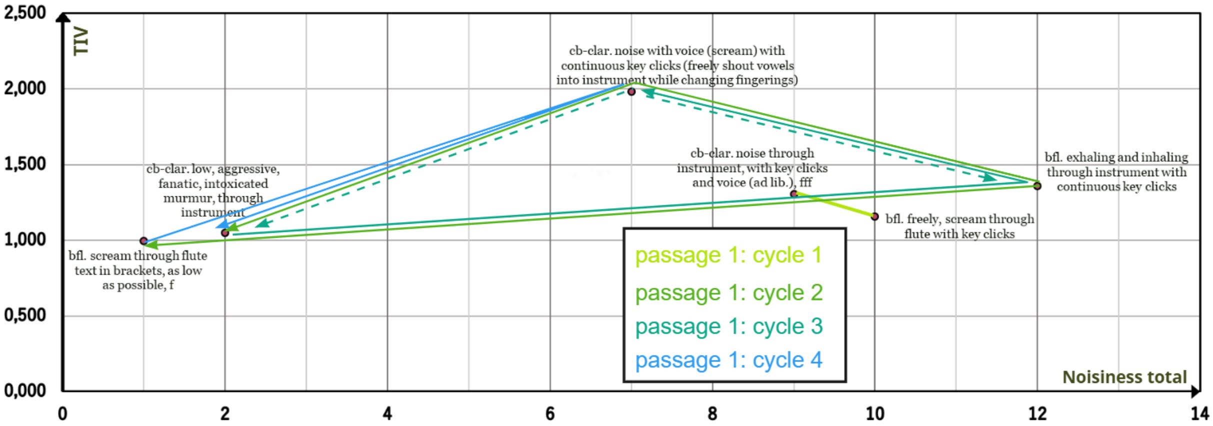


Fig. 4.2.1.-c. Auvinen's segment for contrabass clarinet and bass flute.

In this 3-minute excerpt by Auvinen, now for two instruments, half of the sounds are Froise while the strong **noisiness dialectic** in each cycle in general occurs without pitch region timbres. While the two instruments occasionally are timbrally close to each other, no timbres are outliers. The TIV–noisiness canvas now has explanatory power thanks to the clear timbre-based segmentation and stable nature of the timbres despite the constant activity.

From the two instruments, two timbral pairs are established (cycle 1 gives a diagonal vector as the combination of timbres, and the ending position of cycle 2 gives a mostly horizontal vector) and their vectors are used in both directions, and in the second case that vector is also reproduced elsewhere. Both long and short timbral distances (particularly in simultaneous combinations of the instruments, for exact parsimony) are used, which lends credibility to the vectors. The third vector likewise affects noisiness and TIV yet only makes up cycle 4 and parts of the earlier trajectories. This specific use of the vectorial trajectory is nonstandard however, since clearly different vectors are combined to create parenthetical movement. Centricity, groupings, nor a single preferential timbre does not emerge. As expected, the five other trajectory types are not present.

The light presence of the electronics ostinato as interludes (that, if acoustic, would equate to the Froise region and a medium TIV value) will frame our **listening** of the instrumental trajectories. Each trajectory starts and ends with the two instruments perceivably close to each other and the large differences in the accessed timbral regions lend them even more salience. Whereas the starting situation and the subsequent combinations can deeply agitate the listener, the duo with Froise timbres is sensed as a closure. The noisiness count is likely to affect listening to this passage more than the TIV count.

d) Pesson: Amp–NAmp

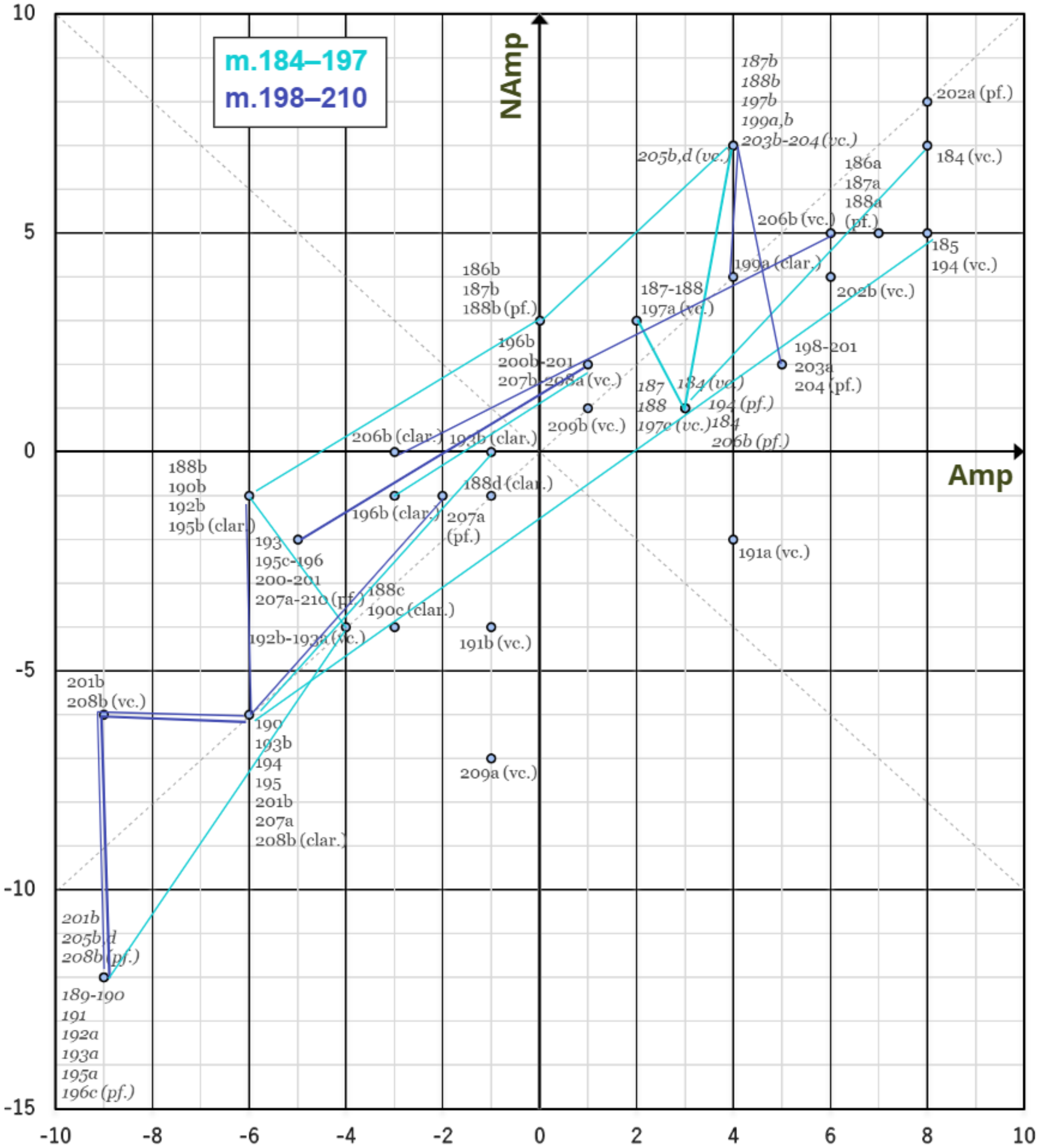


Fig. 4.2.1.-d. Pesson's amplitude morphology canvas. The lines show aggregates.

This excerpt from the middle of Pesson's trio composition introduces at a rapid pace mostly timbres that had not yet occurred in the piece. These situations are arguably perceived vertically, since the order of timbres emerging in the three parts is unsystematic, and most auditory streams are not supported enough by pitch, motifs, or dynamics to transfer from one textural-timbral block to the next. Amid this discontinuity, the stability of the few chosen aggregates becomes crucial.

The aggregates are shown and the numbering shows the chronology by measures. Since this piece uses timbres both in fast succession and as aggregates, the presentation might become crowded very soon.

It is deceivingly easy to evidence the horizontal, vertical, and the two possible diagonal vectors in this piece. Our interpretation comes as Linear since clear groupings do not emerge, the constellation itself is linear (neatly following the noisiness axis) and not many trajectory types are used contrary to this: most movements and aggregates are exact parsimony and vectorial, while those movements that are neither can be explained by their participation in a parenthetical trajectory. The other five trajectory types are again not evidenced.

Of the three vectors, one's diagonal aligns with the noisiness count while another two are perpendicular to this or aligned with the NAmp axis, both starting from (-6, -1) and are replicated on the noisy region. All instrumental duos that are aggregates carry one of these vectors and two of them have a strong noisiness grade dialectic.

Most sounds are Froise, and the divide is clearer against the two pitched timbres, while the noisy region connects with the noisy-Froise. The aggregates may be the most audible to the listener who can follow both the noisy and the pitched member of the aggregate in most cases. The distances between instruments are probably not distinctive enough to be heard, and thus the most repeated pitched sounds (clar. and pf.) and the most repeated noise (vc.) sound may become memorisable anchors for listening.

The amplitude canvas is an apt tool thanks to the wide dynamic range between the agile instruments, nuanced changes in a short time, accentuation, and the natural rapid decays on the cello and piano, of this Pesson passage.

Timbral trajectory strategy summary

For the theorist, these four passages were most exemplary for the Linear strategy. We also found this strategy in less polished form in the passage of Czernowin in the Temp–NTemp canvas (with features of Nuclear with outliers).

Generally, the identification of these pieces as Linear takes our analysis from descriptive to explanatory level. Due to this trajectory strategy, other trajectories than exact parsimony, vectorial and parenthetical were not found at all, while some were more than others, and this had implications for the hierarchy between timbres.

Identification of lines involves interpolation just like lines have been our basic way of notation on the timbral canvas. This makes the linear strategy easy to identify. Yet linearity must be interpreted strictly to not read all trajectories and aggregates as constituting a similar vector as somewhere else. The easiest way to identify the linear strategy, if vectors cannot be reliably determined or compared or if doubling of timbres is involved, is the absence of any other timbral constellation; there are no structurally or audibly significant groups, nuclei, or centers in this strategy.

It has been surprising how many linear and vectorial features were found from composers who did not have access to this taxonomy nor to these timbral canvases. These composers may have strongly thought in terms of noisiness, which would have brought about lines that particularly retain a very similar intensity value (TIV) or noisiness value. Such linearities often pass through the Froise region. Lines that are aligned similarly to one axis and thus retain (mostly) one coordinate value while the other coordinate changes, may also be easier to perceive than lines in which both coordinates change clearly by each new move.

Since lines are our visualisation of timbral movements from one timbre to another, many of the charts risk being over-interpreted as having the Linear strategy. However, linearity requires the use of some vectors to both directions, and the use of similar vectors in different locations in timbral space (thus between very different timbre pairs than the first one).

Linear strategies may be the most schematic and simple **to compose**, especially with the help of the timbre catalogue. For dramaturgy, they may however bring limitations to the size of timbral steps taken, how many different vectors may be introduced, balanced uses of timbral regions, as well as the profiling of timbral regions. This strategy is the closest to many theorists' such as McAdams' (2019a & 2019b) ideas of vector movement in timbral space. The Linear strategy particularly limits the variety of different Froise sounds used, since the Froise region is small and central and any inaccuracies in the vectors' angles will be less permissible for a Linear strategy than when vectors proceed between edge regions of a canvas.

Even though timbral vectors have been a *fascinosum* for theorists, there is little reason to expect that many vectors in a piece would be perceivable in **listening.** Rather, the ultimate compositional contribution of this strategy is a limited selection of progressions and aggregates that often cover a large stretch of timbral space. These are contextualised by the use of leaps (of a similar vector) between different timbres in that same timbral space.

4.2.2. Strategy 2: Nuclear with outliers

a) Auvinen, segment 3: noisiness–TIV

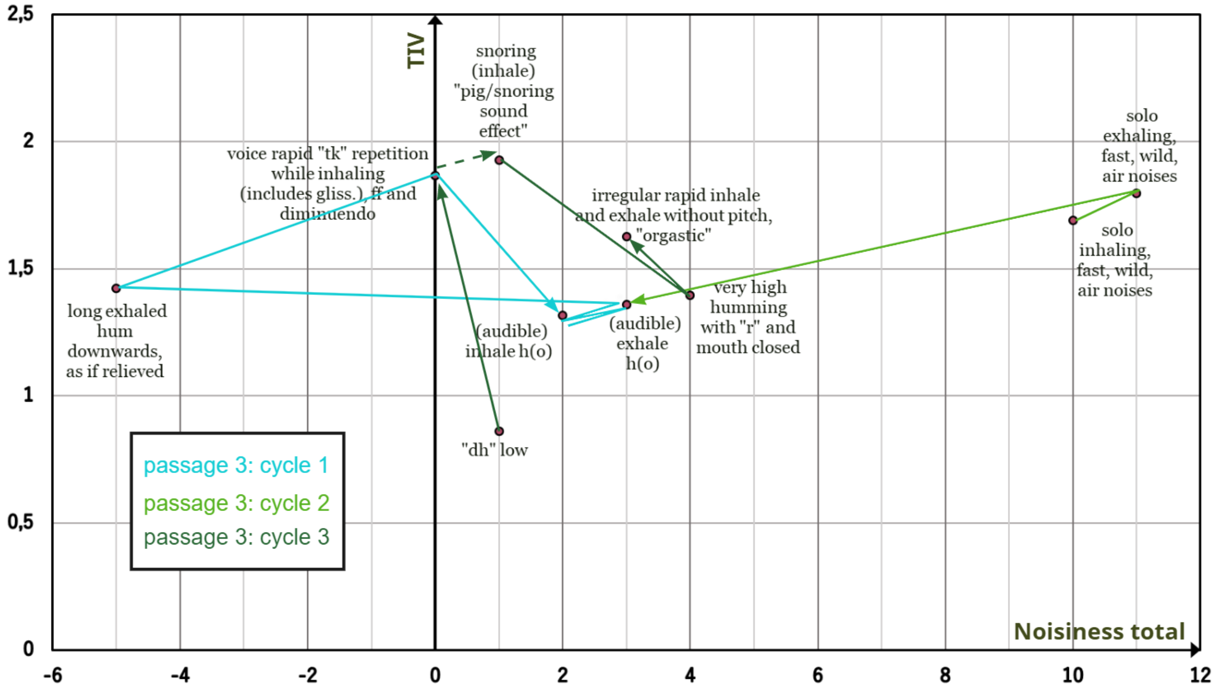


Fig. 4.2.2.-a. Trajectories of vocalist sounds in Auvinen's segment 3.

This vocal passage by Auvinen displays a clear preference for the Froise region: only two very separated timbres are noise, and even the most pitched sound is Froise, at the value −5. A very balanced middle region in Froise is either the starting or ending point of all trajectories. Segmentations are supported by changes between *tutti* and *solo*, as well as long pauses, less by dynamics changes. The segmentation between the cycles 2 and 3 should be considered elliptical.

Some trajectories share similar vectors, yet they are among the rarer features of the Nuclear with outliers strategy. More typically, exact parsimony, quasi-parsimony, and grouping-based (nucleus vs. those timbres noisier or more pitched than the nucleus) are the standard components of the trajectories. Passage 3 is radial, passage 2 parenthetical to the nucleus. Non-parsimony occurs once in each cycle. Centricity is absent, as is expected for this strategy.

Most timbres are single-use; only three timbres are used more than once. These form a salient part for the trajectory of each cycle. The nucleus includes at least the medium-intensity values for breathing sounds (at noisiness values +2 and +3) and their nearby neighbour at +4. Except for one timbre, the other timbres are also more intense than the nucleus timbres. Noisiness proceeds dialectically as the opposites pitched-Froise and noise, and ends with their balance, noisy-Froise close to the nucleus.

Listeners may find the expectation of a central Froise sound of medium tension (corresponding to the nucleus) at every structurally important moment in the phrases rewarding. This expectation is upset perhaps only five times when the largest deviations occur (once in cycle 1 to pitched-Froise, two timbres first failing to exit noisiness in cycle 2, and twice to less intense and more intense Froise in cycle 3)

This canvas version thanks its clarity to the one-layeredness of the music, steadiness of the timbres, and small amount of repeated timbres. In listening, the nucleus timbres may make the most memorisable associations. If not all small timbral differences are perceived, the three cycles may be heard together as if a pendulum movement.

b) Auvinen, segment 1: Amp–NAmp

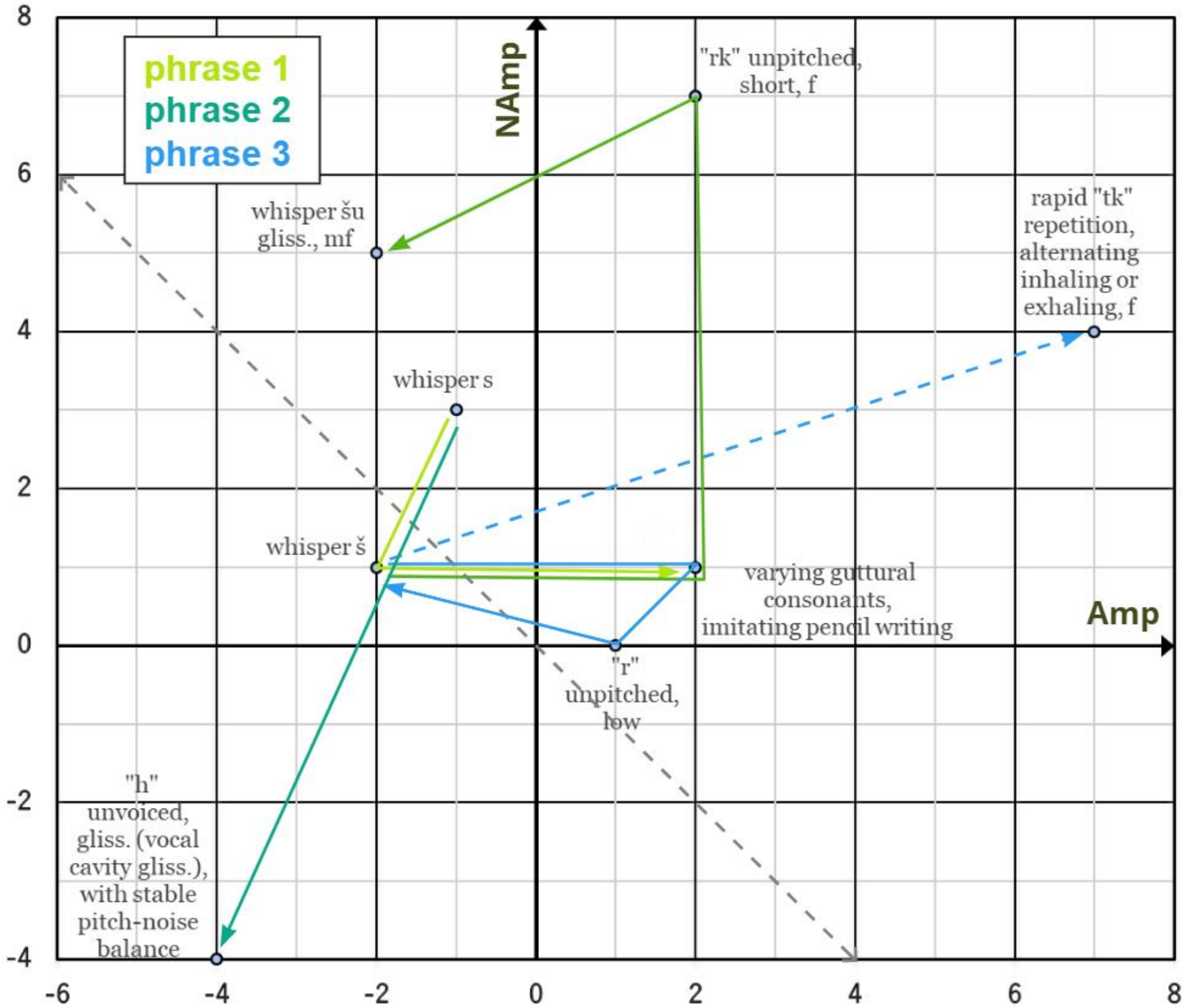


Fig. 4.2.2.-b. Auvinen's first segment, shown here for its amplitude morphology.

A passage by Auvinen that was analysed in the Linear strategy shows now in this canvas more consistent recurrence to and a centrality of Froise timbres, which points to the Nuclear with outliers strategy. The nucleus is formed by, depending on interpretation, three or four Froise timbres that are most central, while there are four outliers to each side, differing in noisiness [142]. Due to its similar Froise value, even the timbre at (-2, 5) could be included in the nucleus.

[142] Note that the noisiness–TIV interpretation of this same passage above led to the absence of a nucleus and the Linear strategy.

The more distant timbres play a subsidiary role in the phrasing yet an important balancing role for the timbral rhythm. Most movements are radial, which is only a secondary trajectory type for the Nuclear strategy, yet the primary strategies exact parsimony, quasi-parsimony, and grouping-based) are also found. Non-parsimony and parenthetical are found less commonly while centricity not at all. This is in keeping with the ideal model of a Nuclear with outliers strategy.

This canvas version was representative due to this passage's wide dynamic range, accentuations and nuanced changes in a short time. All three cycles cross the noisiness divide; in all, the noisiness progression is the same as mentioned in the previous canvas made of this passage.

A listener may find after hearing the first cycle that the Froise location of the nucleus should be memorised (as one group if not separately) since they will cross between noisiness and pitchedness, occur often, and movements outside them are clearly away from Froise and dramaturgically differentiating. At the latest, the one-time occurrence of the *"r" unpitched, low* timbre may serve memorisation.

c) Rădulescu: Temp–NTemp

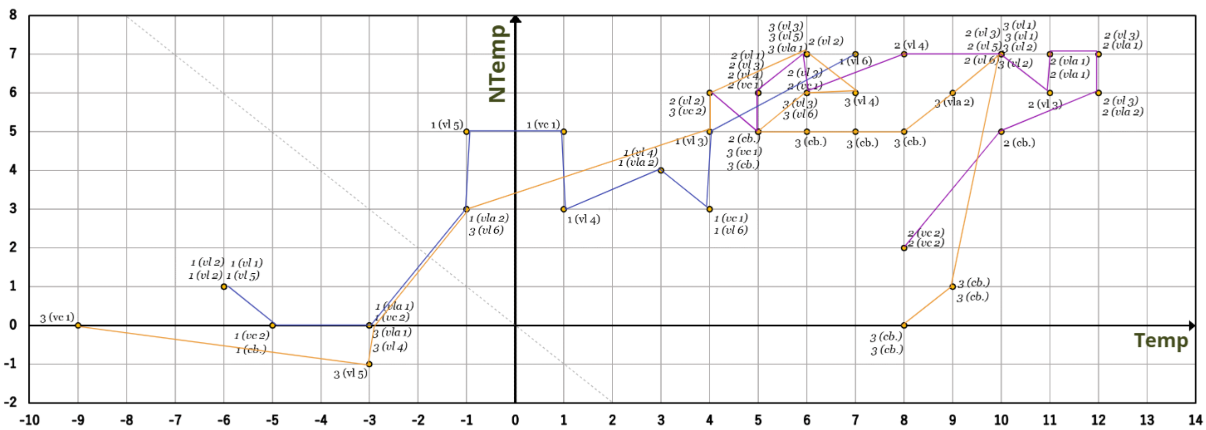


Fig. 4.2.2.-c. Rădulescu's three first stations on the durative morphology canvas.

Here we observe the three first (relatively) steady timbral collections composed by Rădulescu. The weight of the string corpus is on somewhat noisy timbres, many of which are doubled. This dense nucleus stays throughout the three, even though no timbre occurs in all three collections. In fact, the second collection is a Froise-deprived and constricted version of its precedent and subsequent, spread around the same nucleus, making a local ABA progression in terms of noisiness. Few instruments play pitched timbres, and Froise also results from the chaotic combination of 13 different timbres at the same time, and the fact that some parts also have internal alternation of timbres. The outlier timbres in the Froise-focused collection 1 are pitched while in collection 3 also noisy. In addition, the third aggregate ends with a solo double bass multiphonic, which would have a coordinate (-3, 0) that coincides with already many timbres from the first and third aggregate. The observation of changes in individual parts as sequences brought no conclusive information about voice-leading - thus we only study the collections here.

The correspondence with this strategy's typical nuclear constellation is clear, yet trajectories in the 13 instruments are most likely inaudible and lost in this massive and timbrally saturated texture. However, the groupings do not form large gaps, such that it remains possible to hear the timbral collection as a chain built on exact parsimony, quasi-parsimony, and occasionally non-parsimony. Movements in individual parts that alternate between timbres will form radial and parenthetical trajectories, albeit unlikely to be heard. Vectorial similarities are rare, and the nucleus does not host any centric trajectories. The listener is at each new aggregate more likely to first adjust to its focused region on the canvas (which brings the general ABA perception of voice-leading relative to the presence of Froise) and only then listen to differences in timbral density.

The generally fast pace of timbral shifts, made of variations of any size and in several instrumental parts likely contributed to the explanatory power of this durative canvas version.

d) Saariaho: Amp–NAmp

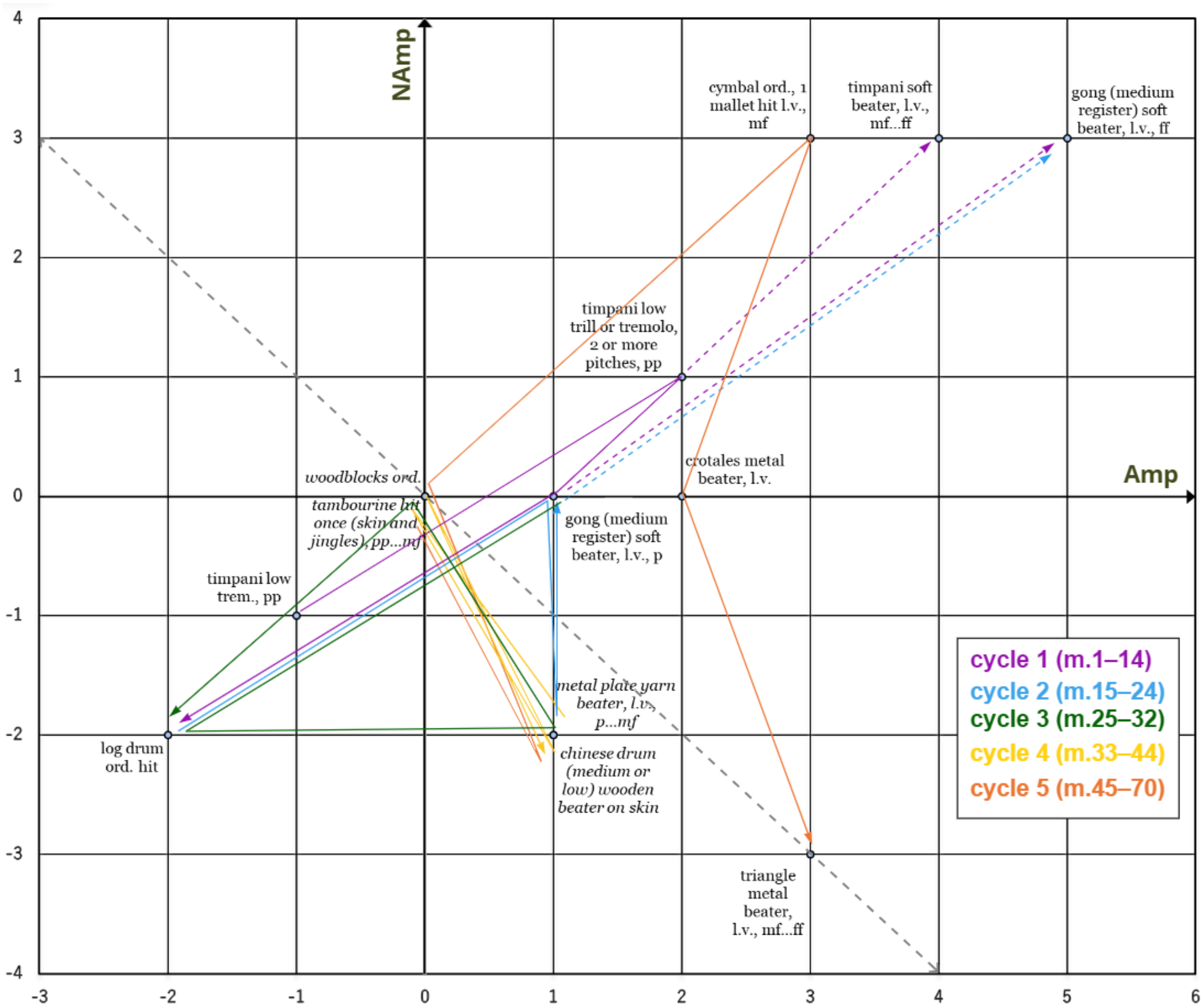


Fig. 4.2.2.-d. Saariaho's amplitude morphology in the five cycles.

In this strongly textured and recursive passage by Saariaho, we skip the surface level and only consider additions to the instrument collection.

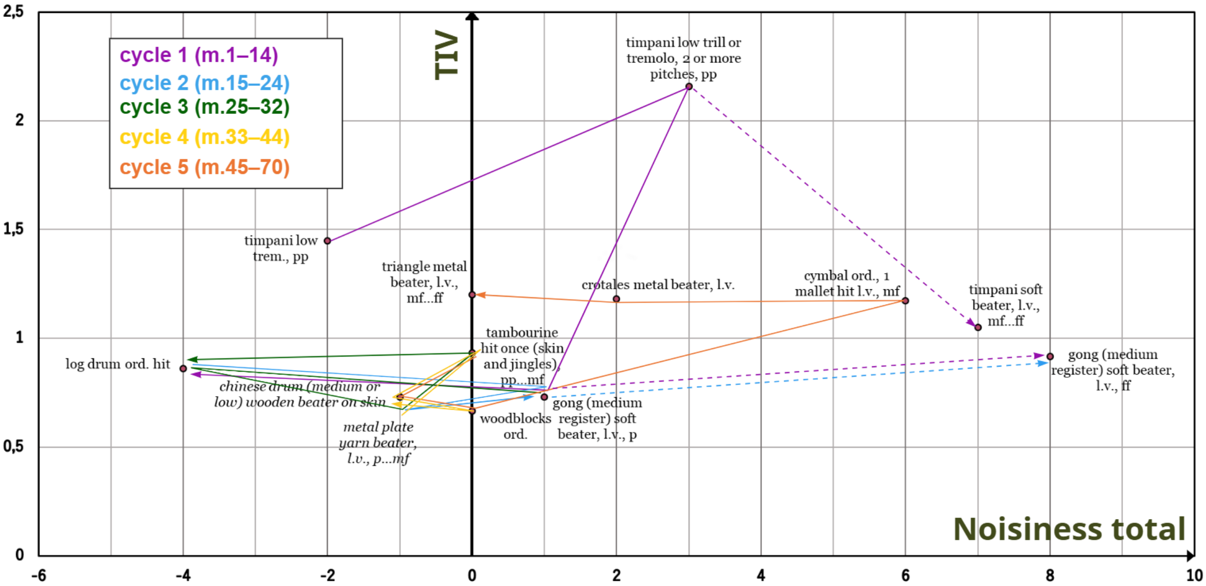
The nucleus can be seen to have 7 or 8 (with the triangle) Froise timbres, and no more pitched timbres are available. In the dense nucleus, two points are even doubly populated. Thus all 5 outliers are more noisy than the nucleus [143]. Cycles 3 and 4 do not access outliers at all, as if gathering energy for the fifth large cycle that spans the nucleus only in the start and end, and accesses outliers between. All movements at least start or end in the nucleus.

Apart from the trilled timpani, the noisiness dialectic is between pitched or neutral Froise and noisy Froise. The cycles participate in this at widely varying levels yet most of them start and end at the same or similar noisiness value and are parenthetical entirely or locally. Typically to this strategy, no centric movement occurs, radial trajectories are common (cycles 1, 3, and partly 5), while exact parsimony and quasi-parsimony are the most common. Some trajectories make occasional use of non-parsimony to introduce new timbres. It is slightly untypical that many of the noisy outliers can be grouped, and that the nucleus is sparse.

The NAmp–Amp canvas can explain this work due to its wide dynamic range and the percussive decaying nature of the timbres, and apart from the figuration, the timbral shifts are slow.

Since the noisiness differences in the nucleus are small, analytical **listening** is required and it is likely to fixate to whichever timbres are the least and most similar to each other (these are likely to be some of the Froise timbres) at any time in the dense texture. Once the listening is “grounded” this way, the listener might be able to listen for the temporarily most extreme timbral pair, which opens the Froise-noise dialectic and dramaturgy of this piece.

e) Saariaho: noisiness–TIV



[143] Some outliers are close to the nucleus yet differ from it particularly by their outside connections.

Fig. 4.2.2.-e. Noisiness–TIV canvas of Saariaho. Note that also here the metal plate and chinese drum share the identical coordinate.

This canvas version has a clear division between the nucleus and outliers. The noisiness grade dialectic, amount of Froise timbres, and the parenthetical trajectories are the same as in the previous canvas. The noisiness–TIV canvas adds the aspect of intensity, which generally diminishes considerably after the first cycle and increases only during the last cycle, as if a stabilisation.

Due to the differing densities, the nucleus has to be considered smaller than in the previous canvas version yet its makeup is slightly different; the six very neutral Froise timbres at the noisiness values −1, 0, and +1 are included.

The correspondence to this strategy's trajectory types is clear. The most typical are exact parsimony (particularly in the cycles 3 and 4), grouping-based (cycle 5) and quasi-parsimony (cycles 1 and 4). Of the occasionally expected trajectory types, non-parsimony characterises cycle 1. Radial as a secondary trajectory is again found in cycles 1, 3, and 5. Centric trajectories are absent. Vectorial trajectories would be possible in the Nuclear strategy yet are not unambiguous in this example. The explanatory power of this canvas version comes from that timbres do not change gradually, timbral swaps are slow, pitches change constantly, and the sounds are percussive.

Unlike the strategy of **listening** provided by the previous canvas, this analysis favours a listening based on Froise to first identify the nucleus, continuing to a listening for intensity to follow the dialectics. Since the differences within the nucleus are small, the voice-leading may be most perceivable when either intensity or noisiness value changes greatly (particularly cycles 1, 2, and 5).

f) Andre, segment 3: Freq–NFreq

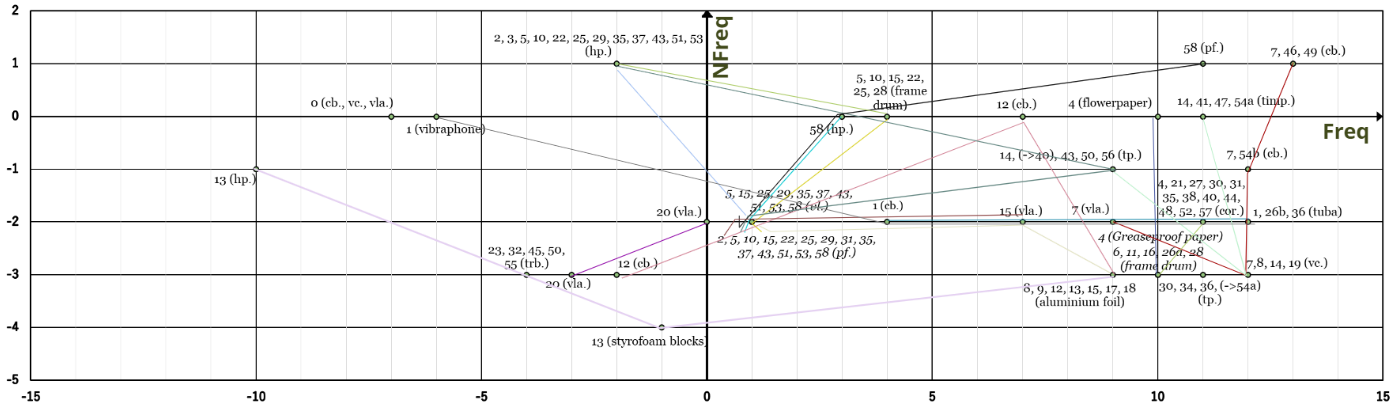


Fig. 4.2.2.-f. Andre's frequency-based morphology canvas. Trajectories are only shown by numbering, to not overcrowd the presentation.

This segment from the coda of Mark Andre's composition has a complex network after a large aggregate in which we only notate the aggregates and entrances of timbres [144].

There are plenty of outliers in this large timbral habitat, yet **two interpretations as to the nucleus**. The violin and piano timbre at (1, -2) is numerously accessed and often also aggregated together. The alternative view is an ambiguous group of about 8 timbres of noise and noisy Froise (the right edge of the canvas). These timbres are however in the composition less connected to the other timbres and mostly rotate in aggregates among themselves.

The main dialectic seems not to be about noisiness grade; there is only one pitched timbre while about half of the timbres are Froise and half noise. The aggregates further combine Froise and noise. Rather, **the size of the timbral (and noisiness) space that is accessed by an aggregate** at any moment and whether the nucleus timbres are included in that aggregate might determine the dialectic.

Contrasting the interpretation as Nuclear with outliers, the trajectories use exact parsimony relatively rarely. Other features however are in accordance with this strategy; centric trajectories do not occur, and the nucleus timbres are accessed so frequently that circles away and towards them are not created. The grouping-based trajectories have to do with movement from the two timbres in the nucleus (1, -2) outwards, yet rarely all the way to the larger nucleus. Secondarily, some very similar vectors are formed by the aggregates and by the movements. Non-parsimony is typical both in sequences and in aggregates. Judgements as to radial movements cannot be made because of the frequent aggregates. The classification is mainly done based on the constellation trajectories where they can be determined.

An interpretation of this canvas as our fourth strategy, a **Solar system with groups**, would be centred on the harp timbre at (-2, 1). It would gain support from the common presence of the harp and explain the lack of exact parsimony. Whether this harp timbre has enough salience in this full texture and in competition with the similarly common aggregate (at 1, -2) is however questionable. The recurring trajectories are thus parenthetical, not centric. Due to the peripheral location of this sun, its effect as a pivot timbre in all directions is limited.

Furthermore, quasi-parsimony is much more common here than non-parsimony, which also points toward the Nuclear with outliers strategy instead of the Solar. One obstacle for a more apt definition comes from the fact that the timbres at the noisy end are difficult to define either way as an untypically sparse group or as an untypical secondary nucleus.

This frequency canvas version bears results perhaps since Andre’s chosen exact pitches are kept most constant and played loudly, while they also seem the least structurally pertinent in **listening**. One feasible manner of listening is by

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[144] Many of the timbres go on for several seconds and overlap with many preceding entries, yet however lose their salience soon, since they have no dynamic changes and/or the line is blurred by doubling. Many timbres are also known from earlier in the piece.

noisiness grade, to early on identify the Froise nucleus and its competing noisy nucleus. Listening may maintain both nuclei as legitimate for quite some time. The aggregates are unlikely to be perceived as central material or memorised, rather which regions of timbral space are accessed by the aggregates and individual entrances, since differentiation in the noisiness realm remains clear.

Timbral trajectory strategy summary

These works were analytically the most exemplary for the Nuclear with outliers strategy. We also found less clear examples of this strategy in the following passages: Furrer's cycle 6 (Amp–NAmp which also has features of Grouped, vectorial trajectories in individual parts such as viola), Rădulescu (Amp–NAmp), Saariaho (Freq–NFreq which also has features of the Merged strategy), Zubel (Freq–NFreq). Additionally, Czernowin's Amp–NAmp had many vectorial trajectories, and the Freq–NFreq canvas had features of the Solar system, in which piano is a centre and the nucleus is centred around the ratchet sounds. A long axis forms between the ratchet region and one piano timbre.

Generally, the identification of these pieces as Nuclear with outliers takes our analysis from descriptive to explanatory level. The nucleus constellation (as well as the possible doubling of timbres) and the trajectory strategy that typically goes with it, means the absence of the centric trajectory and the relative rarity of the vectorial, while some were present more than others. Several hierarchies were built regardless of a timbre's placement in the nucleus or outside it.

The timbres of the nucleus are seldom used all at once. Rather, they tend to form individual pivotal points on the phrase or trajectory level, the power of which can be attested in listening. Compositional, associative, and dramaturgical functions may be assigned particularly to the outlier timbres. Intermediate types may be found in which some outliers participate in small groups that are however smaller in number and space than the nucleus.

Compositionally the Nuclear strategy provides a prime way of minutely varying a certain spectromorphology or type of timbre and exhausting its timbral region to the full. Outliers may be chosen as almost opposites to the nucleus or for some complementary roles. It may also be dramaturgically fruitful to occasionally shift focus from the nucleus to some of the outlier timbres and explore possibilities of aggregation.

For **listeners**, the nucleus in a Nuclear strategy tend to be identifiable very early and not questioned afterwards. If the nucleus is wide, listeners may be able to follow its inner differentiation in Froise or intensity, which may inform a general listening strategy also for the outliers. In the rare cases when the nucleus does not (entirely) lie in the Froise region, a focus on Froise is secondary and may be related to the outliers.

4.2.3. Strategy 3: Grouped

a) Lachenmann: Temp–NTemp

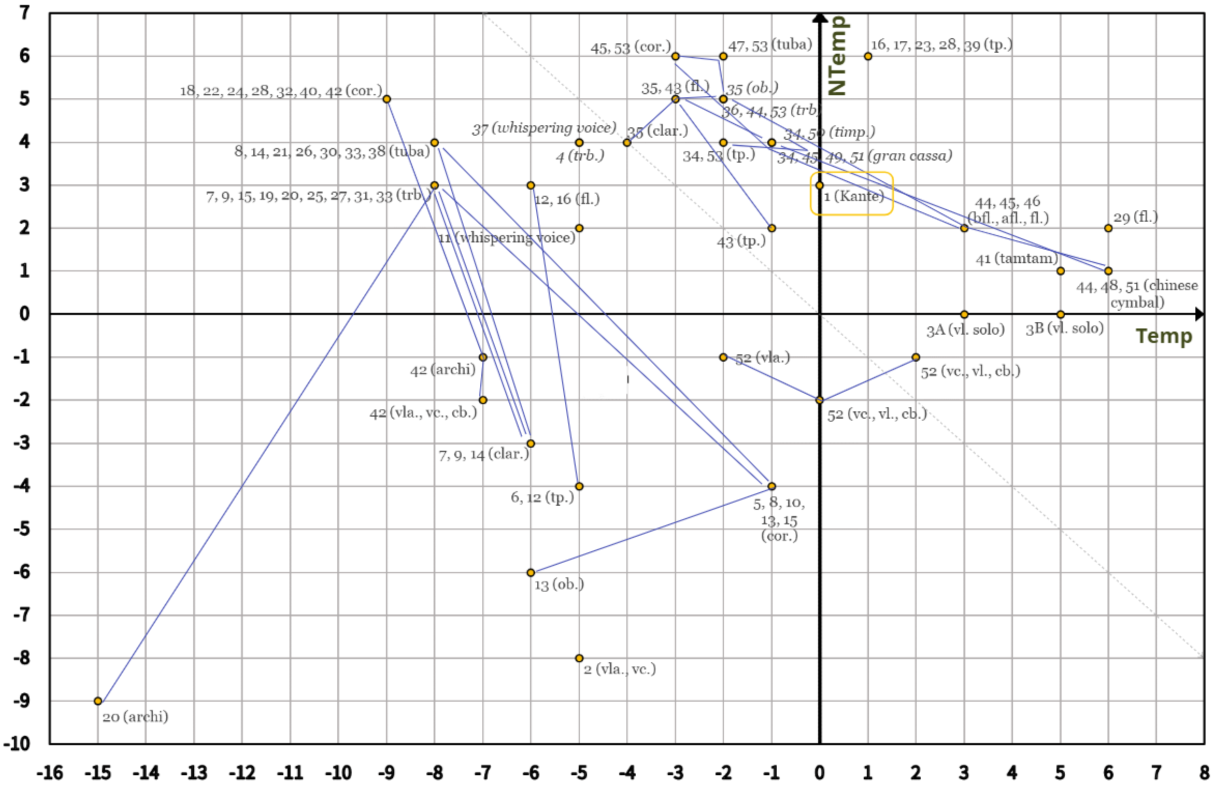

Fig. 4.2.3.-a. Lachenmann on the durative morphology canvas.

This very amorphous orchestral excerpt by Lachenmann relies on four timbral groups. It creates mostly closeby timbral connections in aggregate onsets (marked with blue lines) while actual chronology (marked only with numbers to not overcrowd the presentation) follows diverse logics, two of which are instrumental family and noisiness grade. The **maintenance of a noisiness state is the main dialectic**, as evidenced by many aggregates in diagonals somewhat aligned with the Froise boundary line, and the progressions that cross this divide. The steady values of noisiness in most of the numerous aggregate entrances are indeed composed so consistently that this is likely the main manner of listening. When more neutral Froise sounds become present soon in the piece, the maintenance and moves to/from Froise values create the gradations based on which **listeners** may perceive the local form in this excerpt.

The starting timbre (boxed yellow) separates two major less dense groups of noisy-Froise which will start to emerge into audition later in the passage. These groupings can start to be perceived early in the passage. The group in the second quadrant that can be defined as 3…6 noisy-Froise timbres is the smallest. Except for 7 pitched timbres, all timbres are pitched-Froise or noisy-Froise (the flute timbre with a noisiness value +8 is included). Very rarely accessed are the outliers: #20 as well as some in the pitched Froise region, many of which participate in aggregates with other timbres. The large gaps in the middle region underline the four groupings (which are ambiguous for timbres close to the Froise divide) and the strict noisiness dialectic that does not aggregate noise and pitch until the very end (#52). This exemplifies the second name of this strategy, "Field series".

Landmarks of the Grouped strategy, such as some presence of centricity unlike most canvases, is difficult to judge due to the aggregates that point to two or more points in timbral space. However, many movements are grouping-based (within one of the four groups) or quasi-parsimony when moving outside the group or to its other edge – for this use, non-parsimony also occurs. Radial and exact parsimony trajectories are less common than in the Nuclear strategy. In keeping with the Grouped strategy, vectorial trajectories are not found, while many aggregates do follow the diagonals that (closely) maintain a noisiness value and thus the main dialectic.

The success of this durative canvas version is probably due to the many iterations and the fast pace of timbral shifts that sometimes imply only small changes in instrumentation.

b) Romitelli: Amp–NAmp

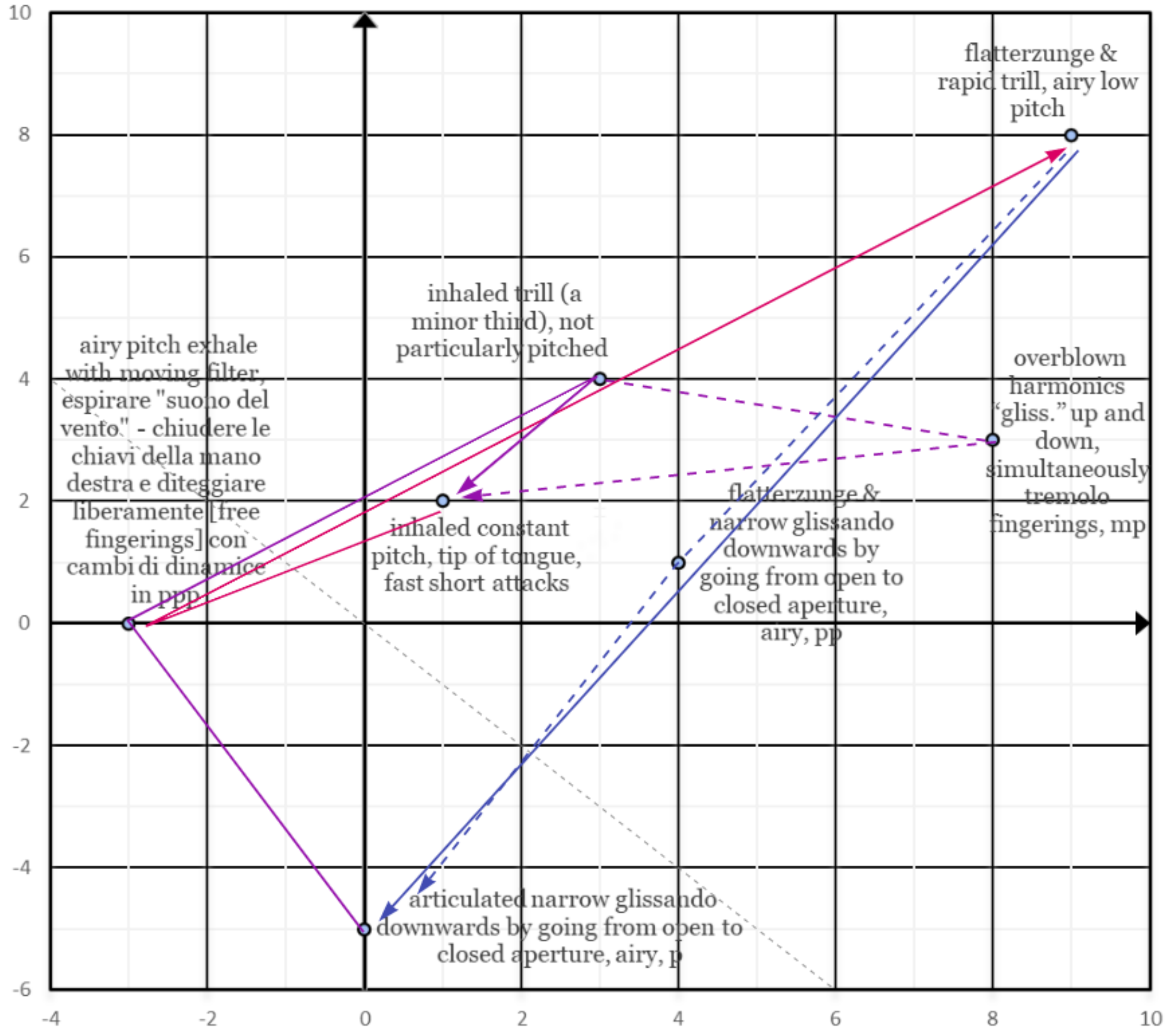

Fig. 4.2.3.-b. Amplitude morphology of a Romitelli cycle for Paetzold recorder.

In this cycle for the Paetzold contrabass recorder by Romitelli, we see a group of three noisy-Froise timbres amid two extreme pairs, of noise and pitched-Froise, when we follow our numeric boundaries for Froise. The timbres have medium distances both between groups and within each group, which allows the grouping and the interpretation that the overblown harmonics also rather belong to the middle group (making the Flatterzunge trill an outlier). This is supported by the accessing order of the timbres. The noisiness course starts with the Flatterzunge & rapid trill timbre as a noisy outlier from which **a main noise-pitch dialectic** (to the articulated glissando) is strongly maintained, and proceeds to the pitched-Froise region, to dwell in the noisy-Froise region.

The cycle is fluid and does not repeat verbatim each round – we show the alternative and substituting timbres (that Romitelli takes from the middle group) by dashed lines. Beyond this chronology and an overlaying simpler dialectic of inhale-exhale timbres, Romitelli uses no means to underline any single timbre as a preferential starting point and makes parenthetical movement far more common than it would be in any of the idealised strategies. Some of these timbres are newly introduced while the "suono del vento" has been present from the beginning of the piece.

One diagonal vector is repeated (between two of the same timbres) while there are two other distinct diagonal and two more horizontal vectors. Features of the **Linear strategy** are present in that all quasi-parsimony and grouping-based trajectories can be explained as vectors that repeat elsewhere. However, the radial trajectories involving the two inhaled sounds only portray radial movement, which should not be present in the Linear strategy.

The Amp–NAmp canvas is explanatory of this piece since in this cycle of a wide dynamic range and nuanced changes in a short time, timbre cannot be separated from texture or amplitude, morphology is more crucial to listening than noisiness degree, and all timbres will be iterated.

The **listener** is likely to follow the pitch–noise dialectic soon and prefer it over the inhale-exhale dialectic, any local pitch hierarchies, gaps in timbral space, or changes in dynamics (since this canvas particularly speaks for the role of amplitude rather in morphology than in greater form). Some of the three extreme timbres may be identified as extreme and focused on, while perhaps one Froise timbre from the middle may also receive a subjective preference in listening. Any such choice will help put the focus on the main dialectic and on Froise presence (and its gradations, if the focus as to the chosen middle timbre shifts during listening) and give a simplified and hierarchical impression of voice-leading while the continuous nature of the cycle has compositionally obscured that hierarchy.

c) Bauckholt: noisiness–TIV

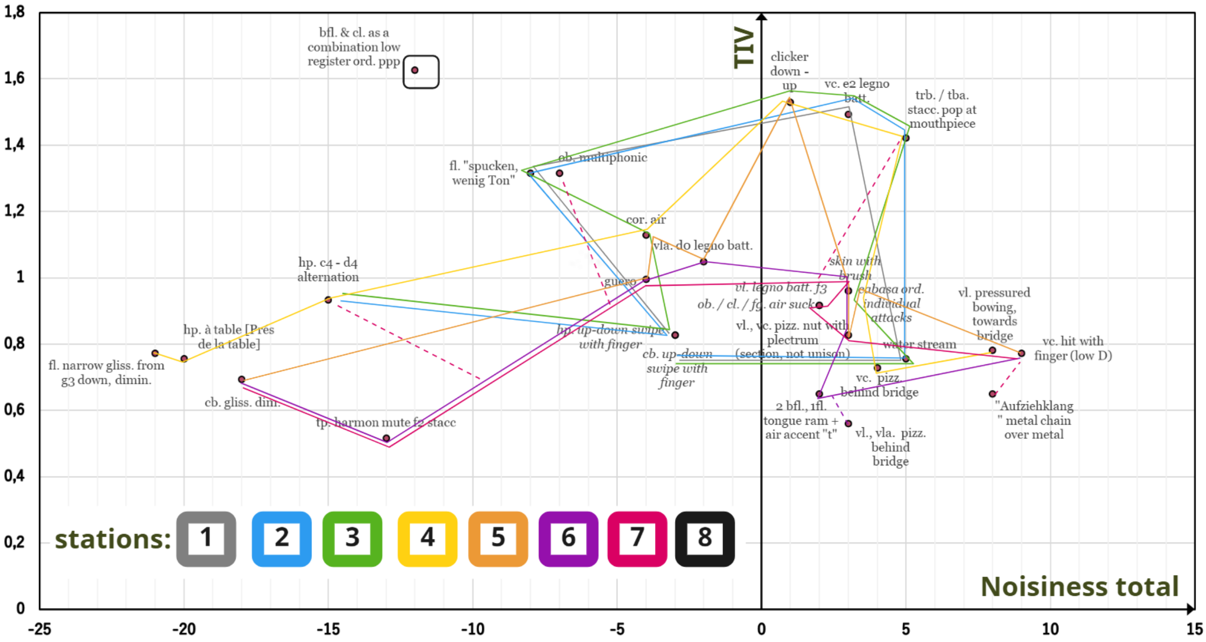

Fig. 4.2.3.-c. Bauckholt's eight aggregate stations on the intensity canvas.

In this orchestral piece, Bauckholt builds eight quasi-aggregates from disparate orchestral timbres, glued together by a *perpetuum mobile* of independent pulsations that are perceived as entities – due to the slight nonsynchronicity we call them stations. Because of this texturation, our aggregate-based approach does not presume abstract timbral transfers from one instrument to another yet we can tell how the aggregates are placed, grow and subtract from station to station (these movements can be verbalised) yet retain about half the timbres at each turn. After station 7 is reached, stations 6, 7, and 8 alternate and receive later additional timbres; many of them are recurrences of earlier timbres, shown with dashed lines.

We may discern four groups of instrumental sounds (with 5 noise, 7 noise and noisy-Froise, 4 intense noisy-Froise, and 11 noisy-Froise, that internally have small to medium distances) and one outlier that makes its own station (8), a beating sound made of only two instruments that becomes crucial for the dramaturgy against the large multi-pitched aggregates. The considerably lower TIV values in some preceding aggregates also pave the way for the intensity and high TIV value of station 8. Almost each station activates all the groups. **A simple noisiness dialectic is overpowered by a dialectic of timbral space**, which in this case is made of both noisiness and intensity. Froise as the majority timbre is always present and only the most pitched group presents a dialectic between pitch and Froise, and the three most noisy timbres do not successfully extend this into noise.

Due to the aggregation, trajectories cannot be determined and instead we can use the four terms (consolidating, dissipating, expanding, focusing) that describe the evolution of timbral space (explained in Table 4.2.6.-2 below). Even within the aggregate, it may not be useful to view the rapid exchanges of entrances as trajectories. Exact parsimony and quasi-parsimony may be interpolated for many of the aggregates, yet grouping-based trajectories are not seen, since all aggregates 1 to 7 combine timbres from at least three of the four groups. Crucially to the Grouped strategy, vectorial trajectories are not evidenced; from among the numerous vectors that the timbral entrances might activate, none is salient. This canvas also has features of the Nuclear strategy in how the far-apart timbres are accessed to consolidate a timbral collection, before undergoing additions or removals, or of the Merged strategy since later additions to the timbral collections approach the other groups.

In its multi-layeredness, Bauckholt's texture remains light, and the noisiness–TIV canvas' explanatory power was further increased by its large amount of timbres and the segmentation based on clear timbral difference since no timbres are transformed.

In the absence of composed hierarchical cues from the texturing, a **listening** for the evolution of timbral space use may be a likely holistic approach to this piece. The listener is likely to attend to not only how large the region is and how rapidly the novel timbres are incorporated, yet rather to how the pitched and noisy extreme members of any aggregate are presented at any given moment. Such a strategy, while not centering on and differentiating Froise since it is the mediating region, would nevertheless give a separate role to Froise as the majority sound type in these aggregates. The Froise region differs the most in intensity, and shifts to clearly less or more intense Froise timbres may there be the audible cues.

Timbral trajectory strategy summary

For the theorist looking at the Grouped strategy, these works were the most exemplary. We also found this strategy in less polished form in the passages of Furrer's cycle 6 (Temp–NTemp, where bcl. is outlier), Auvinen's passage 1 (Temp–NTemp and Freq–NFreq), Lachenmann: Amp–NAmp, Romitelli (Temp–NTemp, with features of Linear), Romitelli (Freq–NFreq). Additionally, Furrer's cycles 1 and 2 in the Freq–NFreq canvas also displayed some features of Nuclear (the nucleus includes the string starting timbres and bcl.) and of Merged; the piece on the larger scale again makes radial trajectories since the cycles repeat.

Generally, the identification of these pieces as Grouped took our analysis from descriptive to explanatory level. Groupings may not be immediately audible or visible on a score yet are revealed by positioning in an adequate canvas version and by the trajectory types which in the Grouped strategy heavily rely on exact parsimony, quasi-parsimony, and grouping. Due to the constellations which may vary considerably as to the sizes and positionings of the groups (as well as the possible doubling of timbres), the vectorial trajectory type was absent, while some trajectories were more common than others. Grouping impacts the hierarchy between timbres in that shifts in timbre are either in-group or between-group and the individuality of timbres in a group may suffer. Groups are seldom large enough to conduct dialectics on the noisiness continuum, yet between-group movement does achieve this.

For the composer, the Grouped strategy brings evidently many options for creating timbral vacuums and groups of distinct or more connected identities, as well as minute variations of timbres within a group, or changing the amount of timbres and different instruments in each group, for dramaturgical effect. To not obscure the division of the groups, some timbres that would lie between groups may have to be excluded from a whole passage, however.

The Grouped strategy poses a challenge **to the listener** initially, firstly because the constellation may be difficult to perceive soon, secondly because many dialectics can occur, and lastly because the choice of listening strategy is here often not guided by aggregates. Once an apt listening strategy is chosen and the main dialectic in the music found, timbral dramaturgy in Grouped strategies is translucent to listen to for long spans of time.

4.2.4. Strategy 4: Merged

a) Sciarrino: noisiness–TIV

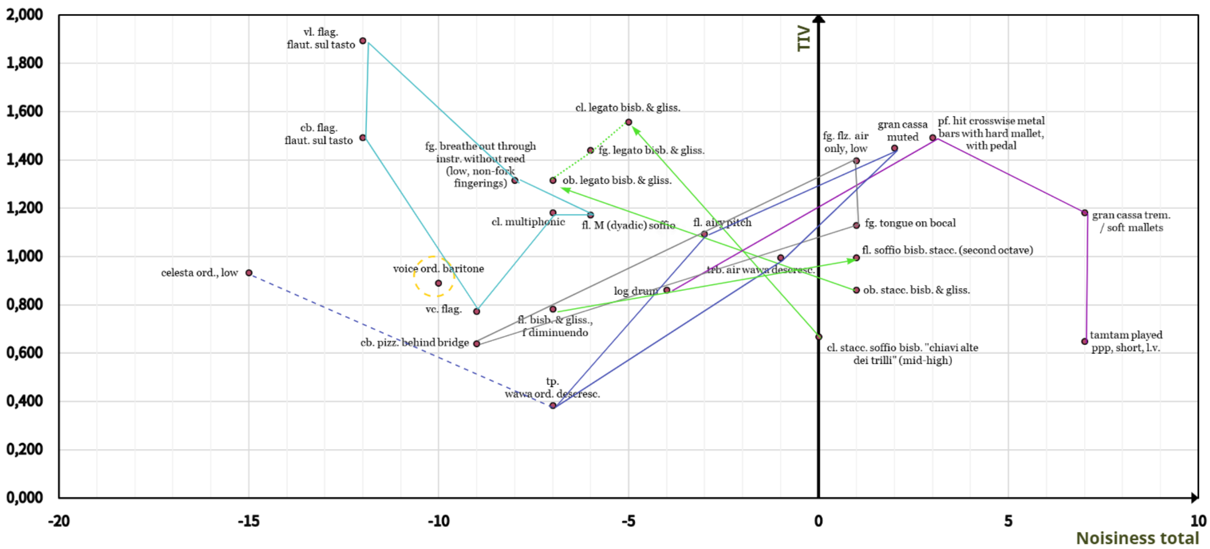

Fig. 4.2.4.-a. The Sciarrino piece's groupings in intensity: pickup attacks (grey), Froise aggregate (dark blue), resonance (purple), bridge (light blue), motivic episodes with a static and mobile state (green), and baritone solo (yellow).

The groups are made of timbres in a slightly overlapping way, which has led to the merged sense of the timbres. Particularly the aggregate takes up large stretches of timbral space yet the different roles (in duration and articulation) of the aggregate timbres follow clear timbral regions. This variety is kept in check by the clear blockwise use of these groups. The six types of blocks following the grouping in timbral space are the Froise aggregate and its simultaneously starting resonance group, its often-preceding pickup attacks group, and its following bridge group (often made of a multiphonic), motivic episodes (either static or mobile), which all include Froise timbres, and the baritone solo. The joint aggregate, resonance, and bridge group are the largest group. Only the groups that risk the most blending with each other (bridge, baritone solo, pickup attacks, and motivic episodes) occasionally occur in isolation. The same grouping is kept throughout the piece and only the aggregate faces minor changes at each of its 12 occurrences [145]. The celesta as the most pitched timbre is added at the end yet no general process towards pitchedness is discernible.

We could divide the groups into states of timbral-energy (Froise aggregates and pickups) and movement-energy (motivic episodes and baritone solos) [146]. Timbral-energy is characterised by fusion of simultaneous similar descriptor values, not visible in this canvas presentation, while movement-energy means a surge in dissimilar morphological activity. This makes the morphological canvas versions unlikely to explain the workings of this piece. The noisiness–TIV may be successful since the passage is not multilayered nor dense, timbres are numerous, timbral changes even in the motivic episodes are strict, and segmentation is based on timbral differences.

Sciarrino composes with the individual instruments using a sweeping filter-like process and with a similar **noisiness dialectic** in mind, in that the noisiest timbres only feature as onsets and the most pitched sounds remain at the end, clashing with the remaining extremely noisy sounds that were held by resonance. Each cycle starts with a timbrally wide aggregate of three groups and ends with a smaller group on the pitch or pitched-Froise region.

As befits the Merged strategy, the most used trajectories are quasi-parsimonious and grouping-based [147]. The groups except the bridge group are built more on quasi-parsimony than exact parsimony (if we want to read the aggregates as trajectories). Since chronology within a group does not occur, radial and parenthetical trajectories cannot be determined [148]. Vectorial or centric trajectories are absent. The Merged strategy supports a merged constellation; no particularly dense areas are found for a Nuclear strategy, sun for a Solar system strategy, or vectors for a Linear strategy. The constellation itself does not display the grouping straight away – it is only done contextually.

The blockwise introduction of the aggregates makes the main dialectic in timbral regions clear to the **listener**, while the choice of listening strategy may not be initially clear. The motivic episodes of the woodwinds are the group that has inner voice-leading (the gradual deconstructions of the Froise aggregate are not perceived through voice-leading) and they can point to the more extreme regions

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145 The most exceptional aggregates are to be found in m. 12 and 18 and concern the occasional absence of instruments, their durations, dynamics, and pitch alternation. On the authoritative recording, one mainly hears the presence or absence of instruments, and questions of balance are secondary.

146 Such a dichotomy is probed by Beat Furrer to describe types of static or flowing energy invested within textures though not limited to them; *Bewegungsenergie* and *Klangenergie* (FURRER 1997: 234). The notion of timbral energy is also found in ANDERSON 1999.

147 The overall form reflects the groupings. In addition to what the canvas shows, the sequence of the blocks in time is ordered by conventional structural planning that involves mathematical consistency in the duration of the blocks and the division of the lyrics of the baritone, yet this path of analysis found not effect on the general noisiness dialectic or the role of Froise in this piece.

148 The parenthetical trajectory is evidenced rather on the upper structural level since the aggregates proceed in mostly the same order.

since their timbres are in the Froise region. Thus a reductive listener might focus on the most Froisy sounds in any group, and to this the baritone makes the only exception.

b) Zubel: Amp–NAmp

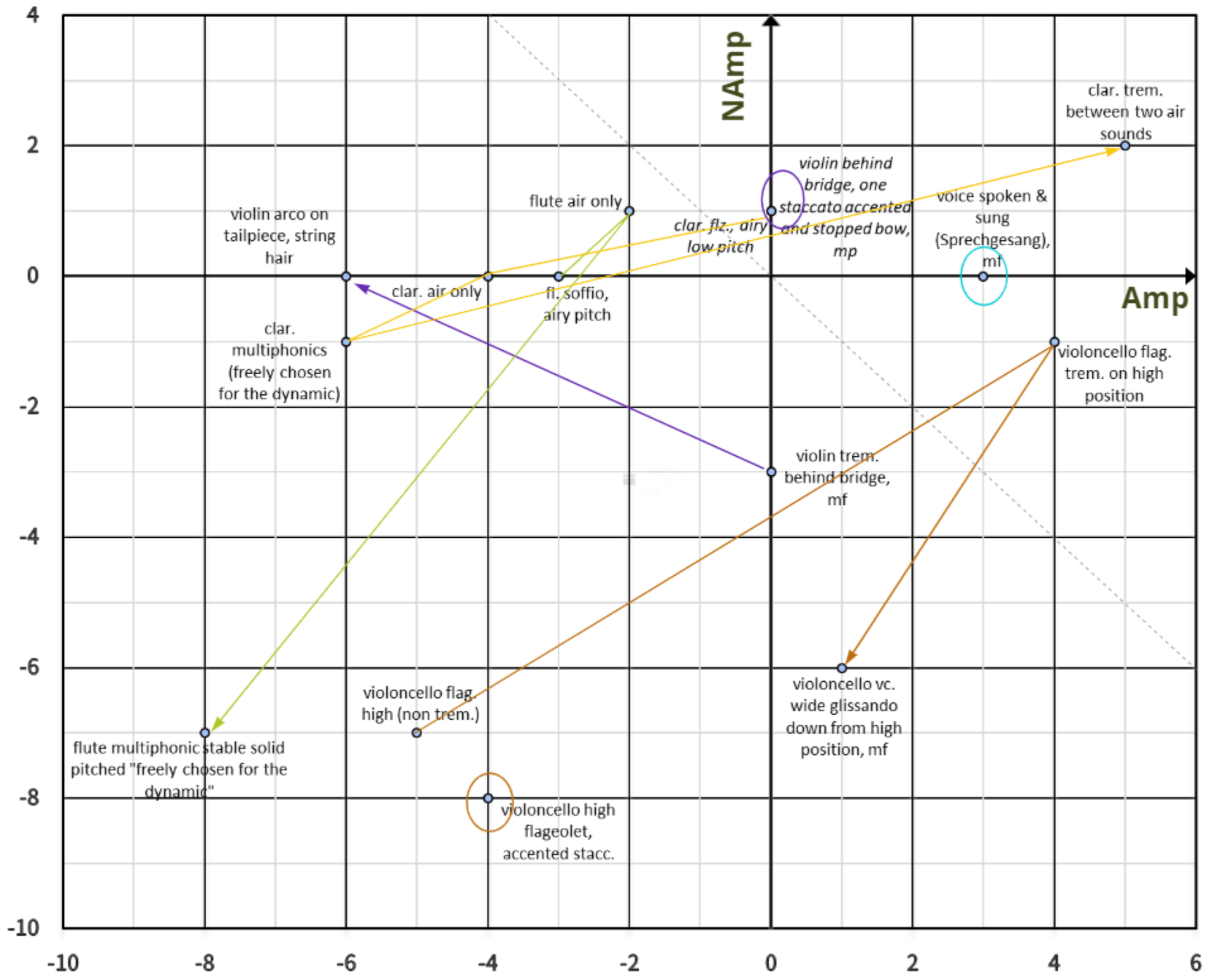

Fig. 4.2.4.-b. The amplitude morphology canvas for the Zubel piece. The score also indicates for the voice a half-whispered timbre which however lies within the wide range of timbral variation that Sprechgesang entails.

In this kaleidoscopic chamber setup by Zubel in which each instrument follows a fixed order of timbres, only the mutual placement of the lines changes, no timbral combinations emerge as structurally superior. Thus, our approach is via sequences in the individual instruments. Even timbres that are added towards the end of the piece do fit very close to the existing regions and routes of timbral activity.

In the case of the flute and clarinet, one of the three timbres is central between another closeby timbre and a clear outlier. For the violin and cello, these distances are more equal and the central timbre is not decisively closer to either one of the other two timbres. Nevertheless, no preferentiality is audible. Each instrument ends its phrases with an outlier timbre (which also constitute the four furthest away timbres in the four quadrants), except in the cello. In the violin, initially only two timbres are present, and thus the outlier status is confirmed only later.

Some groups such as the violin and clarinet are more connected than others – in this sense the late addition of the voice must be seen as a necessary integration of the cello and clarinet lines which does not happen elsewhere in timbral space.

Only three timbres classify as pitched while all others are Froise. The violin trajectory is the least preoccupied with a **noisiness dialectic**, although a particular proliferation of 7 timbres in the pitched Froise region by all instruments' trajectories brings about an unsteadily pulsating saturation of that Froisy percept (best viewed when the canvas is turned 45 degrees); **variations in the dynamic presence and instrumental makeup of the pitched-Froise region** may amount to a major listening strategy besides the entire noisiness continuum which also varies frequently. Such listening reveals a rare type of voice-leading since instrumental source is discarded and only a narrow (Froise) region at a time is observed.

The amplitude-related morphology shown in this canvas differentiates the timbres particularly well and in a way that may make most timbral distances perceivable to an attentive **listener**.

The Merged strategy supports such a merged constellation in the lack of a nucleus, a sun [149], or consistent vectors. In keeping with the Merged strategy, most trajectories are grouping-based and within the instruments, quasi-parsimonious. The instrumental parts themselves fulfil the commonly related parenthetical trajectory since they repeat as such (only separated by rests). Exact parsimony, which also should be expected in this strategy, is found in only some instrumental parts yet more often at the coexistence of two instrumental parts. Expectedly, the vectorial and centric strategies are absent. The clarinet is closest to forming within its own part similar vectors that however are not replicated by other instruments.

The amplitude canvas may thank its success to the piece’s wide dynamic range, nuanced changes in a short time, lack of a timbre-based segmentation, and the interconnectedness of texture and the recurring timbres.

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[149] The violin tremolo, although central, is not a sun due to its very different distances and the fact that the other timbres do not form groups needed for the strategy Solar system with groups

c) Saariaho: Temp–NTemp

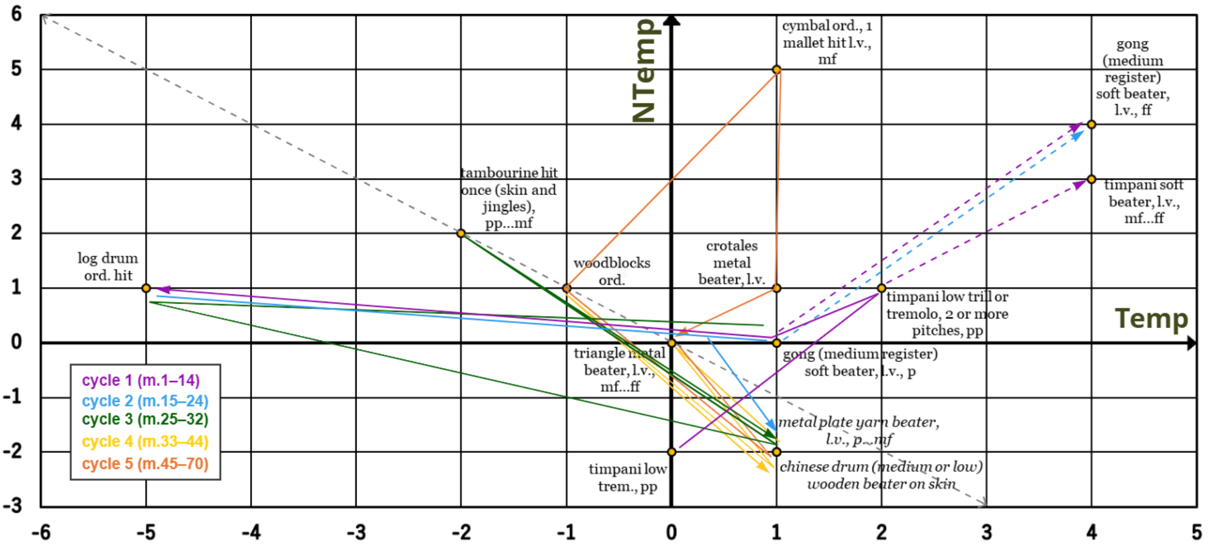

Fig. 4.2.4.-c. Saariaho's dramaturgy on the durative canvas.

As above, our notation of the Saariaho passage is halfway between the sequence and grouping approaches, since all introduced timbres remain present in the texturation throughout a cycle. There are no pitched timbres, one noise timbre, and 12 Froise timbres. All cycles feature Froise prominently, and in this canvas the **noisiness dialectic is somewhat replaced by moves to timbres that have a less balanced Temp–NTemp proportion** such as the timbres at (-2, 2), (1, 5), and (-5, 1). The dense use of the Froise region encourages comparison of the temporality (Temp–NTemp) proportions inside a sound which is uncustomary. Thus we should not expect this canvas to be a primary choice for many **listeners**.

Due to the small distances to most timbres, the dense centre region does in this canvas no longer quite reach the identity of a nucleus or even a clearly definable group. Many movements are of the radial type with a wide reach, except for the fourth cycle. In terms of noisiness, cycles are more concentrated since clear pitched timbres are missing. The fourth cycle is decisive also since the log drum as the most pitched outlier has been abandoned for good, only one earlier timbre is utilised, and the focus shifts to Froise before the last cycle that is heavily directed toward the noisiest available timbres. Typically to the Merged strategy, centric and vectorial trajectories are absent, whereas the moves towards the extremes in cycles 1 to 3 are explained as non-parsimony and grouping-based trajectories. The parenthetical cycles are identical to the previous Saariaho analyses.

As can be expected of a temporality canvas, the material (metal, skin, wood) of the percussion instruments is very independent of their timbral coordinates. The success of this canvas version comes from the fast pace of timbral shifts, iterations of timbres, and that segmentation is determined by pauses rather than timbres.

d) Lachenmann: Freq–NFreq

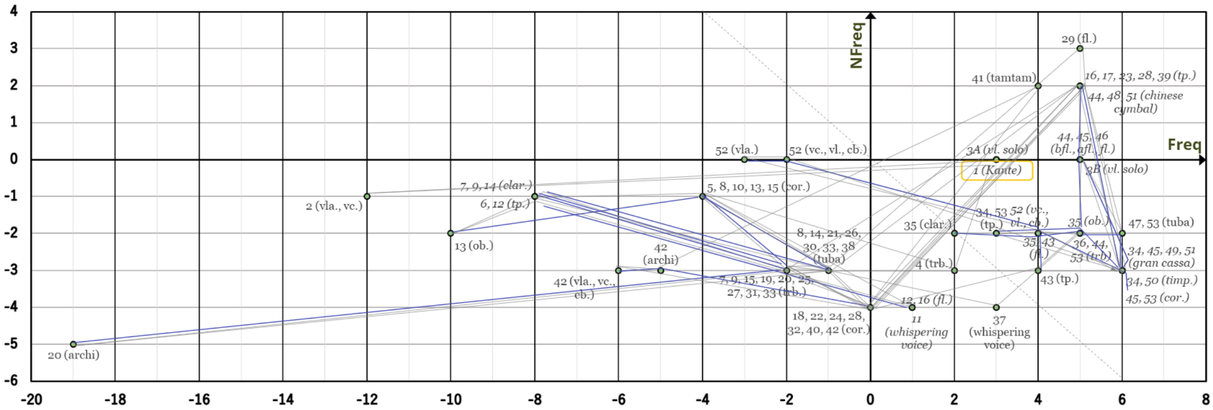

Fig. 4.2.4.-d. Lachenmann's frequency-based canvas. The aggregates are shown in blue and the chronological trajectory of timbres in grey and in numbers.

This orchestral passage by Lachenmann displays a detailed **dialectic of noisiness** with overwhelmingly Froise sounds. With lines, we show the aggregates that again prevent us from determining most trajectory types.

Particularly many simultaneous combinations follow timbral vectors that are aligned from upper left to lower right [150]. These lines (except for the trb. – cor. combination) neither quite retain the noisiness value nor an exact proportion between their Freq and NFreq values. This may be what makes these timbral pairs particularly flexible, in terms of some aggregation ability and many implications for next voice-leading directions.

The first large move to and from point 2 confirms the Froise–pitch dialectic; after this, noisiness changes in smaller yet perceivable increments, with timbres that often seek to bridge the earlier gap between points 1 and 2. The starting timbre (Kante) comes across as an outlier for a long stretch of the start, before that timbral region is revisited. However, many timbres replicate its proportion of larger Freq value and smaller Nfreq value. Many aggregates later deliberately cross a divide of timbral space built on this proportion (by moving diagonally from lower right to upper left), and are interpolations over both sides of this implied line of balance. Many of these aggregates are also a shorter replication of the same diagonal and stretch of noisiness space as in the first move (points 1–2), although these later vectors are not similar. Similarly to the durational canvas which brought a Grouped strategy result, the timbre #20 is also here a pitched outlier that seems like a necessary break halfway in the noise – Froise dialectic.

The most neutral Froise region is here sparsely populated, as is apt for a Merged strategy that does not have a gap nor often-accessed sun or nucleus timbres in the middle, while pitched and noisy Froise are about equally common yet hardly interconnected in the composed chronology. Most trajectories are grouping-

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[150] Too many different vectors occur for us to ascribe a systematic Linear strategy however, and the common quasi-parsimonious trajectories foreign to the Linear strategy would all have to be explained as vectors, which is impossible.

based in the sense that movements seek to remain in the same group and timbral region. Non-parsimony and parenthetical movements are relatively rare.

The most rewarding **listening** to this canvas would follow our previous analysis of this passage on the Temp–NTemp canvas in the Grouped strategy, with the exception that although the general dialectic is again based on noisiness, groups are probably not perceived when listening for the frequency aspects of timbre.

The clarity of this canvas version likely boils down to the ubiquity of iteration (especially of the timbres that are central for groups), the textural multilayeredness and overlaps, narrow dynamic range, and rapid timbral shifts.

Timbral trajectory strategy summary

From the analytical point of view, these works were the most exemplary for the Merged strategy. We also found this strategy in less polished form in the passages of Andre's segment 2 (noisiness–TIV), Bauckholt (Freq–NFreq and Amp–NAmp), Lachenmann (noisiness–TIV), and Zubel (Temp–NTemp). Additionally, Czernowin's noisiness–TIV canvas had gradual shifts in the focus in timbral space by accessing slightly intertwined groups. Only a few timbral pairs repeat and thus establish themselves. Sometimes a strong focus on temporary nuclei formed, which made Nuclear with outliers another possible interpretation.

Generally, the identification of these pieces as Merged took our analysis from descriptive to explanatory level. Due to this constellation (as well as the possible doubling of timbres) and the trajectory strategy that typically goes with it, certain trajectories were not found at all, while some were more than others, and this had implications for the hierarchy between timbres.

The Merged strategy can be seen theoretically as a combination of many aspirations that the other strategies have. **For the composer**, it is a very flexible one, since access to timbral regions can have profound meaning for dramaturgy without being overly restricted by adherence to and constant realisation of certain constellations or trajectories. It allows many single-use timbres and extensive centering on some timbres, as aggregates and in sequence. It will however take effort to avoid the most exact parsimonious combinations while keeping in mind the density of some regions and their need of also being absent for long stretches of time which supports the timbral vacuums that can be crucial to dramaturgy.

This strategy supports constellations that have elements from other constellations. In keeping with this, only the central and vectorial strategies are absent, and radial trajectories are extremely rare.

The Merged strategy supports movements and aggregates along the axis and diagonally at small to medium distances, which can allow dialectics based on not only noisiness and intensity, yet also on the grade of blending. This may also be the most suitable strategy for exploring timbral distances. Compositionally they allow Froise perhaps the most free rein; Froise sounds may make up any proportion of the entire constellation and are typically highly infrastructural and at the centre of action. The more Froise sounds there are, traversing through

Froise sounds in a noise-pitch dialectic becomes unavoidable, yet if Froise makes up the majority, different dialectics such as use of timbral gaps, the TIV value, or proportion (of the axes in a morphology canvas) may be rather used to affirm Froise.

Pieces that correspond to the Merged strategy can be challenging to **listen** for their noisiness dialectic, especially if adjacent timbres are at similar distances, usage of timbral regions is undifferentiated, or if they incorporate no features of the Grouped strategy.

4.2.5. Strategy 5: Solar system with groups

This strategy could also be called the pivot, since one timbre mediates much of timbral movement to the other timbral regions.

a) Zubel: noisiness–TIV

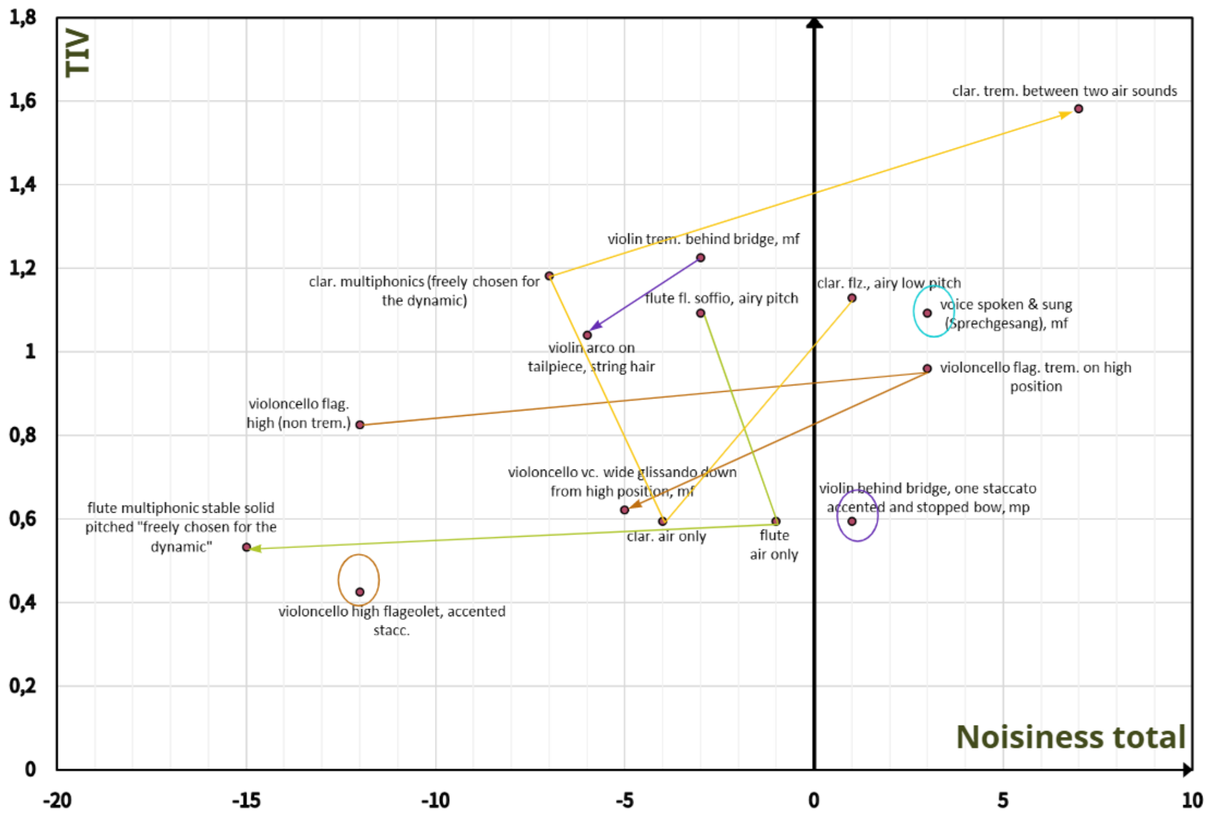

Fig. 4.2.5.-a. The instrumental lines of the Zubel piece on the intensity canvas.

In this canvas of the Zubel piece, the instrumental trajectories are even more connected than in the Amp-NAmp presentation, and have roughly equal sizes in timbral space (the violin's limited set remains in a small space even after its third timbre is added). Again, every instrument provides outliers in timbral space, and here the clarinet (the most noisy timbre) and flute (most pitched) do interact closely intertwined in the noise region nevertheless. Indeed, now each direction is utilised to the extreme; no centre can be determined since there is a gap in the Froise timbres of moderate tension. The main timbres that start or end each instrumental line are positioned centrally in a ring in the Froise region. Although a gap in timbral space forms without any centre, the role of the centre is divided between the instruments. Three noisy timbres are set slightly apart from all other timbres which are Froise - they also have a role of low tension in a general tendency in which noisy timbres also have larger TIV values. The distances are large enough that **TIV values may even prevail as a dialectic over the noisiness total in listening.**

In how the timbral regions are accessed, we note the nearby grouping of violin-flute-clarinet-cello, in this order, in two separate places. Of the later timbral additions, the cello, violin, and voice seem to have a balancing effect by filling the three largest gaps in timbral space.

Only four timbres are outside the closest circle of the constellation, and this circle is not dense enough to be a nucleus. No linearity or grouping is found in this region, and thus the interpretation of this constellation as Solar system is the closest, even though **paradoxically the sun timbre in this Solar system strategy is missing**. In keeping with this, all trajectories are radial instead of vectorial (they could be explained by non-parsimony except for the violin), and while exact parsimony should be rare for this strategy, it is occasionally encountered in the fleeting combinations of two or more instrumental lines. As is typical to the Solar strategy, the parenthetical strategy is absent. Except for the violin, all trajectories of instruments include one timbre from each group below and above the middle gap, as well as at least one outlier; this produces an explanation as grouping-based which provides an explanation for the unexpected presence of the radial trajectories. The typical trajectories centric and non-parsimony are evidenced both in how an individual instrument zooms in on the empty timbral region in the centre and does not have a parsimonious option in the same instrument to proceed to.

The noisiness–TIV canvas may be a robust visualisation since timbres do not change gradually, and a sense of lightness is brought to the multilayered texture by pauses and predictability in the instrumental lines.

The **listener** is unlikely to notice the regularity of the constellation and may not always be able to follow the instrument lines. A holistic focus in listening may direct at noticing distances between timbres in the unpredictable textural combinations in which the timbres occur. This already can affirm Froise since most combinations manifest several grades of noisiness and in this piece the pitched-Froise sounds in such snapshots are the sound with shortest voice-leading distances. This region of Froise will vary the least and constitute a timbral centre albeit fluctuating.

b) Romitelli: noisiness–TIV

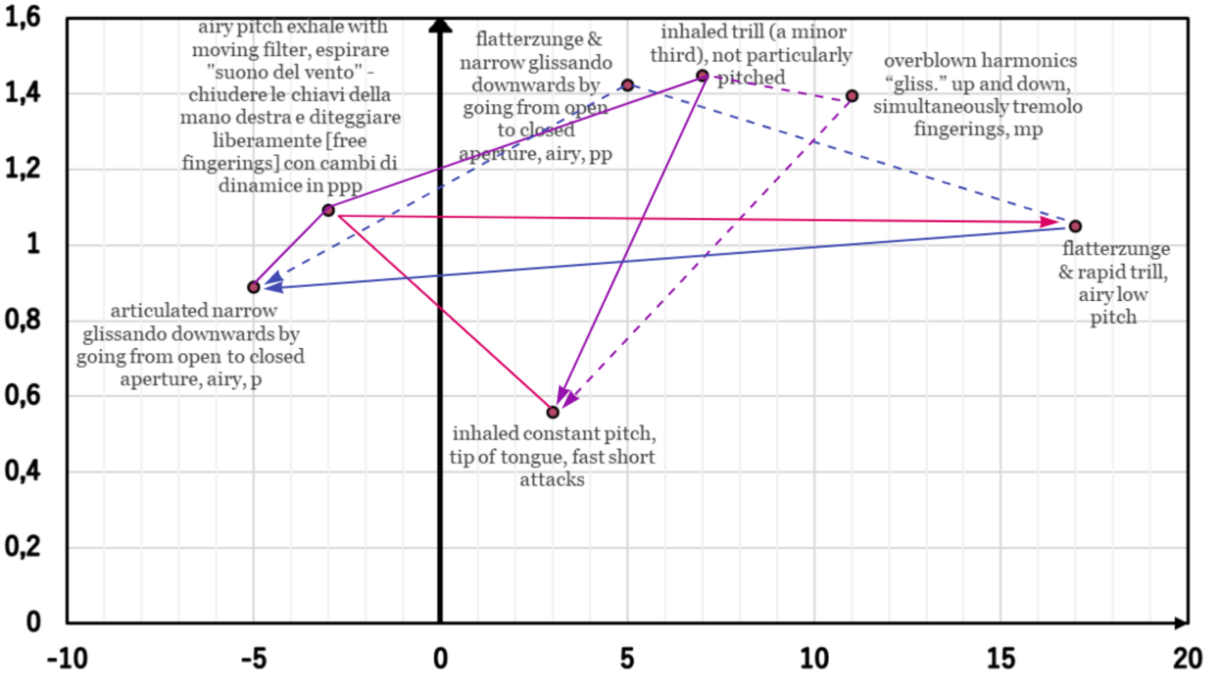

Fig. 4.2.5.-b. Even though the Romitelli piece's cycles connect fluidly, the Flatterzunge trill timbre is shown as the starting point on this intensity canvas.

Different to the Amp–NAmp canvas earlier, this canvas shows Romitelli's dialectics between pitched Froise and noise as more jagged; small balancing moves are taken after larger changes in noisiness. The alternative versions of the timbral cycle are again shown with dashed lines and the shares of timbres are the same as in the previous analysis that resulted in the Grouped strategy. The inhaled attacks which have the lowest tension come across as the sun in a partial solar system. All the other six timbres are located at approximately equal distances from the sun, however one-sided. This sun has a passive role since the largest tension can be found from the longest distances (from the Flatterzunge trill to the two most noisy timbres). Only the movements to the sun break the consistency with which noisiness values are explored on this canvas. The fact that the airy pitch exhale is accessed more often than the sun lends it a small role of centricity and is partial evidence for the Grouped strategy, which explains one otherwise nonstandard case of exact parsimony.

An interpretation through the Merged strategy would also be a feasible explanation for this piece's smooth timbral movements, except for the Flatterzunge trill timbre which does not connect with its immediate neighbours.

Noisiness values here have a very balanced distribution, and thanks to the sun timbre, **Froise remains the emphasis for listening**. Each crossing from right to left, to the pitched-Froise timbres, spells a step of at least 6 points in noisiness and is likely to be perceived as a divider for a phrase – regardless of which timbre the listener understands to be the starting timbre in Romitelli's continuous and ever-developing timbral chain.

The noisiness–TIV canvas brought a complementary representation as a different strategy than the previous analysis of this piece. This is aided by that Romitelli's textures are not multilayered, the timbres are without natural decay, and the exact pitches play some role in shaping the interconnected cycles.

c) Czernowin: Freq–NFreq

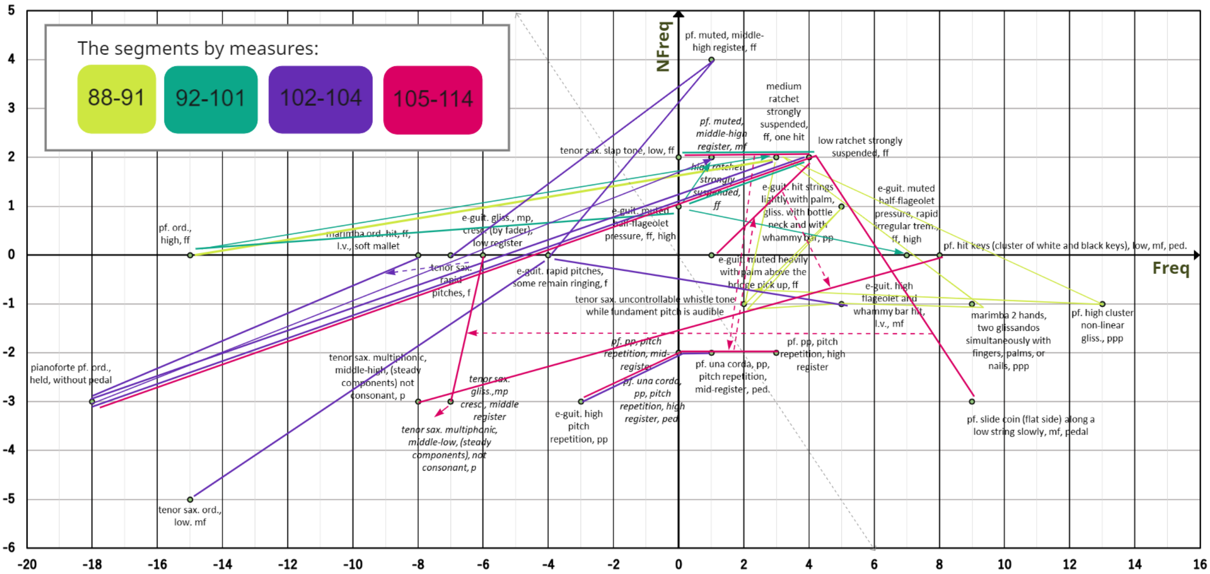

Fig. 4.2.5.-c. The Czernowin excerpt, in four segments.

In this Czernowin passage's each segment (which are elliptically connected), a resemblance with the previous ones is maintained especially by holding on to the two piano & ratchet aggregates by recurring centric movement. While the timbral region focus of each segment shifts considerably – and this may be the driving **noisiness dialectic** for this presentation – many of the situations can be understood as approximations of a ratchet sound. The gradations in noisiness are available steadily especially on the pitched region. A primary concern for most trajectories seems to be noisiness and the sizes of stretches in noisiness that result from aggregation across wide regions on the canvas. One type of medium stretch and of a large stretch seem to appear in each segment. These may be the most recognisable in **listening**, while the ratchet timbres may be held as a memorisable reference timbre.

Since pitch is constantly present, the frequency canvas expectedly had the most explanatory power, even for this timbrally adventurous passage. Furthermore, here many timbres are inseparable from texture, segmentation of the piece is rather based on changes in instrumental mass, and most exact pitches were kept constant while being less structurally pertinent than the timbral dialectic.

In another interpretation as Nuclear with outliers, a nucleus mostly in the first quadrant has at least 8 timbres of noisy Froise that are present in each segment yet do not have many more noisy timbres to access. The ratchet timbres are included here yet occur more than the other nucleus timbres, and other characteristics of the Nuclear strategy such as exact parsimony and group-based trajectories are hard to find.

d) *Furrer cycle 6: Freq–NFreq*

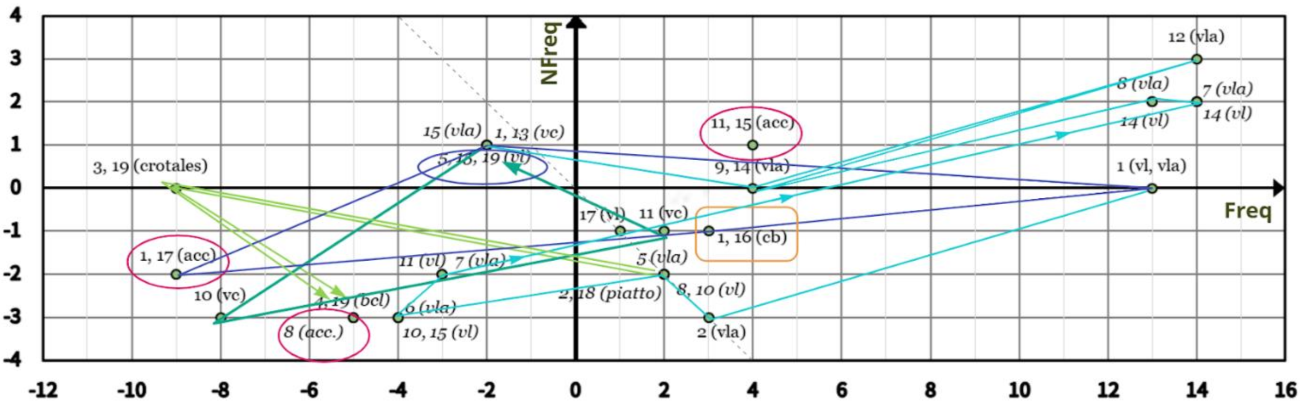

Fig. 4.2.5.-d. Furrer's longer cycle on the frequency morphology canvas.

In Furrer's sixth cycle, there are different timbres than in the cycles 1 and 2. Here four groups are formed: 9 timbres that count as pitch and pitched Froise, 3 timbres as a detached centre "sun" at the coordinate (-2, 1), 9 as neutral or noisy-Froise, and 6 as noise [151]. Despite these groupings, grouping-based trajectories are not as common as expected in a Solar system.

This sixth and last cycle starts at point #5 in a small timbral region, while numbers #1 to #4 indicate the end of and bridge from the previous cycle (and the ending "reverberation" at #18…19, then combined with the sun). The timbre at (2, -2) also carries three distinct instruments yet does not face the systematic use typical of a sun. Centric and non-parsimony trajectories are common, and many trajectories that do not explicitly access the sun timbre (such as the block B, the reverberation group) do access timbres that are at a rather constant distance from the sun. The visualisation shows occasional vectoriality yet it is hardly audible. Pertaining to the Solar strategy, exact parsimony and radial trajectories are absent, and only the wider cycles are parenthetical.

Although unlikely to discern through the texture, we illustrate the timbrally narrow cello part and the more complex viola part. The complex timbral sequences are an unlikely way to listen to this multilayered texture in which we must count with occasionally high grades of aggregation of the three or more string instrument lines. For instance, the entrance of the cello (#10) is prepared timbrally by the other lines moving to the relatively closeby timbres. The loud end situation (#1, dark blue) takes up maximal timbral space while the timbral region in which the following "reverberation" bridge material is clearly separate from the rest of activity. This region only fills up moderately with additions late in the cycle. The secondary dialectic may well be the size of timbral space taken at any moment. Temporarily left timbral gaps are very accurately filled by additions to instrument mass (acc., cb.). The **main dialectic** is that of slightly pitched timbres against an amorphous Froise aggregate (into which texture the noises

[151] These noises by the vl. and vla. likely aggregate and do not contribute to a pitch-noisiness dialectic. Their great distance to all the other timbres excludes an interpretation as the Merged strategy.

are blended), two phases identical with the blockwise general form. Due to the clear segmentation of the preceding cycles, the sun timbre will be the same and reinforced by the repeated use of that coordinate. In **listening**, the two nearby timbral regions might be diffictult to distinguish and thus the main dialectic might most clearly rely on the grade of aggregation especially since this canvas compares timbres for their frequency aspects. Frequency in the concrete sense is a crucial factor for aggregation, and also timbres that have similar Freq–NFreq proportions (if not similar values) might blend together easier than if the similarity only existed on the durative or amplitude canvas. **By listening to the grade of aggregation in this case, the listener receives information about the width of noisiness values and timbral space used**, in a dense piece in which this information may be otherwise difficult to perceive.

The NFreq–Freq canvas had explanatory power perhaps since there are fast timbral shifts of various sizes, most timbres are iterated, and timbre cannot be separated from texture, pausing instead of timbre determines the segmentation in the piece.

e) Andre, segment 4: noisiness–TIV

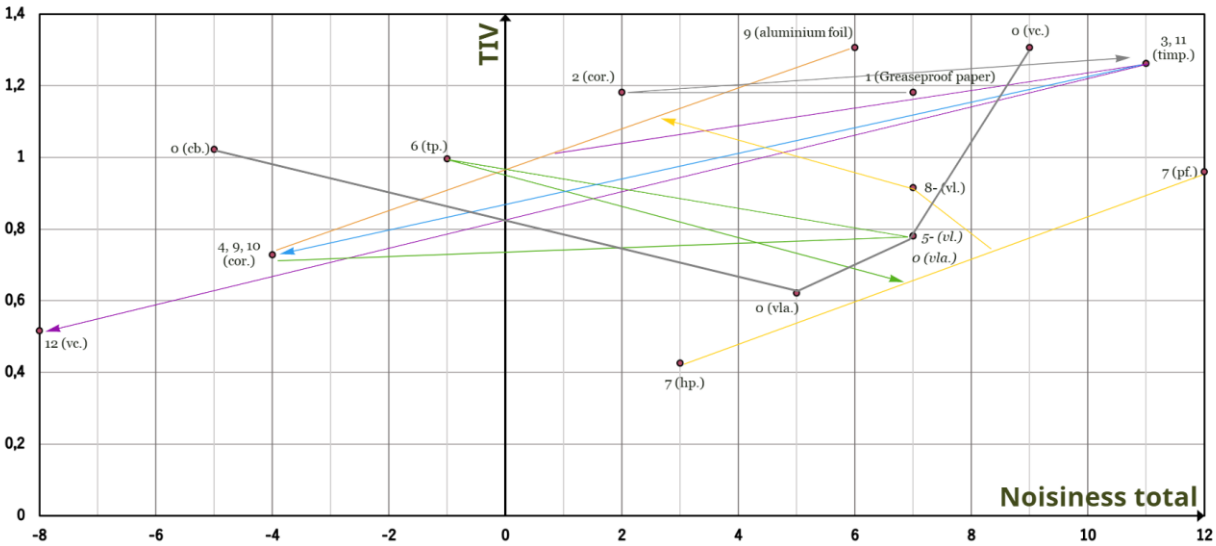

Fig. 4.2.5.-e. Andre's ending segment on the intensity canvas.

The ending segment of Andre's piece shows in this canvas 15 timbres at 14 coordinates.

We make a rare interpretation as a Solar system with groups similarly to the Zubel piece's analysis above, with the reservation that there is no sun and thus the typical centric trajectory is excluded. Rather, almost all movements cross the timbral gap around the assumed sun in the noisy-Froise region. It is notable that there are two groups: five timbres around pitched Froise, including the horn at +2, and ten timbres around the region of intense noise and less intense noisy Froise. One **dialectic of noisiness** arises from these timbral regions alone; a tendency to proceed from the Froise timbres to both the noisy intense and pitched non-intense extremes on this canvas. Yet this interpretation has its limits since this short passage is the conclusion of a longer passage and of an entire piece. **Listeners** here are likely to make use of two local listening strategies that correspond to the two axes (noisiness and tension), since a specific listening that directs at Froise against non-Froise sounds is unable to differentiate between the two groups or to notice the timbral gap.

Most movement is aggregate-based in that the two main groups take turns, and the aggregates that combine the two groups are so rare not to disturb this division. The lack of a sun simplifies the types of movements used, and non-parsimony becomes the most common type of movement.

An interpretation of the seemingly vectorial trajectories through the Linear strategy is unfeasible due to the lack of exact parsimony and the many aggregates. The horn timbre at
-4 recurs yet this does not form parenthetical or centric trajectories, which renders the Grouped strategy unlikely. Apart from the gap in the centre, timbres are spread in the space with somewhat equal density that does not speak for a nucleus. Since exact parsimony is rare in the aggregates and non-existent in the sequences, the Merged strategy is unlikely.

This noisiness–TIV canvas derives its explanatory power from the circumstances in Andre's passage in which most timbres do not change gradually, many timbres remain stagnant, morphology plays a negligible role, not all timbral entrances blend with the underlying timbres, and there are slow timbral changes and small dynamic differences.

Timbral trajectory strategy summary

For the theorist, these works were the most exemplary for the Solar system with groups strategy. We also found this strategy in less polished form in the passage of Furrer's cycles 1 and 2 on the Temp–NTemp canvas, in which the starting string timbre that stays the longest is the timbral centre. It had also features of the Merged strategy, due to some exact parsimony and the radial overall form of the cycles.

Generally, the identification of these pieces as Solar system raises our analysis from descriptive to explanatory level. Particularly meaningful is being able to explain the dramaturgical role of the sun timbre (or timbres) in timbral progressions and on the noisiness continuum, which may otherwise go unnoticed by listening or score study alone. Due to this Solar system constellation (as well as the possible doubling of timbres) and the Solar system strategy that typically goes with it, the exact parsimony, radial, and parenthetical trajectories were not found at all. Some other trajectories were more common than others, and this had implications for the hierarchy between timbres.

Compositionally, the choice of the "sun" timbre (or timbres) is crucial, as is its positioning in timbral space and the directions to timbral space that open from there. If preferred, it may be possible to obscure the identity of the sun by the use of aggregates around it, since this strategy perhaps least supports aggregation around wide distances, and by contrasting dramaturgy using the same pitch or instrumental source. The role of the groups or outliers can be varied yet is less likely to be identified as rapidly as the sun timbre due to its recurrences. We must note that even without trajectories, it is possible to give more **salience** (by duration, loudness, Gestalt, and so forth) to some substances and thus create **centric** situations within a trajectory strategy. This will resemble the Solar strategy, yet the Solar system as a strategy is defined by its constellation and the secondarily most common trajectory types in addition to centric trajectories.

For the **listener**, the Solar constellation is the easier to recognise, the more the sun timbre is separated from the other timbres and the more regularly the other timbres are positioned in timbral space relative to the sun. The recognition of groupings early on and of large timbral leaps (non-parsimony) can add meaning (PAINTER et al. 2011) and aid further perception. Froise can play a role in a noisiness dialectic in which the non-center timbres interact with each other. Alternatively, in the most recognisable case, the sun timbre is the most neutral Froise timbre and interacts with and against the satellites which can be pitched-Froise and noisy-Froise.

4.2.6. Summary of TTS and possible yet omitted strategies

For reasons of brevity, our study considered only the five most found timbral strategies that did not seem to overlap conceptually with each other. Already above, we occasionally had to bend the original definition, such as in a Solar system strategy without the “sun” which indicated the characteristics, yet did not have a centre timbre however. Many strategies were determined based not solely based on the timbral constellation but on which movements were more likely to occur in an idealised use of that strategy. As found out above, some timbral trajectories resemble parsimony more closely than others. We can summarise these five strategies thus, from the most parsimony-favouring to the least (Table 4.2.6.-1.)

Table 4.2.6.-1. The five most common timbral trajectory strategies (TTS) found in the repertoire.

Timbral constellation and cardinality	**Explanation**	**Groups, density, distribution**	**Typical movement and trajectory type**	**Less typical movement and trajectory types**
		1. Linear		
Linear, two or more timbres	The nearest (parsimonious) point will have a similar vector and/or distance as the point has from the previous	No groups are necessary. Small density. All directions are not required equally, often rectangular or	**most movements**: vectorial, exact parsimony.	**occasional**: parenthetical.

	point.	sharp shape.		
2. Nuclear with outliers				
Timbral nucleus constellation with outliers, 3 or more timbres.	one block or heap, few outliers	At least one group. Large and quite even in the nucleus, smaller for the outliers. Small often circular area, points have mostly similar distances to other points.	**most movements**: quasi-parsimony, exact parsimony, grouping-based. many movements: radial.	**occasional**: parenthetical, radial, non-parsimony (when moving outside the nucleus). **rarely**: vectorial.
3. Grouped				
Grouped (or "Field Series"), 2 or more timbres.	separate blocks and (possibly) individual outliers. A group can be reaccessed, and groups are not used exhausted to the full	Two or more groups. Density of all timbres varies; the separate groups each have large densities. Medium to large area with no particular shape.	**most movements**: quasi-parsimony, grouping-based. **many movements**: exact parsimony.	**occasional**: parenthetical, radial, non-parsimony. **rarely**: centric.
4. Merged				
Merged, 3 or more timbres.	"weaved", "intertwined"	one or more groups, most or all of which overlap. Large density in the groups, medium in the transitional points. Typically large yet not in all	**most movements**: quasi-parsimony, grouping-based.	**occasional**: exact parsimony, parenthetical, non-parsimony. **rarely**: radial.

		directions equally.		
5. Solar system (or "Pivot") with groups				
Solar system-like constellation of timbres around a central "sun" timbre. 3 or more timbres.	one center "sun" and several satellites and heaps around it. Separate groups and satellites do not directly connect with each other.	One or more groups. Small density at and around the pivot point, slightly larger when further from the pivot point. Large and circular area.	**mostly**: centric. **many movements**: grouping-based, non-parsimony.	**occasional**: quasi-parsimony. **rarely**: vectorial.

Many pieces were positioned clearly within these archetypes while a minority **combined** two or more. Passages of a piece can also display different strategies than an entire piece. The archetypal nature of these five TTS is seen in that these five timbral trajectory strategies share very little in common. It should thus be possible to maintain one TTS for a long time without it being mistaken for another strategy or for a pair of strategies. The other strategies are in many ways more complex. Here categorical perception works in favour of this small number of archetypal TTS's.

Other strategies that we can imagine were not to be found as clearly. They also had either too much overlap with some of the five or a too obscure definition in terms of timbral constellation or the trajectories it favours. Under this rubric we identify the following additional timbral trajectory strategies (yet forego their visualisation):

◆ **Nuclear without outliers**: with distinction to the Nuclear with outliers strategy, there is one block or heap and no outliers.
◆ **Non-linear sequence or chain** could be described as "pointillistic" or as "satellites that are their own suns", where the vector changes considerably with each move and yet there are no groups and the "unbounded" (term from MERMIKIDES & FEYGELSON 2017) constellation lacks a particular shape.
◆ **Grouped without outliers**: with distinction to the Grouped strategy, there are no outliers, and parsimony is more common.
◆ **Zoned**: a solar system strategy without groups, or in which groups are determined by distance from the centre. This strategy would be realised only in the case of similar distances of many points to the centre timbre and a lack of groups, so the zones practically become the manner of musical grouping and override considerations of parsimony.
◆ **Circular chained**: here a circular constellation of timbres would be met with trajectories that underline that shape. Circular movements are recognizable and

typical of music also outside timbre [152].
◆ **Circular not chained**: the circular constellation is hollow inside, or centre timbres are not favoured. This would resemble the Non-linear sequence, since the particular circular positioning of the timbres would not be acknowledged in the timbral process at all, and thus used differently than a Solar system that lacks a "sun".
◆ **One-sided Solar system**: a special case of the Non-linear or Unbounded constellation in which large sectors as viewed from the centre are not inhabited by timbres.
◆ **Solar system with no preferentiality**: here separate groups and satellites can directly connect with each other, without proceeding to the centre, as opposed to the Solar system with groups.

These eight strategies that we can imagine and use for compositions were thus not evidenced in the analysed works. In some cases, the differences are nuanced and for instance concern the presence of outliers, "suns", or grouping. **Features that distinguish the timbral trajectory strategies from each other** are (at least) timbral constellation, cardinality (number of timbres), number of timbral groups, the movement and trajectory types from the most likely to the least likely used, observation of parsimony in voice-leading, density of the constellation, distribution and positioning of timbres in timbral space and respective to the Froise region, as well as similarity to (visual) Gestalt principles.

'Pure' strategies are difficult to find in pieces and thus a large corpus of works from different compositional styles was needed. Even then, a minority of pieces neatly displayed features of two TTS's at maximum, or had irregularities related to an otherwise clear strategy. As much as analysts have tended to place value on compositions based on how well they fit into compositional and, increasingly, psychoacoustic models and systems, we should expect that completely functional and analysable uses of Froise will be found in "freely" composed works as well. Further theorists could dissect these strategies into the smallest common principles that can be seen to make them. Our analytical observation cannot explain all of the obvious functionality in music.

Most analyses have shown a perceivable dialectic on the noisiness–pitchedness continuum; all dialectics are summarised in chapter 5.1.2. Those works that focus on Froise and do not utilise the entire noisiness–pitchedness continuum have also displayed timbral differences in different ways that can likewise be shown on timbral canvases.

For the aggregate-based approach, the easiest to identify were different timbral states or even stations that are clearly segmented in time with a separate timbral region that does not overlap with any other timbres from other passages in the music. In these cases, we see either

▪ alternations between sets of timbres, or
▪ rotations between sets of timbres (same as alternating yet with more states).

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[152] See KEIL's (2012) "kreisförmige Strukturen in der Musik".

Often, however, the timbral movements proceed to always new states, as most clearly in the Bauckholt piece analysed above. New timbres are added or earlier ones left, and the size of the timbral region changes consequently. The terms in Table 4.2.-1 can be used to describe operations in timbral space.

Table 4.2.6.-2. Ways of describing changes in timbral aggregates.

	adding timbres	leaving timbres
changes are near the centre of the timbral region	*consolidating*: selecting timbres (by adding new ones that are near the centre of the timbral region or leaving earlier far-away ones) such that the distances between some or all the used timbres **diminish**.	*dissipating*: selecting timbres (by leaving ones that are near the centre of the timbral region) such that the distances between some or all the used timbres **increase**.
changes are far from the centre of the timbral region	*expanding*: selecting timbres (by adding new ones that are far from the centre of the timbral region) such that the distances between some or all the used timbres **increase.**	*focusing*: selecting timbres (by leaving earlier far-away ones) such that the distances between some or all the used timbres **diminish**.

The sequence-based approach does not require considerable interpretation.

Most polyphonic music in which timbres start and end independently of other timbres might favour a different presentation on a 3-dimensional canvas that shows chronology on one additional axis. Such a chart would become extremely crowded with time data and would need a computerised presentation instead of a paper surface. The greater unknown in such an approach is however perceptual masking, since new timbral events tend to take salience from timbres that are already sounding.

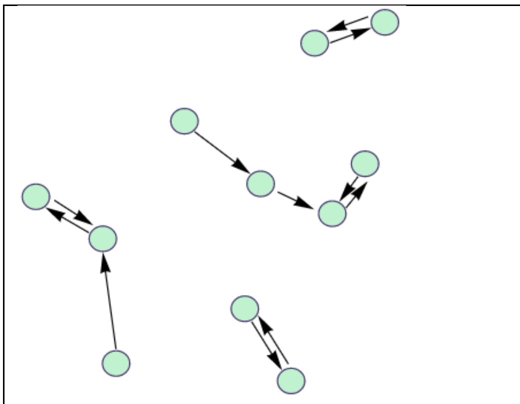
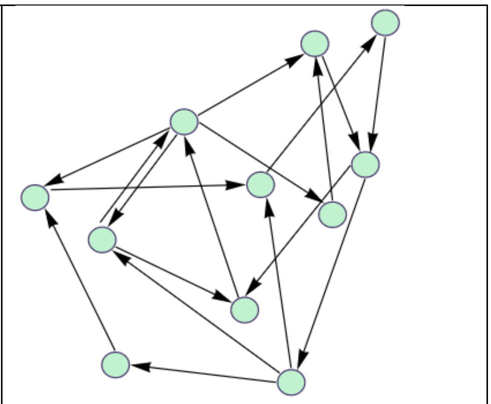
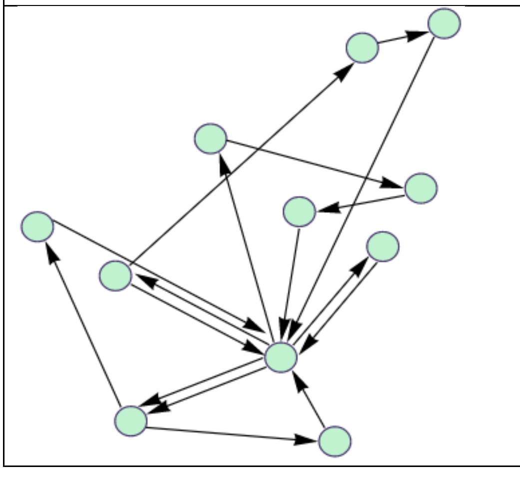
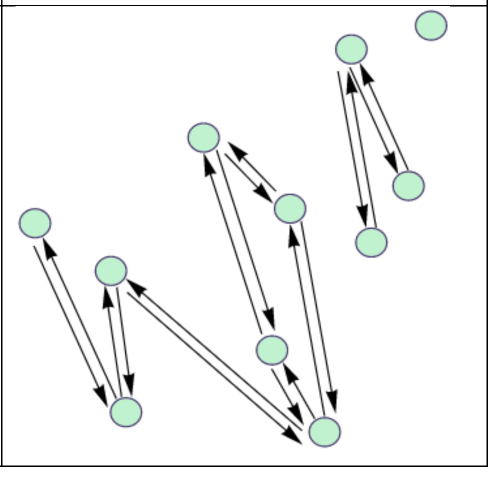
Compared to tonal analysis which integrates vertical and horizontal features, noise syntax has very few means (beyond blend) of **integrating the aggregate-based and sequential features**, and thus both approaches must be considered legitimate. The grouping approach is necessary especially in pieces with dense onsets and a blurring of clear “voice” identities (by a timbre seemingly moving into two different timbres, or two different timbres seemingly merging to a third one).

Above, we have given idealised illustrations of the trajectory strategies. We have to remember that the concretisation of these trajectories comes when they are scaled to any magnitude, transposed to any region of timbral space and used with any of the canvas versions. The shapes that were shown as simplified 2-dimensional points' relations to each other still consist of timbres that bear very concrete associations and intensities, and listeners cannot fully fade out instrumental aetiology either. Both the general and particular understanding of events in timbral space are inseparable and crucial for analysis. The strategy, constellation, analysis approach, and the trajectories all contributed to these analyses, and other methods of classifying the pieces on the grounds of spectrotemporal movement may exist.

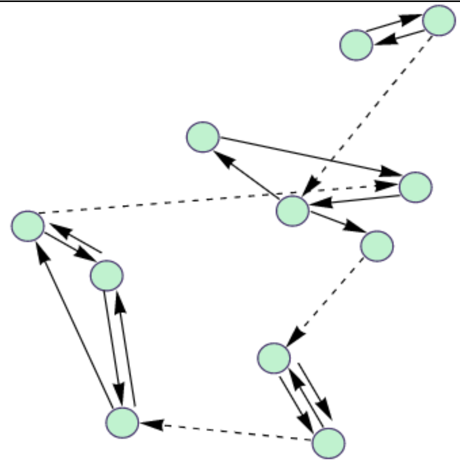
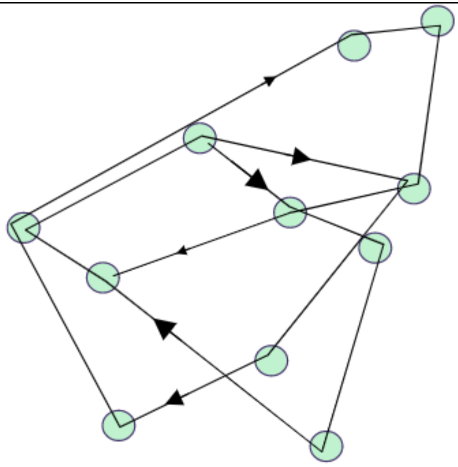
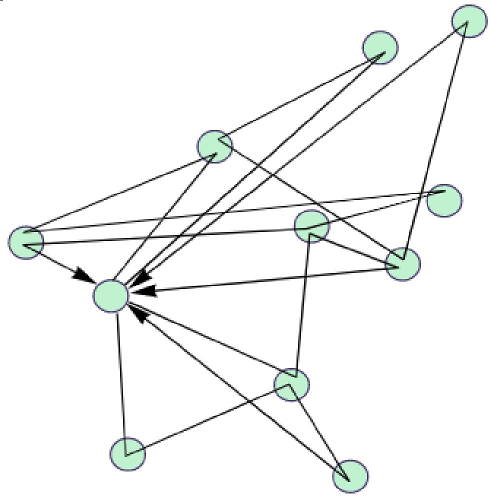
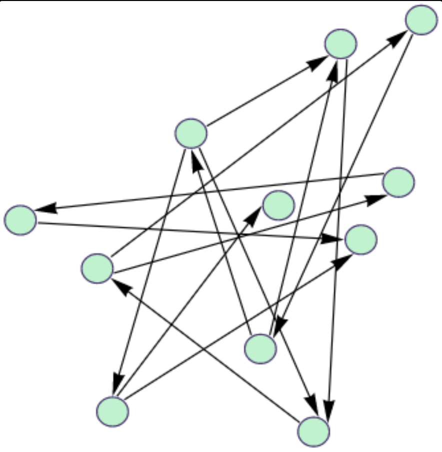
4.3. Summary of trajectories on the timbral canvas

After the examples from actual compositions, the theorist would want to ensure that the eight trajectories can be identified in further compositions too – like the five TTS were idealised above. From the listener's viewpoint, an encounter with different trajectory types may not necessarily mean that audition focuses on all of them, and neither that all trajectory types would be able to bear form equally effectively. If we take parsimony to be a main form-bearing factor for movements in timbral space (analogously to what is known about the importance of parsimony and contour perception[153] in pitch space), we could rate the trajectories' effectiveness by how closely they resemble exact parsimony. Explicit non-parsimony should be in this sense the least structurally effective trajectory type. Based on our analyses of the works we can now idealise these trajectory types and present them in the order from the most to the least structural:

Table 4.3.-1. Illustrations of the timbral trajectories and their implications for parsimony, shown on one and the same constellation.

	1. exact parsimony 2. quasi-parsimony	
	3. centric 4. vectorial	

[153] MARVIN (1989:106) considers that listeners perceive pitch contour faster than exact pitches. Whether this applies to timbral trajectories vs. exact timbres remains an open question.

	5. grouping-based 6. radial	
	7. parenthe-tical 8. non-parsimony	

The centric and parenthetical trajectory types are closely related. The less form-bearing trajectories are also found in this repertoire and can play a crucial role in musical dramaturgy – extreme form-bearingness is not a primary aspiration for all composers.

On **vectorial** trajectories, we must notice that in the TIV-noisiness canvas, vectors that are horizontal correspond to the noisiness-pitchedness continuum and vertical vectors may most accurately show changes in intensity (TIV). In the other canvas versions the axes are less independent, and thus vectors at 45 degree angles (2 different ones or 4 ones when considering the vector direction as well as angle) relative to the axes can best describe the noisiness-pitchedness divide, or changes in the distribution of the respective spectral feature without changing the grade of noisiness. If we are able to evidence certain vector angles or rough vector directions to be favoured in a piece, this could help understand Froise dramaturgy.

The types of trajectories draw us to define parsimony closer. As a piece progresses, more timbres are typically introduced and crucially, **earlier timbres are discarded**. If the inactive timbres in long pieces are not removed from the visualisation, timbral space becomes more crowded, all the while timbral points differ as to how easily listeners can be expected to recall them. Parsimony in the relative way that we have defined it, starts to lose its meaning. When parsimony is not indicated as an absolute numeric distance in timbral space, and instead defined by what nearby neighbours do timbres have, and if now those neighbours are not being accessed any more, from any timbre, those inactive timbres should not be maintained as part of the timbral space since they block the creation of parsimony between the active timbres. **Alternatively, if we were to define the range of parsimony as an absolute numeric distance** (and thus akin to the pitch realm where the definition of parsimony follows the psychoacoustic just-noticeable-difference), we would get very different results in pieces that have lots of timbres compared to pieces that have few timbres. In the latter case, timbral outliers would by definition not have any parsimonious connections to the other timbres, a notion that would mislead the analysis. We must understand the setup of timbral space more like the setup of a scale; in longer timbre-based works the timbral collection is in flux and timbral connections are perceived more locally (timbral space has no pre-conceived structure unlike tempered scales, and comparison between timbres might not happen across events that happened several minutes apart as it might happen with pitch events). If parsimony is understood as a relative measure and if an unnecessarily long segment of music is taken as the basis of contextual parsimony judgements, those timbral strategies that most rely on parsimony, such as Nuclear with outliers and Linear, become unavailable, while longer pieces tend toward classification under the Merged and Grouped strategy. To our knowledge, no current literature addresses this question of timbral memory, and thus our only remedy is to make only short passage analyses that follow borders of timbre-based segmentation, or secondarily of segmentation based on other means.

When we have analysed the repertoire, it has been convenient to **identify general idealised** model strategies in the use of timbral space, and then **order pieces** according to which such model they fit most closely. Pieces that are considered under the same model can inform us as to how to use similar strategies most effectively and to combine strategies and use different strategies in different aspects of timbre (as was shown, canvas versions from the same passage of music did not always all utilise the same strategy). Above we have concentrated on the top five (likely) most form-bearing strategies for the use of timbral space (Nuclear with outliers, Grouped, Solar system with groups, Merged, Linear), as was shown by the ranking of trajectory movements by their parsimony. These five make use of the most form-bearing trajectory movements, while the remaining strategies are either associated with the less form-bearing trajectory types or use the highly form-bearing trajectory types only rarely. The other three strategies might also occur in music yet clear examples of them were not found in the studied repertoire. Even with our selections, examples do typically unequivocally support one strategy yet are not a literal reproduction of it. In this, reality merely aligns with, and is not subject to, theory. The weighting discrepancies in our timbral typology also play a role.

We must view the listed strategies as mere **prototypes** that have an idealised shape and preferential order of the trajectory movements that the strategy makes use of. In addition to identifying the timbral constellation, one way to determine the timbral strategy in a passage is to consider **which types of**

movement are common, and what is their mutual order of likelihood. Some trajectories for example are characterised by recurrences, and in this consideration not even the choice of canvas version matters.

4.4. Analytical findings from Froise dramaturgy

"we cannot just set up a generic space and take the objects as being "points" in such a space. Rather is it necessary that each point carries its space with it like a snail carries its shell. Referring to Artistotle's description of real things as a combination of substance and form, we view a denotator as being a substance-point within its form-space" (MAZZOLA 2002:50)

In the realm of timbre, no understanding of functionality is widely accepted and ours is even among the first to propose the adoption of the concept of functionality for timbral music [154]. Even then, our proposal is not a single uniform method, rather a basic way of thinking about quantifying aspects of timbre and presenting the results of that work in two-dimensional space (modules 1 and 2), by selecting one or more of the numerous presentation types. In this third module, it is likely that one of the more common axis combinations will render on the timbral canvas **a somewhat systematic constellation of timbres** that also corresponds to compositional strategy, such as the temporal segmentation or the separate movements in the piece. We must remember that whatever constellations we see depend on the graph axes that we have chosen. With the clarity that one good selection of timbral canvas brings, we must also be able to prove **why the other graph types are not as apt at describing the piece** (in chapter 4.5.); that is, what makes these two axes compositionally and eventually auditorily relevant in the piece. The selection of the most powerful canvas graph(s) itself is only half the justification, and the rest will need a verbal examination. The canvas should reveal features of the piece's workings that are not immediately palpable based on its notation alone. These include aspects of **musical unity and coherence**[155] that occur with a certain listening strategy. The idea of multiple routes to a unity is not entirely new, at least according to Wiese for written prose: "phenomenal unity should satisfy at least the following core constraints: phenomenality, globality, and necessity." (WIESE 2018:26), which are all fulfilled by the TTS and dialectics of noisiness, and

> "phenomenal unity is not a single phenomenon. This can either mean that there are *different kinds* of phenomenal unity relations, or that, in the same subject of experience, there can be *multiple instances* of phenomenal unity at the same time. Both options suggest that we can experience different wholes

[154] By analogy to tonal music analysis, we are now at the stage where we can identify chords and we can determine their relationships to each other generally as well as in the context of a piece. Our next step would be to find out how the chords are made into progressions to create music, whether we want to see it as serving expression, narrative, flow, or some other more clearly defined concept entirely. Here the tonal–timbral analogy however ends.

[155] For critique of coherence requirements in music, see LÅNG 2002, DECROUPET 2010, and KRAMER 2016.

at the same time." (WIESE 2018:124).

For Wiese (2018:28-29), phenomenal unity has gradations, and does not have to encompass all perceived parts as long as a larger phenomenal field is unified by sufficiently many relations between the parts [156]. Then, Wiese's unity comes partly also from the dispositionality that many parts can be connected yet only some will be in the actual piece. Due to the conceptual weight of these terms, such phenomenal unity is what our above analyses have labelled as musical dramaturgy.

For our classification of strategies with noisy timbres, the **constellation matters**, for several reasons:

▪ constellations indicate the amount and central positioning of Froise sounds in the timbral movements. A compositional strategy that creates a Froise-based piece involves a strategy that characteristically uses the Froise region in the constellation.
▪ many trajectory types are technically downright impossible in some constellations.
▪ in ambivalent cases, the timbral gaps (**vacuums**) in a constellation hint at which timbres should function as Froise. The fluidity of the boundaries of Froise allows us to bypass the strict –7…7 range, given an applicable context in timbral densities and grouping.

With larger collections of timbres (cardinalities) also **temporary vacuums in timbral space** occur which make radial movement unlikely, and parenthetical more likely. Three is the smallest number that allows vacuums and "rejuvenation" or "renewal" of at least one timbre (coordinate point) at a time[157].

At this point it would be superfluous to analyse these works with conventional musicological and analytical means that do not address Froise [158]**.** This is partly because most analyses only concerned passages, not entire works in their formal unfolding, **pitch-based methods can still be additionally used** and will yield modest results, and because in the case of full works (Furrer, Saariaho, Sciarrino, Zubel) the **formal solutions were in support of Froise and timbral voice-leading** – the particular formal solutions that were beneficial for Froise included binary, ternary, continuous development, and canonic principles and as such were used in the same way as in pitch-based repertoire. The beneficial participation of Froise in form is thus only as a novel substance that is located

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156 This comes close to DENK's (2001) term continuity.
157 Our historical analogy may be drawn with emerging tonal functionality by Carissimi, Gabrieli, and others who made musically the most out of a limited network of functional, mostly unaltered, steps.
158 We may point the interested reader to existing work analyses works from non-Froise perspectives. Furrer's Wüstenbuch has been covered widely, see articles in KUNKEL 2011 by writers Obert, Mosch, Ender, Maintz (on the libretto) as well as MAINTZ 2014a, MAINTZ 2014b, and JUNGHEINRICH 2011. Wüstenbuch has been covered in the articles of TADDAY (2016). To our knowledge, no previous explanatory analyses of these pieces have been published, while some works have musicological or program leaflet texts available. Since we do not study the genesis of the works, this literature will not be further engaged.

inside a familiar formal scheme (when that originally tonal-functional scheme is adapted to sound-based music), not as some groundbreaking new formal scheme or principle. Froise is a sound type that allows for any formal treatment[159]. Without undergoing detailed formal analyses with conventional methods here, our analyses suggest that **all existing formal schemes and small-scale forms are able to support Froise and vice versa**.

We clarified that composers could choose the trajectory types in pieces rather locally, and mostly independently of what constellations are formed by the timbre collection in the piece as a whole. Admittedly, segmentation was required and we have not examined full pieces apart from Saariaho, Sciarrino, and Zubel, but instead dramaturgically crucial passages from pieces. In some cases, these passages constitute only temporary immersions into a Froise-based, noisiness-based or sound-based (depending on what the main stance of the piece is) stance, respectively. In those cases, a focusing on Froise further complexifies dramaturgy. Froise can then be understood as a "niche" which within a highly complex system constitutes a "local use of signals and resources" (HOLLAND 2014:59), while other parts of the piece may be interpretable with previously established tools of analysis. Our method works to show the functioning of Froise for dramaturgy also on the scale of (not only the chosen three) whole pieces.

We have here spoken for an "explanatory pluralism" [160] and posit that for no piece can a case be made that could genuinely promote the presence of only one timbral trajectory strategy [161]. Indeed, for some pieces all their four canvas versions were listed as successful examples of different strategies [162]. Moreover, some pieces displayed features of two strategies even in one canvas version. We underline that these findings should not be taken as errors; the variety of interpretations allow for different listening strategies as well as for ambivalent situations (for which many styles and eras in music are particularly esteemed for). Since our eventual focus is on the compositional use of Froise, in the following, we will address the pieces individually rather than as proponents of a timbral trajectory strategy. The above analyses have used insights from our timbral analysis checklist from chapter 3.3.2. as it fits discussion of Froise strategies, and its other considerations are rather for full-length analyses.

Some of the compositions that we have analysed have also been analysed from other points of view [163]. Below, we give these references where available and

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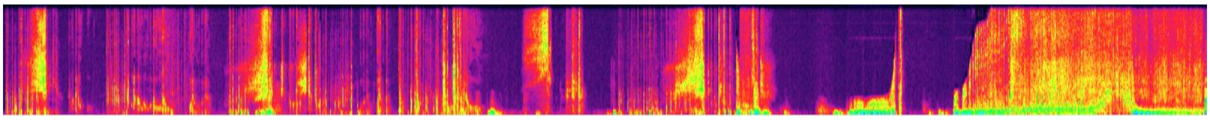
[159] Due to the pitch content in Froise, an interval-driven form is possible although outside our focus.
[160] See PINCOCK 2018.
[161] Even in tonal music, no piece is only made of its chord progressions, rather, melodies and the registral setup of chordal pitches also play an interconnected role. Thus if an altogether different listing of timbral trajectory strategies should be established, it would also require to be built on psychoacoustic criteria or listening-based evidence.
[162] A case in which a piece shows the same strategy in all canvases was not found. Whether such a situation has implications for the robustness of the piece's timbral organisation is yet to be seen.
[163] In addition, many of these composers have been more generally described in books and articles, which could be used for a further comparative or cross-output analysis of

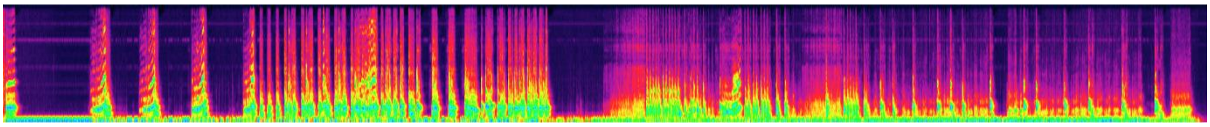
short concluding remarks from the Froise perspective for each piece. Self-explanatory charts of FFT analysis of all works are given, to compensate for the lack of full scores and audio files in our publication format. Score examples of most works are available in Appendix 4.

Auvinen, segments 1–3

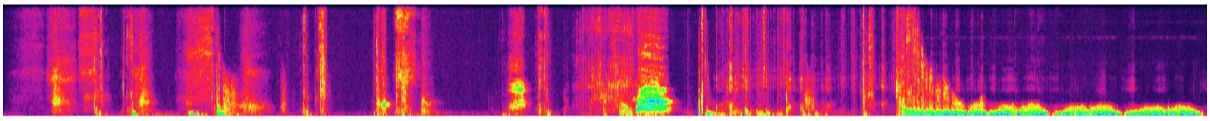
Our analysed segments follow a long instrumental introduction in the third act of Antti Auvinen's multimedia opera *Autuus* (2015). This segmentation follows both changes in the video screen, pacing of the sounds, dynamics, instrumentation, and in the timbres used.



The first segment lasts 2’20’’ on the recording. The electronics overtakes the choir by loudness at the end.



The second segment lasts 3’02’’ on the recording. The electronics Froise sample maintains a soft, low, timbrally unchanging, pulsating role.



The third segment lasts 1’16’’ on the recording. The electronics only join towards the end.

This work, perfomed in Helsinki in 2015 and 2021 (with unpublished video recordings), we can expand our context to analysing Froise sounds in electroacoustic and multimedia composition. The setup is flute and bass flute, bass clarinet and contrabass clarinet, cello (with pedals for delay, distortion, and octaver), piano, harp, 2 samplers, electronics (live and fixed), and 11 singers. All musicians are on stage and have slight amplification to allow the fragile timbres. This passage has no processing and the tape part is only present in the second segment and even then negligible due to its constancy.

Writing actions on paper are displayed on the video screen, artificially sped up and down, and combined with the electronics playing the associated Froise sound from the pencil's movements. Also, choreography, a spoken interview, subtitles, and recorded closeups of the soloists are shown on the video. The choir for instance begins with guttural sounds that imitate the writing by pencil shown on the video screen. Towards the end of the movement and stage action, one

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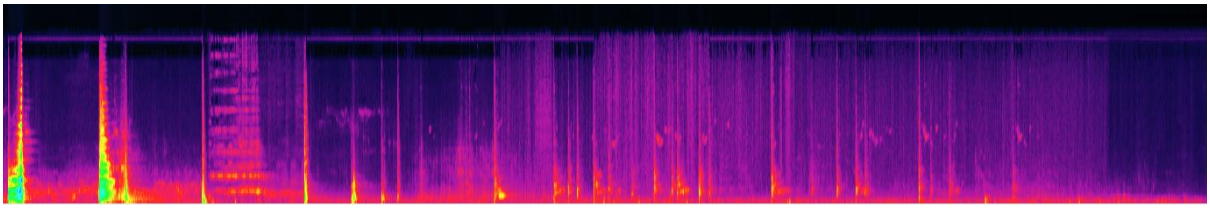
any of the composers and in diverse traditions such as musique concrete instrumentale, saturated spectralism, and sound-object composition. It would take a wider corpus of analysed works to be able to generalise any connections with established compositional school and uses of timbral space.

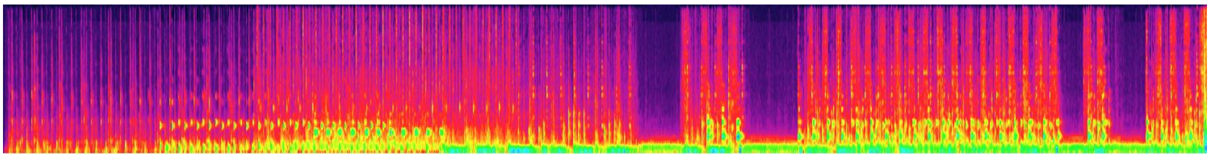
brother murders the other. Supporting this narrative, many of the sounds become more and more affective and emotionally derailed.

Andre



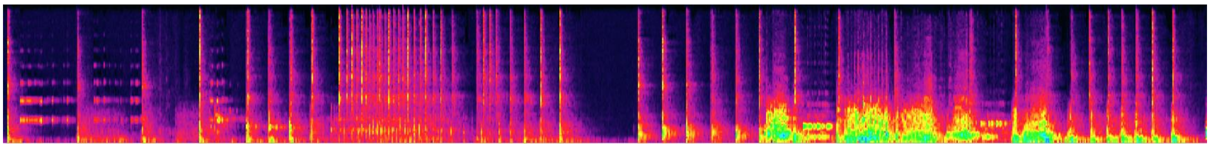
From this orchestral piece, our analysis considered its last passage. In a dialectic that breaks from pitched chords via Froise to wide noise, Andre works with fragile and unpredictable timbres which in many cases are doubled. Since there are still numerous timbres in this passage, we relied on a segmentation into three segments (A-C) and an elliptically bordered codetta (D) (this fluidness is considered monadic by the composer) [164]. Our analysis reduces doublings and ongoing timbres, to focus on the sequence-analytical approach. This excerpt lasts 4′57′′ on the recording.

Bauckholt



The timbral "stations" were numbered according to the instrumentation chronology which is readily evident by listening and at the latest with the score. Bauckholt's music is covered at length in OBERSCHMIDT (2014). This excerpt lasts 3′49′′ on the recording.

Czernowin



The instruments in this piece seem independent yet together form impressions of the Froisy ratchet sound. The form is non-traditional and thus the passage was chosen based on timbral listening [165]. This excerpt lasts 0′47′′ and is in the last third of the recording.

Furrer, cycles 1–2 and 6

Furrer's piece juxtaposes two heavily Froisy timbral states as blocks against each

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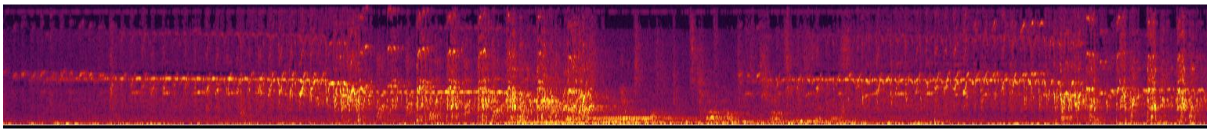
[164] This exact segmentation was also agreed in a personal meeting with Mark Andre in Prague on April 10, 2022. A similarly interesting passage amidst the piece (m. 113–224) was also studied yet would have needed extensive contextualisation on both sides of the excerpt.
[165] For a musicological aspect into this piece, see EDWARDS 2019.

other, which is quite typical of the composer[166]. In each cycle, the considerably longer state is made of a polypulsating corpus of bowed string layers and occasional accordeon that realise different timbral processes to and from noise. Many processes emerge from a base Froise timbre and continue to be handled rather statistically, and achieve a general progress toward more pressured and noisy bowing each time. We could call this layer carpet due to its texturation. The strings stack in close imitative formations and play almost constantly, and their absence creates high points. The contrasting rather short block (which we call reverberating) creates its own sense of space with the staged reciter's voice (not included in the score or analysis), percussion, and bass clarinet multiphonics. The returns to Froise are more distinguished. Since the layers hardly overlap or interact, we concentrated on the changes in the five occurrences of the carpet texture only. Delicate structuration steers the durations of each block, supporting the general dialectic

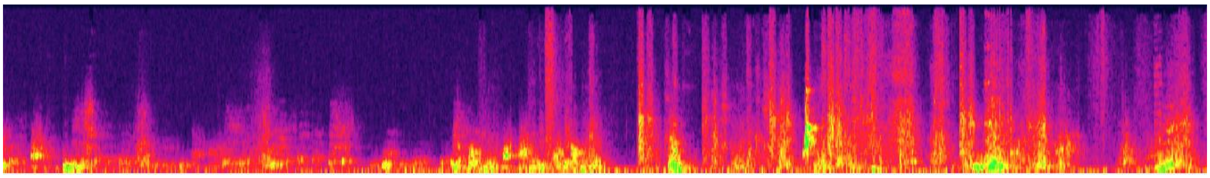
In this piece, the mainly noisiness dialectic is complemented by **frequency organisation of spectral regions**. Since this cannot be made evident by our canvases or the TTS's, this further analytical direction deserves some elaboration here. The frequency design of the accordion supports the frequency regions present in the noisy timbres. The opening of the high violin scratchy pitches establish the **main sound** and create the **spectral contrast** to future sounds. The main sound has an approximate frequency region compared to the steady multiphonic, a simpler and more solid timbre which soon emerges and at times is doubled with resonating instruments:



The later emerging accordion then creates a timbral approximating extension to the main sound as its spectrum is more harmonic yet closely retains the violins' strongest frequency region. Two intense double bass entrances on a repeated multiphonic open an in-between frequency region that was previously left empty between the main frequency region and the bass clarinet multiphonic. Both times, the successor two pitches of the crotales provide a similar extension to the narrow range between the main frequency region and the region of their first overtones. They can also be interpreted as growing from a weak spectral component that arose just earlier from the addition of the lower strings of the violins. This excerpt lasts 3′40′′ on the recording, of which the six cycles have the following lengths: 13′′, 13′′, a combined 13′′+50′′, 33′′, 35′′, and 1′03′′.

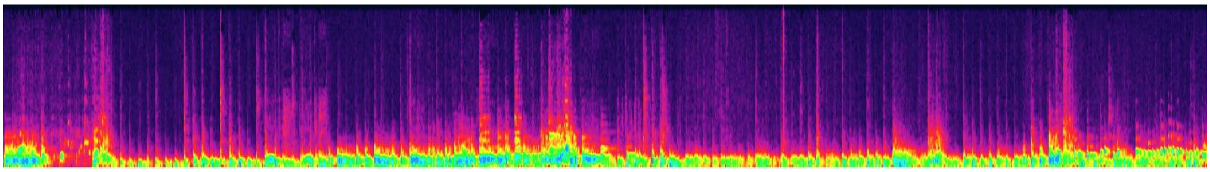
[166] On Furrer's compositional style, see FURRER 1999.

Lachenmann



As a prolific writer, Lachenmann's music can be also understood and analysed through his own formulations and theoretical framework. However, to our knowledge, no prior analytical or musicological sources exist for this work. This excerpt lasts 0'53'' and ends the first third of the recording.

Pesson



Our selection is from the middle of the piece and constitutes a Froisy niche in a somewhat interval-based composition. Many passages in Pesson's output (which has been analysed in English in titles by William J. Drummond) achieve a strong timbral focus without a particular focus on noisy sounds. This excerpt lasts 0'56'' and starts the last third of the recording.

Rădulescu

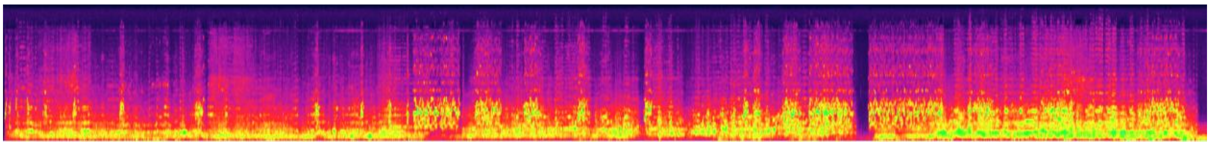


Fig. 4.4.-1. Horatiu Rădulescu: Thirteen Dreams Ago, stations 1 to 3. FFT visualisation of the timbral transitions by the amplified string section and electronics. This excerpt lasts 4'00'' on the recording.

Since Rădulescu's notation may not be obvious, we show the timbres as they are in our taxonomy and canvases, which used the approximative string instrument code abbreviations equally for all string instruments (Table 4.4.-1.).

Table 4.4.-1. The timbres found in the Rădulescu excerpt, by instrument.

	First station "Noisy thought" (0:00–2:00)	Second station "Soundy feeling" (2:00–4:05)	Third station "Elementary intuition" (4:05–5:50)
vl. 1	000002TTVVV	F00001TLLf	120i01TmLL 120i01TmLLf
vl. 2	000002PVVV 000002PPVVV	F00001PVpnLLf 100001PVpnLL	120i01TmLL 120i01TmLLf

vl. 3	00b002PLL 00b002TTLL	F00001LLf F00i01LLf 100i01LL (all T vs. PP)	F00001PVpnLL 100001PVpnLL
vl. 4	00b000PLL 00b002TLL	F00001TVLLpnf 100r01PPVLLpn	f00001PVVV flaut. 100001PVVV flaut.
vl. 5	000002TTLL 000002TTVVV	100i01TTVLLpn	f00001TVVV flaut. 100001PVLL
vl. 6	00b000PLL 110002TLL	100i01TTVLLpn	F00001PVLL 000001TTVVV flaut.
vla. 1	f00002TTVVV	110i01TVLLpnf 110i01TVLLpnh 110i01TVLLpno	f00001PVVV flaut. 100001TTVtlLL
vla. 2	000000TTLL 00b002TLL	F00i01PPLLf	F00r02TTpnLL
vc. 1	f00000TTLL 00b000PLL	F00001PPLLf F00001TLLf	Multiphonic F00000TV
vc. 2	f00001PVVV f00001PPVVV	000i01VVV PP vs. P T vs. [ord.]	F00002PVmLL
cb.	f00001PVVV	F00001TVf F00r01PPVf	f00i02 flaut.; F00002 VVV vs. V; P vs. TT End: solo multiphonics

Due to the length and notational uncertainties of this piece, our analysis has only observed the timbrally clearest points, the first three such perceptually important sections (corresponding to the marked passages "noisy thought", "soundy feeling", and "elementary intuition" from 0:00 to 4:30. Since at the start of them a total change of sounds occurs. Luckily, most of them lie outside timbral bridges and thus represent sections in the timbral rapidly (r)evolving landscape. Nothing implies a timbral linearity between the sections in practice, yet after an understanding of the timbrally stable points, an informed reduction of the complex passages that carry timbral processes could be continued [167]. Rădulescu subjects pitches to a strict (yet apparently secondary) invariant spectral organisation, described in the instruction pages [168]. For Rădulescu, the focus might have been a spectral concern on blending, exactly written harmonics, and the undertone series, yet the noise and Froise surface also allows sound-based listeners to regard exact pitches as the negligible, necessary medium that carries timbre. We should not simply imply a timbral linearity between the plateaus in

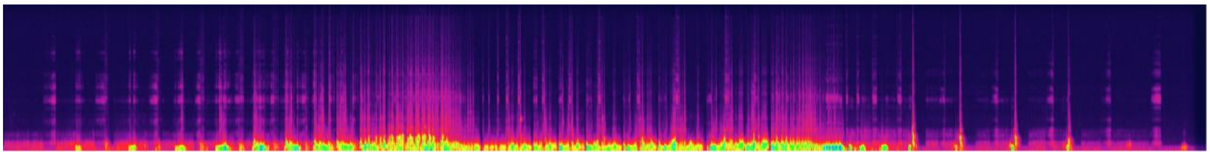
[167] It is tempting to also rely on auditive analysis only, or to apply the principle of tension and release (or of flux and stability) to individual descriptor processes, or Gestaltic methods. Rădulescu also asks for "SEMPRE arco/legno tratto LISCIO (legatissimo)", which might mean a preference for a smooth continuum of sound despite the irregularity in the individual parts.

[168] This edition's legend does not include an explanation for any of the accidentals. There seem to be standard accidentals for quarter-notes, yet it is now clear whether the up- or down arrows refer to exact cent increments or an amount relative to a nearby harmonic.

practice, yet an informed reduction of the complex passages that carry timbral processes cannot be done before a prior understanding of the timbrally stable points.

Rădulescu's use of microtones and scordatura is for him not exceptional (TOPOLSKI 2012:112 [169]) as neither is his adventurous regulation of bowing pressure, position, speed, unstable flageolets, semi-regular alternation between any such states, the use of *arco* and *legno* playing in the string corpus simultaneously [170]. This leads into a unique type of Froise – not only are the instruments played in timbral conflict with each other so that out of those different simultaneous combinations an idiosyncratic micropolyphony texture of Froise is born, unlike Ligeti's or the sonorists'. Apart from the systematic titles for each 16 sections, no further organising principles are evident.

Romitelli



The work merges the musician very closely together with the instrument, with the inhale–exhale patterns and resonation of the human voice through the instrument. A virtuosic solo texture with rhythmic forward-looking urgency from key noises and tonguing, and is a classic piece for the Paetzold contrabass recorder. We do not regard exact pitch or small dynamic differences between the occurrences of the same material. We also consider pitch repetitions as the same material as scalar pitch progressions in cases when the other features of timbre are strong and counteract pitch perception (such as with inhaled pitches).

Many of the timbres later emerge as combinations of two previously introduced timbres or morphologies. This shared aetiology should however not distract us, since in resorting to such familiar timbres and morphologies, Romitelli may have strived towards more middle-level unity and might also have been genuinely limited by how many novel-sounding timbres can anymore be produced by the instrument.

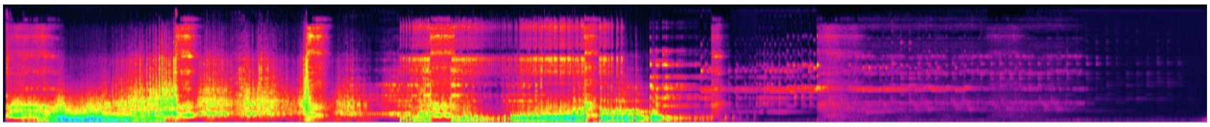
One approach would be to look at when the new timbres are introduced in the piece and how much time is between these occurrences. This approach would have to be complemented by a motivic analysis that observes how material is treated meanwhile, when no timbrally new material is introduced and the processes have to do with pitch level, dynamics, ordering and duration of the hitherto introduced timbres.

Analyses could be done of the further cycles (on the first manuscript page,

[169] "Przy okazji omawiania twórczości Radulescu warto podkreślić zjawisko *scordatury*, czyli specjalnego systemu strojenia instrumentów (zwłaszcza smyczkowych, np. według mikrotonowego odwzorowania widma), stosowanego przezeń od lat 70. i *Credo*; systemu strojenia, którego poszukiwał także Johannes Fritsch w *III Kwartecie smyczkowym"*.
[170] Further see DOUGHERTY 2014.

centred around the "suono del vento" timbre, or on the rows 7 and 8 of the third page, centred around glissandi and humming). This piece lasts 8′30′′ on the recording.

Saariaho



This piece presents several cycles of percussion on a rather unchanging electronics background. The electronics part has been excluded from the analysis for its relatively detached role and for the acoustic focus of our analysis method. Likewise, the elaborate internal texturing within the percussion part has been heavily reduced, to concentrate on the "timbral accents" brought about by the addition of contextually novel timbres.

This piece and its sixth movement have been covered from a musicological viewpoint (see DI SANTO 2017, MEYER 2011, and MEYER 2012). Much has been written on Saariaho's style, aesthetics, output, and intentions from musicological viewpoints. We have listed KANKAANPÄÄ 1996, SIEGEL 2014, SINERVO 1997, and Saariaho's own writings in our bibliography (particularly SAARIAHO 1986 and 2013).

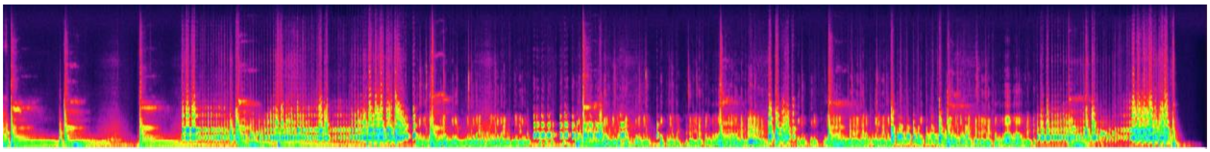
Saariaho builds five timbral cycles, each smaller than the previous and operating in an even narrowing Froise region, until the last one. The fifth cycle claims back much of the timbral space and rounds the gaps that were previously created especially with the crescendoing in the timpani and gongs which made them open the most noisy ground in the early phases of the piece. The first and fifth cycles are clearly circular (clockwise and counterclockwise, respectively) while the middle cycles have a zig-zag form where the circularity may not be perceived because of the close positioning of the timbres in timbral space. The timbres in the middle region of the canvas (triangle, crotales, tambourine) are each given much presence within their cycles.

Most movements in timbral space involve quasi-parsimony and radial mostly counterclockwise movement that ends with larger TIV values than where the trajectory started.

Saariaho's use of Froise often results from textural micro-movement and from layering sounds that by themselves have mostly simple spectral content. Thus, the perception of Froise at any given time is subject to the individual lines' pauses, dynamics and timbral directions in a polyphonic texture. There are only a few exceptional passages where the sound is complex, stable, and not participating in polyphony.

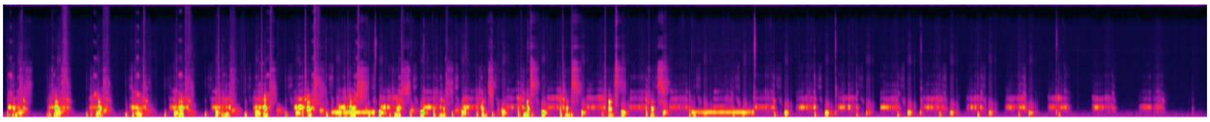
The principle of a simple noise dimension put forward in Saariaho's 1986 article was consulted and has been confirmed by the composer to be valid also for this work and later works (SAARIAHO & VESIKKALA 2020). This movement lasts 3′24′′ on the recording.

Sciarrino



The piece makes experientially the most out of recycled extremely short materials that not quite attain individuation, a "maximalist repetition", to use a term by BOYLE (2018, iii and 2ff.). Sciarrino's own work description (SCIARRINO 2007) invites listeners to remain open for the suggestibility of this composition, its communicative attempts at the shards of a lost wholeness ["frantumi di totalità perdute"], and recalls even psychoacoustics and animal languages. Sciarrino's compositions have been written about widely; see for instance BELGIOJOSO 2014, McCONVILLE 2011. On this work, see KNESSL 2005, GÜNTHER 2008; to our knowledge, no prior explanatory or musicological analysis exists. This movement lasts 2′52′′ on the recording.

Zubel



Zubel as a singer-composer has a wide output which has been viewed for its skilled use of instruments for timbral continua and texturation [171]. We know of no prior analytical or musicological sources for this work. The next analytical steps could relate this movement of *Cascando* to the previous movements, to compare the compositional means used. This movement lasts 5′58′′ on the recording.

By the above analyses, centred first on one TTS analytically at a time and then on the piece more musicologically, we have introduced the third and final module of our analytical method. It required application of our timbral categorisation method (module 1), presentation of four different timbral spaces (timbral canvas versions) and mutual placements of and temporal progressions between the timbres in timbral space (module 2), and the contributions of module 3: interpretation of the constellations, groupings, and trajectories that form between timbres.

We consider the results from the third analytical module the most decisive for both theorists and composers. Its five TTS's show manners of making musical entities out of disparate sounds in a sound-based dramaturgy and is where considerations of listening strategy can begin.

All the analyses were done to show that Froise can have functionality in the spectrotemporal process of a piece. Again, our method seeks to explain only part of the functionality of this music; the rest can be explained very well

[171] See for instance NYFFELER (2009:30–31).

without timbral analysis [172]. They were all subject to reduction in our method. Froise does not constitute considerable changes to these methods in fields that did not (originally) consider Froise; durations, motifs, and exact frequencies exist in Froise sounds too. Where the complexity of Froise brings the greatest shift to listening and analysis is in sound-based music and music that is based on harmonic partial structure.

Our analyses of short (uncomplete) passages reveal in each case at least one TTS at play in at least one of the timbral canvas versions. The role of Froise in these dramaturgies varies; sometimes Froise sounds are at the centre of action, are the most common sound, the most salient, or most used in combinations – and in some cases not. Our goal has been to show in as many compositional dramaturgical uses of Froise as possible, and thus compositions from a range of composers and instrumental setups have been selected[173].

The timbral trajectory strategies found constitute the voice-leading that was sought by our original thesis. Voice-leading occurs here in that there is an identifiable material, sound, and a scalar medium, noisiness, in which it can be audibly led in time. The nature of Froise and noise as material however means that the scales based on noisiness are several and their nonlinear interactions need at least two-dimensional presentations, and preferably four of them. In this updated view of voice-leading that serves sound-based music, each perceivable timbral shift is indeed several shifts at the same time (according to different canvases and different listening strategies), and the medium for movement consists of pitch intervals as well as of timbre. **Timbral strategies with Froise are at the same time voice-leading strategies.**

The TTS's should be understood in a symbiotic relationship with any listening strategies, that is, as both supporting and emergently arising from listening. As to which particular listening strategy corresponds to which strategy or to which timbral canvas version will be impossible to generalise. Since many listening strategies have already been established by literature, we do not propose that further ones should be recognised. Rather, we speak for a recognition of the noisiness-based and more exactly the amplitude-based, frequency-based, and time-based elements that listeners can focus on using many of the established listening strategies.

We consider **the most important compositional features of Froise music** in their order of ordinariness thus: subjective associations from timbres (which lies outside our method), timbral taxonomy, timbral collections, timbral canvases, identifiable constellations and outliers, trajectories, trajectory strategies, as well as their roles in the overall reward chronology to listeners. In the next chapter, we conclude with a discussion of the role of Froise in musical dramaturgy.

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172 This is by motivic, rhythmic, spectral harmonic structures and interference structures, and exact pitch considerations – aspects which many earlier researchers have covered.

173 A meticulous analysis into an entire composition would have to be conducted to study one of these strategies in a larger context, and to see how the strategy morphs or completely changes in the course of a piece.

5. Discussion and summary

“every aspect of timbre – from its production to its perception, from its indexical relation to sound sources to its iconic relation to metaphor, and to its poised aesthetic position between the material and the sublime – appears to be characterized by insurmountable paradoxes.” (VAN ELFEREN 2021:9)

5.1. Discussion

In this concluding chapter we will discuss our main analytical and other research findings (in subchapter 5.1.) and how they answer our research aims and questions (5.2.). A summary of our study follows in subchapter 5.3. The discussion will relate the findings to **all parts of our original thesis**. We follow by comparing our results to the existing branches of literature, to the little extent that the literature review chapter found applicable. This discussion (5.1.2.) completes for the theorist a practical analytical method that is based on listening to Froise repertoire. While the analytical approach has driven our thesis until now, we finally give the **composer many principles and prospects in Froise composition**. This shows the individual modules of our analytical method in their double role, **as a compositional sketching method** and **an instrumentation handbook** for sound-based (and intrinsically instrumentation-based) music. Since we studied a sufficient amount of compositions and lack the pages to apply our method by composing a new one, we will provide a hopefully inspiring set of **ideas for future compositions with Froise sounds** (5.2.3.).

We discuss the value and contribution of our timbral analysis method and repertoire analyses to the wider field of music analysis (5.2.2.) and composition. We will also review the limitations of our study method (5.1.3. and 5.2.2.) and findings as well as propose prospects for future research (5.3.).

5.1.1. The roles of Froise shown by our analytical method

Our study above has identified Froise as a novel type of sound and as a multifaceted timbral and perceptual phenomenon with lots to give especially to listeners and composers. The functions of Froise in compositions can be analysed and compositionally planned with help of our second main contribution, the novel analytical method that starts with positioning these sounds on the noise-pitch continuum. Our analytical method divides further into a taxonomic tool of timbres, the choice of an appropriate timbral space for presenting the timbres while affirming a specific listening strategy, and into the interpretation of timbral movements and dialectics on that canvas. Our analyses combine these three different structural levels, yet they can also be used separately. In addition to the analytical devices that are unique to Froise listening presented here, theorists and composers who deal with Froise music can adapt various existing compositional devices and tools of music theory from conventional pitch-based composition. Within the timbral repertoire, Froise plays several roles that pitch or noise alone do not play, and can take its own place in composed musical dramaturgy and **aural infrastructure** [174]. Froise presents a new insight into existing repertoire and widens the scope of several fields of research (as shown in chapter 2). The way in which the analytical method (chapter 3) and the analyses (chapter 4) have been conducted and discussed (in this chapter to follow) allows readers to replicate the results as well as modify the system for their own analytical and compositional needs.

Our results can be **applied to analysis as well as composition** (the details of which we leave up to the individual composers). For analysis, or method firstly leaves behind the mere descriptive analyses of past theorists and bridges a way towards an **explanatory, numeric way to analyse noisy repertoire**. Our numeric method is an improvement on similar precedents (on both sides, music and exact science), while our timbral canvases and interpretations of timbral trajectories are likely unprecedented in music analysis. All the three analytical levels lend themselves for use individually in a modular fashion with later, more accurate methods as psychoacoustics knowledge improves. These analyses have shown that noise has **more form-bearing agency** than is commonly relied on by theorists and most composers. The exact strength of the form-bearing features compared to all other rewards from Froise listening is unknown. This agency does not result from the simple presence of a noise sound in a piece, yet rather when precise comparisons between different noise (and Froise) sounds in a piece are made possible by compositional planning and by a listening strategy. The comparisons establish timbral differences and the intentional use of timbral differences in a piece can bring about musical form.

Secondly, our method **expands on its closest reference texts** about Froise and timbral analysis and composition. The stable ambivalence of Froise sounds might force previous computerised analysis of timbre (such as Peeters' method) to refine their axioms, while Froise cannot be analysed with previous pitch-based tools. For Thoresen's visual analysis method, Froise spells a new category of sounds and dialectics and new symbols for them. On the side of Froise, we have also produced valuable information about noise. Noises can be accurately

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[174] Here we can apply Susan L. Star's multiple definition of everyday infrastructure, understood now as the "embeddedness" of Froise inside other structures such as TTS's, its "transparency […] in the sense that it does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks", its "reach or scope […] beyond a single event or one-site practice", Froise being "learned as part of membership" with a detailed or rough definition which brings a "taken-for-grantedness" and "naturalized familiarity with" the objects in the infrastructure on a canvas, Froise's "links with conventions of practice" such as trajectories by which Froise inherits its range of applicability, trajectories being an "embodiment of standards" whereby infrastructure gains transparency when it links to other infrastructures expectedly, "built on an installed base" such as timbral distances and TTS as a "backward compatibility" in instead of "de novo […] it wrestles with the inertia of the installed base and inherits strengths and limitations from that base." Froise also "becomes visible upon breakdown" of a TTS, canvas or aggregate, where the existence of "backup mechanisms or procedures […] further highlights the now visible infrastructure", and Froise "is fixed [or patched] in modular increments, not all at once or globally" since it "means different things locally" in trajectories or on a canvas and an individual TTS. "Changes take […] adjustment with other aspects of the systems involved." (STAR 1996. As cited in BOWKER & STAR 2002:35).

classified using our taxonomy, which addresses their acoustic features for sound-based music, and need not integrate with pitch-based analysis methods. The previously disparate roots of noise composition and timbral composition are now merged. Noisy timbres are accessed via inharmonicity, fragmentarity and percussivity for instance, which also influence Froise. Inharmonic spectra, most directly accessed with percussion instruments or with the use of "extended instrumental techniques" [advanced modes of playing] on melodic instruments (PUSTIJANAC 2017) can now be studied numerically without resorting to FFT analysis. Our method also addresses noisiness as accessed by instrumental gesturing on otherwise *ordinario* playing (see SANGILD 2004). Our method achieves a combined analytical approach to acoustic Froise timbres, noises as complex timbres (MURAIL 2005), to the effects of pitch intervals when integrated with our earlier method [175] or with existing analytical tools for interval-based music.

Thirdly, Froise bridges pitch-based and sound-based musical syntaxes. Our study has value for the long lineage of timbre studies and the emancipation of noisy sounds in composition; the findings confirm the work that many composers have done explicitly with the pitch–noise continuum and refute the last rational inhibitions about Froise as a musical substance. The three modules of our analytical method follow three levels of analytical depth, of which the third one indicates ways in which noisy sounds can constitute a concept of voice-leading in sound-based music, although pitch as a phenomenon has less dimensions than timbre does.

Lastly, analysis from the Froise perspective can **inform performers** to strive for Froisy expression in loosely notated passages where Froise has unexpected importance for dramaturgy, or yet unestablished performance practice (MOSCH 2017). These are the first analyses ever made of many of the compositions. Froise can become a self-evident feature of analysis when performing recent repertoire. One main operation of Froise timbres that we show, **the grade of noisiness**, is a structuring device that steers the functions of sounds for a piece. It is not only a delicate balance between noisy and pitched features yet also a basis for movement (given by identity and precise categorisation) channelled eventually in performance, in which a sound can reorient its timbral context and change its perception by the listener. Froise sounds thus are **not only absolute** yet their identity changes by minute changes in articulation and by compositional context, since they point at several possible directions. These directions must be held in check by performers.

Froise sounds are likely to use many of the same auditory–cognitive routings (on which there is still much research to be done) that music has used for at least centuries, and that the presence of Froise in music has room for individual strong preferences.

Our analysis acknowledged the complexity of sound where it exists and did not

[175] The complexity brought by intervals and chords (acoustic and synthesised) was studied by interference structures, simultaneously yet separately from the present study (VESIKKALA 2018) and produced a computer program.

shun the possible combinations of descriptor values, amounting theoretically over 30 billion. Our method's first module described this timbral complexity hierarchically so that main dividing lines (such as rough perceptions of high vs. low, short vs. long, loud vs. soft, noisy vs. pitched) were taken to be meaningful for classification, whereas minor dividing lines were incorporated into the descriptor conditions with a rough description of their contents. The descriptions allow for and sometimes even indicate a range of variance in the sound. The **noisiness value** of a timbre incorporated the notion that different noisiness properties of sounds interact and may reinforce, cancel, or cover other properties. Once the sound was classified to receive a noisiness value, in the next analytical modules' most canvases we also used more informative data by selecting smaller subgroups of the noisiness descriptors.

Just as there is no prior definition of Froise, there is no prior theorised knowledge about how it behaves in perception, although composers who use noisy sounds will have attained experiential knowledge. Our theorisation about Froise and bringing it closer to being accepted in the compositional-analytical canon can facilitate composition with these sounds and save possibly years of work compared to a trial-and-error approach. We expect to alter a composer's grasp of noise composition technique after the introduction of the term Froise. A mere technical approach to Froise will not suffice – after pinpointing Froise sounds and passages in the repertoire, we also showed which compositional dialectics and timbral trajectory strategies with Froise are being used.

Claims as to the approaches or empirical setups in psychoacoustics implied by Froise were not made here because we lack the means to prove them. Instead, we demonstrated that Froise can be applied to music analysis and that already existing music can be understood through the lens of Froise even before a **full psychoacoustics mastery of the phenomenon by listener-testing** has been achieved.

Different from previously available approaches, our method of analysis teaches its theorist user about the structural relationships of the timbres in a piece. Since our method retains only the outlines of a musical chronology (morphology is included in module 1, durative presentation only included in Temp–NTemp of module 2, as well as the choice between aggregation or sequence in module 3), our remarks stand firmly on the voice-leading level. This analytical distance from the ground level (of listening or notation) makes the theorist or composer focus on the piece's wider dialectics that surpass individual timbral pairs for instance. Composers engage several dialectics when they use Froise in this repertoire, perhaps because the conventional pitch-based dialectic of intervals is (mostly) absent. In addition, the timbral analysis checklist (3.3.2.) enriches the analyst's toolkit and can be combined with 13 more general Froise principles (below, 5.1.2.).

To the composer, our results from the repertoire and our analytical method are contentious. Our method functions with any acoustic sound, will set it in a taxonomy and thus readily relates it to other existing timbres. The timbral relationships shown by a canvas constitute **potentials** that can be either harnessed in several ways or bypassed. The method can guide the choice of timbral collection, the canvas versions used, and the exact progressions of timbres by indicating timbral motions that are unlikely to have the desired effect. During or after the choice of timbres for a piece, the composer can as such apply the five defined TTS's (4.2.6.). However, by using the eight trajectory types in different proportions and contexts, composers may be able to form further effective timbral trajectory strategies. In each case, we propose that all compositional choices with Froise be reflected through the 13 Froise principles (below, 5.1.2.).

To the listener, we expect our TTS and dialectics to be the most pertinent, since taxonomy is likely an unconscious step in listening and the choice of canvas corresponds to aspects of listening strategy that may be difficult to improve for an individual listener. In the best case, any listening strategy linked to any canvas version indicates some TTS and a consistent dialectic in it, and thus reaps dramaturgical rewards from that TTS and from its main dialectics. This comes in addition to any subjective (non-structural and possibly dramaturgically conflicting) rewards that timbres may occasionally bring to the listener. The TTS and dialectics are likely connected to **identifying basic Gestaltic principles** that other domains of human perception also favour, although this thread of study was not taken up here. Timbral constellations can **guide the listener** to remain with a rather structural listening strategy even when some of the timbres involved in the constellations or aggregates are unfamiliar. The TTS's and dialectics may constitute a completing part in timbral listening so that more listeners can perceive auditory rewards in this repertoire.

5.1.2. The found Froise principles and dialectics

A full analytical and compositional quest to define a Froise composition strategy for a passage of any duration could concern various aspects: the timbral range and focus region of all sounds used, the extent and distribution of Froise usage in the passage, guesses as to what is intended by the use of specific Froise sounds, the contexts, roles, and referentialities of Froise sounds, the amount of simultaneous layers that are either independent or merging, the mechanics inside a layer and between them, as well as the likely psychoacoustic, memory, association, and narrative effects. Voice-leading is often determined by statistical evidence (see for instance HURON 2016) which in our cases have been the five TTS, one of which seems to be obligatory and hierarchically dominant[176] for any piece. On the more dramaturgical side of voice-leading and to a less binding extent, we have found 13 topics which we can call **Froise principles** (Table 5.1.2.-1).

Table 5.1.2.-1. Thirteen Froise principles.

> 1) **timbral structurality**: timbral motions are structured around the concept of Froise. This ties directly to the timbral trajectory strategies, all of which

[176] For the similarly uncharted musical substance in microtonality and its hierarchies see BIEHL 2011, for its voice-leading see HUEY 2017.

can accommodate Froise dramaturgically. When strategies are supported in some canvas versions, this gives those canvas versions more structural explanatory power.

2) **dialecticality:** Froise alternates (against either clear regions or polarities in noise or pitch, or with several more extremity points in two-dimensional timbral space). This shows in the positioning of the Froisy, noisy, and pitched timbres within the passage's temporal segmentation. Froise has shown its potential in answering Hallam's (2009:77) questions of timbre's "role of timbre in building and release of musical tension" . This tension is built dialectically and can be done in many more ways than tension has been built in interval-based music. Dialecticality as such is nothing new, and occurs also in interval-based music [177].

3) **gradation:** difference is made between gradations of Froise (noisiness value, TIV value, or the noisiness aspects of frequency, temporality, and amplitude)

4) **intermediacy:** in this special case of dialecticality, Froise emerges as an intermediary in a noise–pitch dialectic, and the polarities are softened.

5) **ubiquity:** Froise is always present in at least one sound throughout the piece. This will undermine dialecticality yet adds to distinction between Froise sounds.

6) **salience:** Froise is given salience on the musical surface (duration, dynamics, motivisation, independence) if not structurally.

7) **transformativity:** Froise emerges in transformations of a non-Froise sound, or timbral features of a Froise sound are varied. [178]

8) **centricity:** one Froise sound is used as a timbral centre, as allowed by

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[177] For example, Heusinger evidences an early atonality dialectic in which harmony and counterpoint are nullified by the presence of timbre, in Schönberg's *Farben* (HEUSINGER 2019: 46). In our analyses of Froise repertoire that lacked harmony and mostly also counterpoint, **dialecticality** was evidenced in gradations of noisiness. It did occasionally also arise between small and large TIV values, the frequency of accessing timbral spaces, and in the quadrants (available in the three spectrotemporal canvas versions) which reflect a different kind of internal variance. The standard noisiness dialectic means tension between the quadrants 1 and 3 and the corresponding diagonal, while the kind of internal tension might be seen between quadrants 2 and 4 and their diagonal direction. Inadvertent dialecticality can lie in Froise itself in the form of multistability. For MÄKELÄ (2004:286–287), timbre can underline turning points by contrasting instrumentation.

[178] Transformativity occurred rather as discontinuous directed transformations, as opposed to alternating and continuous transformations – Thoresen (2015:464) makes this distinction. Continuous transformations and exchanges are available mostly by changes to articulation. Froise by transformations however occurs also by proliferation of sound sources (as in the Furrer and Rădulescu excerpts), or by fusion (different grades of blending). These and other terms for form-building transformations by Thoresen (2015:465) are legitimate with Froise sounds. Many movements to and from the Froise region never constitute an unbridgeable "radical alterity" (MORENO 2013: 217), are blurry (FERREIRA RUIZ & UMEREZ 2018) and could instead be labelled with Thoresen's dialectics.

some of the timbral trajectory strategies. Alternatively, the visual average or weighted average coordinate of a timbral constellation is an abstract centre that lies in the Froise region [179].

9) **infrastructurality:** the chosen Froise sounds are used for the differences they make in aural infrastructure (this term is defined in a footnote in chapter 5.1.1.).

10) **Gestalticity:** the constellations of Froise timbres in timbral space form identifiable shapes and/or the trajectories in timbral space (including the noisiness continuum) follow Gestaltic principles [180].

11) **as instrumentation device:** Froise sounds can underline other compositional choices or blur instrumental aetiology and boundaries [181].

12) **resolution (as in pixelation or definition):** the piece uses (and repeats) many enough timbres so that their distinctions on the pitch–Froise–noise continuum and in planar timbral spaces are made audible. With shorter distances, smoother processes between timbres also become available [182].

13) **symmetry:** Froise enhances symmetries in other realms of sound (even by reinforcing segmentation), or Froise participates in symmetric timbral trajectories or constellations (not evidenced in the analysed corpus) [183].

The points 1, 2, 3, and 4 were crucial for any listening that focuses on noisiness. The implications of points 5, 6, 9, and 13 should be studied in later research.

Even with our findings about **dialectics** (principle 2), more study is needed to conclusively determine one of our secondary questions, the extent to which timbral tension manifests in this repertoire. Noisiness was identified to enable such **a dialectical tension–release pattern** [184], either by intensity (TIV) calculated from noisiness, or when seen as noisiness total from the locally extreme timbral pair along the noisiness continuum. To generalise the found

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179 Particularly **centricity** was evidenced in the Solar strategy.
180 GRONDIN (2016:92–93) lists the main Gestalt laws primarily as proximity, similarity, good continuation, connectedness, common region, and secondarily includes closure, Prägnanz or symmetry, and common fate or common motion. WOLFE et al. (1999:82–89) defines further Gestalts. All trajectory types replicate Gestaltic shapes yet no trajectory type corresponds to one Gestalt rule as such.
181 The use of our timbral taxonomy, canvases, and quadrants as an instrumentation handbook makes Froise such an instrumentation device during a composition process. Traditional instrumentation volumes have listed instrumental combinations that are similar (for instance CHARLES SOLER 2012), yet our taxonomy also indicates gradations within dissimilarity. MÄKELÄ (2004:286–287) particularly notes two opposite approaches, such that timbral instrumentation may seek "negative" or "positive correlations" with other musical layers and dramaturgy.
182 Since each passage had several timbres, the **resolution** question did not arise.
183 On symmetry see compositionally KEMPF 2006, structurally HAHN 1989, and computationally MAZZOLA (2002:135–154). As the second of MÄKELÄ's (2004:286-287) visions for a polyphony based on timbre, thematic-harmonic or poetic symmetries can be underlined by timbre even when timbres themselves do not register as symmetric in listening.
184 This dialectic with noise is also called an unfolding by MARKS (2013).

connection between numeric TIV values (derived from mathematical variance) and a perceived tension, a larger corpus of pieces would be needed.

Intensity was made of **inherent static** (internal) tension in the TIV value of one singular timbre, **combined static** tension between the TIV values of two (or more) timbres, or **combined dynamic** tension due to any changes that occur to a timbral combination. Any timbral canvases can show the combined (static and dynamic) tension values, while the inherent static tension value can be only seen in the TIV value and does not need a canvas [185]. While this tension phenomenon had no contenders, its exact strength remains to be studied.

Alongside the tension dialectics were **two dialectics related to Froise** (variations in the dynamic presence and instrumental makeup of sounds in the Froise region; in more complex situations the presence vs. absence of Froise). Further, our analyses found **nine more general and delicate dialectics**: individual timbres vs. aggregates; crowded vs. relatively empty timbral regions; grade of aggregation and blending; narrow vs. wide space of aggregates or local progressions; the proportional makeup of the complementary morphological features (for instance when between the Temp and NTemp components); more generally the accessing and leaving of timbral regions (quadrants or otherwise) or leaving them for some time unaccessed to create temporary gaps; timbral motions in-group vs. between-group or with nucleus timbres vs. without nucleus timbres; instrumentally derived physical dialectics (inhale-exhale, up-down); and any articulational or textural changes (in frequency, durative, or amplitude aspects) to modify a timbre's coordinate on that respective canvas version.

Many dialectics derived were supported by segmentation, cycles in the passages, or generally musical completion as described in McADAMS & GIORDANO (2009:77-78), paraphrasing PARASKEVA & MCADAMS 1997): "the perceived degree of completion of the music at several points at which the music stopped. What results is a completion profile, which can be used to infer musical tension by equating completion with release and lack of completion with tension". Our repertoire was not large enough to support that endings on any dramaturgical scale would tend to be made of contextually have a smaller TIV value, less extreme noisiness value and proportional makeup of morphological features, are either in the last or most accessed region, or with timbral movements that are contextually less tense (in all the ways described above). Rather, the tension-release pattern seemed to be subsumed by combinations of several related dialectic pairs – some such dialectics are noted by Deleuze:

> *"[f]olding-unfolding no longer simply means tension-release, contraction-dilation, but enveloping-developing, involution-evolution. The organism is defined by its ability to fold its own parts and to unfold them, not to infinity, but to a degree of development assigned to each species. Thus, an organism is enveloped by organism, one within another"* (SAVRANSKY et al. 2017:184,

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185 As in chapter 2, we still disregard COSTA & NESE's (2020) view of frequency centroid in noise as being a major determinant of tension. This aspect can be readily studied with pitch-based methods on the side of our method.

citing a translation of Gilles Deleuze's "Nietzsche and philosophy" (2006:9))

Not all dialectics have to present as polar and maximal attainable extremes – any clearly expressed dichotomy suffices. Even three periodic states such as in the Griseyan intensity metaphor of breathing, inhaling-exhaling-pause (PUSTIJANAC 2017:113), may work.

Thus far, we have put Froise and other sounds in multidimensional contexts relative to each other, discussed the unique results that are achieved by their compositional **combinations** both **simultaneous, sequential,** and **textural**, as well as preliminarily touched on how they can function as voice-leading. The analyses suggest that these works use Froise sounds not as an end-in-itself but for specific compositional goals which varyingly indicates either simply voice-leading or wider dramaturgy such as dialectics. We have seen how flexible Froise is in the hands of skilful composers even without any established theories about Froise or noise dramaturgy.

5.1.3. The limitations and challenges

Above, we do not claim a wide view covering the whole Froise phenomenon in all its complexity. Nor do we claim the theoretical apparatus by itself sufficient or a Froise listening strategy easy to adopt and reap rewards from. There are limitations to our first analytical and compositional survey into Froise as a sound category and to its derivatives. An examination of passages in the repertoire, outlining the questions especially related to listening, and defining the long-awaited theoretical apparatus that is however conceptually separate from Froise are sufficient results.

Identifiable constellation shapes emerge from among the timbres only in some of the canvas versions, and those that are clearest have the best prerequisites for a trajectory strategy as well. **The amount of distinct timbres** (cardinality) and of smooth processes between timbres have varied widely from six (Auvinen's passage 2) to almost 40 (Andre segment 2, Lachenmann, and Rădulescu). **The amount of occurrences of each timbre** differed from unique occurrences to centric "sun" timbres in the Solar strategy, and the length of these occurrences varies often irrespective of how frequent they are. If certain moves in timbral space happen repeatedly, this was interpreted as timbral centricity and pivoting (particularly for the Nuclear and Solar strategies).

Some strategies require a small or large **distribution density of timbres** in timbral space or rely on differences of density. Our method retains the acousmatic approach in that it does not consider how evenly the timbres are distributed among the instruments. Indeed, the timbral distances on the canvas are often hardly related to the instrumental aetiology of the sounds. **Timbral habitat**, as defined by the extreme timbres (edge points) in timbral space affected our interpretations the least, since the strategies were scalable to any timbral space. However, the dialectic on the noisiness continuum is limited by small timbral habitats.

Our canvases did not describe **situations in which timbres are varied only slightly** without affecting their descriptor values; on the one hand, no piece was based on several changes of articulation and thus no trajectories based on this were missed, and on the other hand, pieces that were based on variation of articulation such as Furrer and Rădulescu led to differentiated enough descriptor values.

Our analyses showed that **some canvas versions have more explanatory power**, for instance for voice-leading or segmentation, than others. This has to do with which features of spectrotemporality are utilised by the music. From our analyses, a slight pattern emerges with differences (see Table 5.1.3.-1) as to whether the morphological or noisiness approach is more robust.

Table 5.1.3.-1. Differences in the canvas versions' analytical applicability.

Morphological canvases NTemp–Temp; NFreq–Freq; and NAmp–Amp	The noisiness–TIV canvas
music in which timbre cannot be separated from texture	not dense multilayered textures [186]
when timbral changes are based on morphology	when timbres do not change gradually [187]
when segmentation in the piece does not happen based on differences in timbres [188]	when segmentation based on timbral difference is strong [189]
when morphology is more crucial to listening than noisiness degree (which is however also utilised)	whenever the degree of noisiness is crucial to listening
when the passage has few timbres, or when most timbres are iterated	when the passage has many timbres, possibly timbres that are never iterated [190]

[186] For instance, noisiness–TIV was unable to explain the Czernowin, Furrer and Rădulescu examples satisfactorily.
[187] Thus noisiness–TIV provided the best explanation in the analysis of Auvinen's passages, Bauckholt, Sciarrino, Zubel, Andre's most steady first and fourth passages, and when fixed timbral blocks were chained together (Romitelli).
[188] As in the three segments of the Rădulescu example, in which the segments 1 and 3 inhabit a similar timbral region.
[189] Also seen at the more local level in how groups are accessed in different parts of timbral space (Sciarrino). Noisiness–TIV was an adequate explanation in many cases that segmented elliptically or that had their segmentation affected at least somewhat by timbral differences.
[190] There are exceptions to this observation on both sides. Generally, the larger the collection of timbres, the more difficult it is to determine which canvas is the best explanation for the piece. This again speaks in favour of dense segmentation. Since we have for the most part studied only excerpts of works, it is very likely that these works do change their timbral constellations, trajectories, and trajectory strategies in other segments of the piece that were not discussed here.

we would expect the durative (NTemp–Temp) canvas to be the most explanatory and a default. The other two spectrotemporal charts however were successful (at least in our studied passages) slightly more often and were preferred when the use of timbres seems to derive from differences in frequency or loudness, respectively.	this canvas was the successful explanation quite equally among all five strategies.

Among the three morphological canvas versions, there were also differences. As could be expected, the NTemp–Temp canvas returned good results for those passages (Auvinen pass.1, Czernowin, Furrer cycle 6, Lachenmann, Rădulescu, Romitelli, Zubel) that had a **fast pace of timbral shifts, made of variations of any size**. If Saariaho were to be studied in detail, with the hundreds of individual timbral movements that such an analysis entails, this canvas version might have shown the most exact trajectories while the timbral coordinates remain the same. The remaining works (Andre, Furrer's cycles 1 and 2, Auvinen's passages 2 and 3, Sciarrino) had a comparably slower timbral unfolding or timbral rhythm.

The NFreq–Freq canvas worked well for the passages (Auvinen pass.1, Bauckholt, Czernowin, Furrer cycles 1, 2, and 6, Lachenmann, Romitelli, Saariaho, Zubel) for which the **chosen exact pitches were kept most constant** while also seeming **the least structurally pertinent** for the dramaturgy. Works that did not work well on this canvas, such as Sciarrino, Pesson, and Andre did rely on pitched centres yet for only part of the passage and had a larger collection of pitches, a disregard for structuration by exact pitch compared to the others.

The application of the NAmp–Amp canvas was fruitful for the passages (Auvinen pass.1, Bauckholt, Czernowin, Furrer cycles 1 and 2, Lachenmann, Pesson, Rădulescu, Romitelli, Saariaho, Zubel) that had **a wide dynamic range, nuanced changes in a short time, accentuation, natural rapid decay, and generally instrumentations that have detailed dynamic control**. For instance, in the Andre piece, dynamics were extreme and most *crescendi* were slow, while many sounds had no perceivable dynamic life. The Sciarrino piece likewise made use of slow *diminuendi* and a soft dynamic was shared by all instruments almost throughout.

One good indicator of explanatory power of a canvas are timbres that have identical coordinates. Their use in aggregates or as mutual substitutes is evidence in favour of this canvas version, while their contrasting or indifferent use is evidence against.

Why one of the three spectrotemporal dimensions matches the music more is due to patterns that are not immediately fathomable and possibly psychoacoustic. In each case, they do not explain the psychoacoustics related to these sounds; phenomena such as **memory trace, masking, and salience effects** would remain as unknown as ever.

Froise as a basic material in these works is likely to **affect listening strategy**. With the four canvas versions, we hoped to approach the mismatch between listening strategies for noisy repertoire and "The chaotic proliferation of audio descriptors in timbre research and in music information retrieval [that] has seldom asked the question of whether these descriptors (or combinations of them) actually correspond to perceptual dimensions. Are they ordered on ordinal, interval, or ratio scales? To what extent are they perceptually independent?" (McADAMS 2019b:37). We have approached McAdams' question of perceptual dimensions from the viewpoint that the exact set of dimensions that are perceived will differ also somewhat based on musical style, and the listening strategy that is chosen. For instance, the perceptual dimensions of timbre that are relevant in listening to a spectralist piece that does not have Froise may not be the same as when listening to a sound-based piece that has Froise [191]. The immediate implications from this for listening strategy and perceptual hierarchy remain unknown, yet the considerable reduction of descriptors to a mere 15 that reflect the most commonly mentioned relevant dimensions has been a first step. As to McAdams' concern about the independence of the dimensions, our analysis continued by making combinations (subtotals) of these dimensions, and descriptors inside all these subtotals are likely to have small correlations with each other, something that was not visible by inspection of the numbers. However, it is unlikely that any of the descriptors would independently have more explanatory power than our subtotals on a two-dimensional canvas. Some descriptors might thus be more independent or robust than some others, yet the most robust and explanatory results came from the summated scales.

In addition to the choice of a canvas version, **having to choose between the two methods of interpreting canvases (aggregation or sequence) is unsatisfactory**. On paper, a solution would require making the graphs 3-dimensional (by the added time dimension) which for humans are difficult to read, a wide array of colours, or the comparison of a canvas and another list next to each other. Within the course of a piece, so many different timbres would be shown at similar coordinates that periodic segmentation and observations made from shorter passages remain the only practical option. Two-dimensional videos that could show the entrances and fading of sounds and their relative strengths could be achieved by a video presentation yet would strongly computerise the method. This far, the analyses have required computer for computing subtotals and producing the canvases (in our case using Excel or Google Sheets), while in making the canvas markings a separate graphics program that allows for text and arrow layers to remain in place will be useful when the points on the underlying canvas require modifications.

Similarly to our axioms given in chapter 3.3., our method can match scientific

[191] This question was outside our present focus and needs to be studied before the field can progress.

standards only when it is also falsifiable. As per the Popperian ideal, theories must be formulated clearly enough that they remain formally prone to falsification and to counterexamples, before reliable application and incorporation as genuine theories (SAYRS & PROCTOR 2008:47), and from this we can derive five **falsification countercriteria** [192] for our Froise theories as well:

▪ **relevance** of Froise analysis: no timbres or textures in the music receive descriptor values in the Froise range.
▪ **precision** of Froise analysis: the internal order of the noisiness totals or subtotals is not even roughly respected by the use of timbres in the piece.
▪ **applicability** of Froise analysis: Froise features are not used as much as pitch or noise features (numerically, or in salience or duration).
▪ **clear presentation** of and understanding of the timbres: some sounds may not be given descriptor values.
▪ **compositional (preferably dialectic) logic** in the independent passage chosen: the passage is a perceivable entity yet some individual timbral descriptors or rare phenomena in timbral space dominate without structural consequences, or none of the canvases display a timbral trajectory strategy.

Each analysed passage passed this test [193]. Exceptions to this would be of unsurpassable value to refine the range our analytical method's applicability: "A valid scientific explanation [...] must have empirical content (that is, it must be possible in principle for an observation-sentence to contradict it)" (PELES 2008:65 [194]). We restate that our method is far from a final and exhaustive one, yet it is one of few (if not the only one) currently available for theorists and composers, before there are considerable advances in the study of psychoacoustics and nonlinearity. In our addressing of the central issues the method is a stepping stone for further research.

Other limitations of the method for theorists and composers will be discussed in chapters 5.2.2 and 5.2.3.

5.2. Froise in timbral dramaturgy

With our original thesis statement, we primarily intended to define Froise as a necessary listening infrastructure and main component of musical dramaturgy for

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192 Music theory has been content with systems that will not be refuted or falsified. Our system is a shortcut and prototype, as is typical of the scientific process. It is likely to be falsified at the moment when music theory for the first time will incorporate nonlinear thinking. This will be no easy task: "it is not always the case that a new paradigm is simpler than the old; it may assert the importance of previously ignored or undiscovered elements, thereby actually complicating matters. [...] The development of a scientific model of human hearing has been under way for at least 140 years, since the early work of Fechner, and we are still nowhere near having an established body of laws. By this measure alone we can see that the auditory system is hugely complex, containing redundancies, contradictions, and even deceptions." (LOY 2011b:156).
193 Further research would have to find successful repertoire that is successful despite fulfilling some of these criteria.
194 Citing Hempel and Oppenheim's 1948 "Studies in the Logic of Explanation" in *Philosophy of Science* 15:135–175.

a large corpus of repertoire. It does matter for the holistic musical experience which Froise sounds are used and in which combinations. Simultaneously, we intended to maintain their subjective and local **sense-bearing** nature in that listeners can have unique associations on hearing these rare timbres and that those associations are not conditional on the presence of other sounds. These associations however seem to be contextual, since the same Froise sound enkindles different associations depending on its current relation to simultaneous and chronologically nearby sounds (this cannot be addressed by our numeric-visual method). The role of Froise as a participant and facilitator of aural infrastructure entails our primary intention of Froise also as part of music in the more conventional understanding of musical structure, that is, as a **form-bearing** element. Since the concept of musical form is too ambiguous outside pitch-based tonal music, we have separately observed timbral dramaturgy and dialectics.

Most pieces were not made entirely of Froise; it sufficed to show that timbre was the dramaturgical element in the piece, often also shaping the dialects, and that passages of Froise continue, not cease, to carry the dramaturgy and reinforce the dialectic. For the listener, this mixture results in a **continuous reward chronology** that is made of both subjective, local sense-bearing elements as well as holistic dramaturgical and dialectic timbral elements.

5.2.1. Proof of the original thesis statements

Related to our original aims and initial focus for research, our findings were sufficient. We can now revisit our thesis:

> **Froise** sounds are timbres that exist at a perceptual balance between pitch and noise, and the concept of Froise is indicated to be **unsurpassable and central** for the **functioning** and **voice-leading** of **noise-based music.**

The statement may now be separated into five simpler sub-statements, all of which we have answered by the repertoire and our analysis method:

> ▪ Sub-thesis 1) Froise as a perceivably separate type of sound exists between pitch and noise.
>
> ▪ Sub-thesis 2) The dramaturgy of timbre-based music for listeners does not rely purely on the motivic level or the level of numerous **subjective associations** from timbre but also heavily relies on what the timbres are on the **physical, sonic level.**
>
> ▪ Sub-thesis 3) Musical dramaturgy in this repertoire depends heavily on timbre; timbre plays a role in the dramaturgy of any music, and the more so with much of recent repertoire.
>
> ▪ Sub-thesis 4) Froise is "unsurpassable and central"; Froise sounds are

present in almost every timbre-based piece.

■ Sub-thesis 5) Voice-leading is not limited to the pitch realm.

Below, we give the finite proof for each.

Sub-thesis 1

“Froise as a perceivably separate type of sound exists between pitch and noise”

Our first sub-thesis has above amassed evidence from several perspectives. In the repertoire, Froise cannot gain full meaning without the presence of either pitch or noise or preferably both. The analytical canvases presented a noisiness-based dialectic that used all three categories of sound and lended salience to the Froise region in the noise–pitch continuum. Froise redirects the judgments about the behaviours of sounds; also the non-Froise sounds will be composed and structured differently. Froise motivates a skilful composer to focus their plans on entire **timbral trajectories** instead of two opposite unconnected poles of noisiness and pitchedness. Our timbral perceptually and morphologically focused descriptors approximated the Froise region on the noise-pitch continuum as well as in four two-dimensional timbral spaces. This preliminary method showed the central roles of Froise in compositional dramaturgy and various dialectics built on the noise–pitch continuum.

Froise can be analytically quantified, visualised in timbral space, and reduced, in each case compared to the polarities of noise and pitch, also in contexts where there is only Froise, when clear pitch and/or noise is absent. Froise attains its full meaning in the presence of either pitch or noise or both, and its behaviours are judged differently and also the non-Froise sounds will be composed and structured differently. Froise motivates a skilful composer to focus their plans on **timbral trajectories, aggregates, and longer envelopes** instead of two opposite unconnected poles of noisiness and pitchedness.

Froise causes more nonlinear perceptual phenomena than pitch and less than noise. Froise would most likely constitute Begriffsarbeit to Haffke (2020:205) by bringing an in-between field from theoretical and contextual invisibility in the fields of sound studies and musicology by **ontologisation** that fosters institutional growth (HAFFKE 2020:205) and novel compositional styles.

Taxonomically, most of the descriptors that a Froise sound receives would counteract categorical typicality judgments; the typical member of the category “a sound” associates not with Froise but with a continuous pitched sound that has a comfortable middle register and middle dynamic. When the upper-level context of association is “a sound”, the **Froise and noise value criteria of any of the 15 descriptors would be judged to be categorically atypical[195].**

[195] Within Froise sounds of a similar noisiness total, a Froise with a medium TIV value might be more categorically typical. Even percussive sounds are atypical, since typicality is found in continuous sounds, and furthermore in held rather than in decaying sounds.

Froise has been used in passages and entire pieces of music, whether in form-building roles or not, with intention or not, whether first-time listeners can categorise it or not, and whether or not its presence in a piece has been theorised before. Previous literature from the baskets 1 and 7 introduce Froise and confirm the concept taxonomically as a category immediately below the categorical level made of pitch and noise. We have represented Froise divided in one way to its timbral descriptors and seen that Froise cannot exist without the concepts of pitch and noise, yet inhabits an in-between space and can bring about different listening experiences and strategies than either one separately. Thus Froise exists in a taxonomy of sounds and from the viewpoint of descriptors that are geared at differentiating on the noise-pitch continuum. Froise has remained unidentified for this long, yet the repertoire, logical deduction, and taxonomic evidence have proven the the existence of Froise.

We could write Froise in all capitals since we have shown that its different aspects also form an acronym:

Frequency cores in noise, **R**ecognition of (acoustic) source, **O**bstruction, **I**nharmonicity, **S**trategy of listening, **E**quilibrium between pitch and noise.

Sub-thesis 2

"The dramaturgy of timbre-based music for listeners does not rely purely on the motivic level or the level of numerous subjective associations from timbre but also heavily relies on what the timbres are on the physical, sonic level"

Many canvases showed motion in timbral space that was based on the sonic aspects of the timbres which our method set out to study. Subjective associations that are known to play a role in timbre perception were impossible to rate and compare with each other, and probably such associations are indeed diminished by the musical dramaturgical (sonic) use of the sounds.

Attention to the compositional formation of a piece with Froise is warranted, since Froise sounds have enough dimensions that they are not limited to one unchangeable role in a piece. **Froise in the repertoire was neither limited to** any particular instrument, register, pitch, dynamic, descriptor, any particular duration or position (within a musical phrase, timbral trajectory, or within a piece), any particular constellation of timbres or timbral trajectory strategy, or any particular dramaturgical role (such as an effect or a centre, a contender to pitch and noise).

The timbres' relationships with each other were key determinants in musical dramaturgy, and substituted for lacking subjective associations or motivic work . The relationships on several timbral canvases connected to eight types of timbral trajectories and to five timbral trajectory strategies.

The differences between Froises validated our spectrotemporal method as appropriate for the repertoire, and refinement may come from understanding of this repertoire through emergence. It is likely that composers intended the shown dramaturgy to arise from planned timbral consistency. Authorised recordings can refute the occasional mismatches between notation and the acoustic heard sound.

> From the repertoire studied with the spectrotemporal analysis method, we have seen several ways in which Froise, and sound-based music in general, dialectically **functions in musical dramaturgy**. Our baskets 5 and 6 have introduced the analytical literature.

Sub-thesis 3

“Musical dramaturgy in this repertoire depends heavily on timbre; timbre plays a role in the dramaturgy of any music, and the more so with much of recent repertoire.”

Our studied repertoire consisted of only sound-based works [196]. All dialectics found in our analyses involve Froise timbres, either via noisiness singularly, the noisiness–TIV canvas, or by dialectics such as the access and “rejuvenation” of timbral gap regions on the morphological canvases. Many canvases of the analysed pieces displayed identifiable patterns, timbral trajectory strategies that allow listening to musical dramaturgy by identifiable Gestalts and relatively easy routes in listening. Similar clarity was not found in other aspects of music that are conventionally addressed by music analysis.

These associations should also be preferably contextual, in that the same Froise sound raises different associations depending on any simultaneous and chronologically nearby sounds. Froise as a participant and facilitator of aural infrastructure establishes its more conventional place as a **form-bearing** element. In pieces not made entirely of Froise, timbre was the form-bearing element. Passages of Froise did continue, not cease, to carry the form. Along the criteria for structural music analysis listed by LEVARIE & LEVY (1983:183), Froise can readily participate in all the aesthetic principles, Gestalts, extension factors, and shaping factors, and in that sense achieves a novel compositional structure akin to **tonal functionality**[197]. There Froise as an inspiring vehicle serves and

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[196] The exact distinguishing criteria between sound-based and interval-based repertoire are addressed diligently by THORESEN (2015:76–86), who judges the hierarchic position of timbre based on both its syntactics and (exo)semantics in a piece.
[197] However, in Froise music the functional material is a timbre in one of the chosen perspectives (timbral canvas version), instead of a chord and its chord inversion. Functions are conveyed by the subjective associations from timbres that have the strongest subjective impact. If no such timbres are present and pitch organisation is weak at most, any consistently identifiable timbres that appear in isolation or in identifiable successions (trajectories and timbral strategies) with other timbres will be functional. This contrasts to a tonal full cycle of chords that starts and ends with a tonic

enables a particular musical expression (also for instrument developers and performers) and musical experiences that cannot be achieved by other means. The use of Froise sounds increases compositional choice.

Our presentation of the repertoire and recent directions in music analysis (baskets 3 and 4) validated the theoretical aspect of this sub-thesis. We can state that **sound-based music can partake in dramaturgy when** the timbres themselves are taken as dramaturgical sound material for listening, not mere objects, shadings, or effects, and instead we start to listen for the differences between the timbres and build our musical expectation structures on them (the closest analogy is tonal functionality built on four local aspects: scale step, chord inversion, chord quality, as well as the particular chordal setting, and on a cyclicity of chordal functions on the holistic level). The analytical method (chapter 3) and its application to the repertoire (chapter 4) finalised the proof.

> From our analysis of timbral trajectories, we can see that the functionality of this repertoire relies more on timbral aspects than on frequencies (pitches), motivicity or subjective associations. **Dramaturgy in timbre**, in the form of various dialectics, **is the main** explanation for the functioning of this repertoire.

Sub-thesis 4

“Froise is "unsurpassable and central"; Froise sounds are present in almost every timbre-based piece”

All our canvases in various canvas versions included Froise sounds in central roles in trajectories, in various dialectics as a timbral “control structure” (WESSEL 1979), and principles, compositional usage as suns, centres, outliers, or groups in TTS, and/or by their amount and placement in the timbral constellation. Since noisy sounds can seldom do without a (non-primary) pitch element, Froise features in repertoire that is timbre-based yet not pitch-based. Even a dramaturgy within noise required the noise sounds to differentiate in their aspects that take the sound further from extreme noise and closer to the Froise region.

Froise is also not too distinct such that it can still participate in sound-based voice-leading and perception of auditory streams. Froise in this repertoire was not perceived separately, but as indispensable aural infrastructure, manifesting a typical flexibility of use based on their context and a part of dialectics based on the pitch–noise continuum and/or other features derived from noisiness.

A growing corpus of repertoire centres on Froise sounds, which refutes a conventionalist view that cannot identify their form-bearing capacity, only

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function. Froise dramaturgy consists of durations, types, and proportions of timbral trajectories, the use of regions of timbral space and points of shift or ambivalence between different timbral spaces (canvases).

favours Lachenmannian or Smalleyan wider spectrotemporal gestures made by collections of sounds with less focus on the type of the sounds themselves (LACHENMANN 1996/2004), or views that would see some conflict between our proof of Froise by descriptors rather than larger detailed spectral sound description toolkits such as those developed by CataRT.

We can suggest a listening strategy unlike the tonal conventional, Lachenmannian, overtly associative, semantic or causal, or thinking in terms of more spectral descriptors, or something else altogether. We estimate, although not objectively, that **Froise arises into perceptual focus through a combination of the spectral, structural, and reductive listening strategies**. This or a dialectical way of listening ought to be more accurate for this repertoire and thus more rewarding[198], and at least gives more concepts to assess this music in detail.

With the analysed sound-based repertoire, we have proven that Froise sounds are present widely and are differentiated by musical passages. With an appropriate listening strategy, the centrality of Froise can be appreciated fully.

Sub-thesis 5

"Voice-leading is not limited to the pitch realm."

Voice-leading has not vanished from the repertoire even though pitch-based voice-leading (as per conventional analysis methods) was scarcely evidenced. Our canvases showed voice-leading in timbral space by trajectories and TTS's. Our updated understanding of voice-leading applies to sounds and still to intervals.

Sound-based voice-leading operates with the emergence of timbre and detaches from pitch-based ones, also in the three features of linear systems: **equilibrium** made of "periodic motion or asymptotic equilibrium**", linear causality** acting "from an environment [and cause] external to the system" that enacts a calculable "change in the system's structure", and **negative feedback** that steers "the system back towards its initial equilibrium" (BERTUGLIA & VAIO 2012:261–265). Particularly linear causality is lost in timbral composition as a nonlinear system which does not face external thematic-motivic pressure which is replaced by the five timbral trajectory strategies.

Now rather a single timbre at any moment challenges that equilibrium, any centralisation, and balance. The feature of negative feedback was perhaps still most present; parenthetical and centric trajectories are somewhat common, since a trajectory of Linearity, vectoriality or non-parsimony did not repeatedly cover large swaths of timbral space in one direction without returning towards its starting position. Froise creates an "adaptive complex system" by being "an open system, made up of numerous elements that interact with one another in a

[198] Besides some other common strategies of listening and music understanding, including yet not limited tonal conventional, Lachenmannian, or thinking in terms of more spectral descriptors.

nonlinear way and that constitute a single, organized and dynamic entity, able to evolve and adapt to the environment" (BERTUGLIA & VAIO 2012:276[199]).

Many of these situations can be only partially explained by linear movements as we have done, or subjective associations from timbre. The emancipated timbral and textural Froise and noise in recent sound-based music has made linearities too abstract[200], and for many composers not even worth pursuing. The focus shifts to any compositional tools that affect a listener's continuous perception of **reward chronology** from a piece. Voice-leading in the updated understanding[201] is one solution to cultivate this.

> In the analysed repertoire, we have proven voice-leading principles (taxonomies, constellations, trajectories, and strategies) that resemble those used in tonal-functional music yet are unique to sound-based music. By adhering to these principles, Froise fits an updated understanding of voice-leading. Froise strongly supports, alongside other timbral material and pitch material, or singularly determines auditory segmentation of the analysed pieces.

5.2.2. Implications for music theory

Our findings can considerably **advance goals and amplify current tendencies in music analysis**. As we saw in the literature review, Froise is virtually unknown to literature, noise analysis is heavily reliant on FFT analysis and even then does not render satisfactory results since the "multidimensional character of timbre is not supported by a practical system of well-defined and clearly linked dimensions" (ŁĘTOWSKI 1992:17), many methods are fixated on pitch and some not combinable, existing taxonomies of sound are not useful for theorists, and thus far it has been possible to write about sound-based repertoire only musicologically (descriptively) and not analytical-theoretically (explanatorily). All these lacks are mitigated by our study.

Froise certainly is not the only explanation for this repertoire. Rather, the explanation of a piece through Froise is one part of a hybrid approach to music analysis, which is long overdue due to the previous focus on unitary descriptions of works: "Rather than a single idea or a unitary concept, hybridity is an association of ideas, concepts, and themes that at once reinforce and contradict each other." (KRAIDY 2005, introduction). The literature that can be applied to Froise is wide: Froise in the study of timbral difference and taxonomy, noise, musical form, pitch-based voice-leading, psychoacoustics, not all of which we can study here. A Froise timbre as dramaturgical sound material, not mere object,

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[199] Translation of GANDOLFI, A. 1999. Formicai, imperi, cervelli. Bollati Boringhieri, Turin, p. 19.
[200] Materially or structurally. See TSAO 2007 and *Linienführung* in MAGNUS 2010.
[201] This flexibility that we witness in voice-leading expands its conventional scope, and the dynamic turn in musicology (see GAGIM 2015) is in keeping with it.

matters, and its relations to other timbres matter to timbral dramaturgy.

The topics that have hindered the wider adaptation of voice-leading methods in noisy repertoire include **psychoacoustics and human perceptive ability, reduction, numerisation and visualisation of timbre, role of blending and aggregation, texture and texture-derived Froise, segmentation, rewards from mimetic listening, interactivity of layers, analysability, discrepancies in the intention – notation – performance chain,** and **the spectral–spectrotemporal divide**. Our present focus does not allow an adequate reflection or treatment of these fields of study.

From the **theorists' viewpoint**, we have found **several strong resources and some risks**. In **the compositional aspects**, which we will be able to discuss in chapter 5.3, there are predominantly resources.

Among the **resources for theory**, we identify:

◆ The **visualisation and numerisation** of timbral distances. This is more detached from noisiness in the three morphological canvases.

◆ The ability to bridge the **spectral–spectrotemporal divide** for the first time with a theoretical method. Methods of spectral (harmonic) analysis, spectral interference structure analysis, and pitch-based methods can be used in tandem with our three modules.

◆ **Combinability with pitch-based and durational analysis tools**, as well as other conventional analysis tools. For instance, spectral hearing can affect perceptions of metre (JAKUBOWSKI 2018), and much repertoire combines sound-based and interval-based composition which still allots pitch and intervals some role.

◆ **Four different canvases**, each of which sheds light on different aspects of Froise, noisiness, and timbre generally. We did not encounter established Froise passages for which no timbral canvas would have explanatory power. Presentations using similar descriptors of spectrotemporal timbral space that in some ways different timbral canvases are a possibility to explore.

◆ **Contrast, development, and variation** as ingredients of musical dramaturgy are enabled by Froise sounds, also by tiny modifications to the timbres. Contrast can be reliably shown as proximity on the timbral canvases. Especially when contrasting more than two timbres at a time, it helps that contrasts can be shown on four different canvases. It confirms the intuition that no absolutely contrasting timbral pairs exist – rather, timbral contrasts are multidimensional.

◆ **Segmentation** is shown to be crucial for our method in the case of longer pieces. On the other hand, analysis on the timbral canvas can replicate segmentation evidence from other audible features[202] and support them. We

[202] See PHILLIPS et al. 2020, ANTUNES et al. 2011, BAUER et al. 2017, HARTMANN 2017, JENSEN 2006, KAISER & PEETERS 2013, HOŘÍNKA 2008, CAMBOUROPOULOS 2001, and ROCHA et al. 2013.

prefer short excerpts, of about 30 seconds at a time, depending on the pacing of timbral entrances.

◆ the **15 spectrotemporal descriptors of noisiness** that can be observed also separately. For us they were used in larger compound groupings, a practical compromise taken to represent the noisiness and Froisiness qualities of the repertoire. This affected the accuracy and resolution of the timbral taxonomical method and subsequent steps in the analysis such as placement in timbral space, trajectories, and trajectory strategies.

◆ **Centrality** of a timbre on a timbral canvas relative to the other timbres. This may sometimes correspond with the salience of a central timbre.

◆ The aggregate-based and sequence-based analysis approaches and their combinations. In general, there are several ways of making a timbral reduction and the philosophy of these reductions is unchanged from traditional analysis[203].

◆ **Tension-release patterns (in Froise principle 2)** as the most common dialectic, variously shown either in TIV values or in canvas movements toward the edges, to less crowded regions, to other timbral groups, or to numeric averages, and more. Such movements can be used to show in some pieces a rudimentary strategy of timbral cadencing.

◆ The **infrastructural importance (Froise principle 9)** of a timbre for a piece. This includes features based on the timbres' immediately perceivable salience and upper-level structurality on a timbral canvas.

Our study has **limitations** that may be mitigated by further research while some will remain features of our approach. As the **risks and desiderata for the future from our analysis method**, we identify:

◆ **Individual listeners' differences in categorical hearing**, which are less a challenge for interval-based voice-leading yet jeopardise the strength of any sound-based voice-leading. This affects the perceived salience of sounds and thus any timbral sequences, aggregates, comparisons, and processes between them. The pitch–noise border is likewise perceived individually (SEITHER-PREISLER 2006) and curtails the perception of Froise.

◆ Our method hardly considers **timbral averages** implied by interpolation between two or more timbres. This would not even be a solution for handling movement to and from aggregates. Some timbres will inevitably be closest to a canvases' visual average or weighted average coordinate, yet this often cannot override the actual common trajectories that are made – indeed, even suns and nuclei can be located at the edge of a timbral collection.

◆ The missing psychoacoustics research, test audiences, and the relative extent of Froise compared to human perceptive ability that reflected in the prototypal state of our method. Additional psychoacoustics constraints which are poorly understood will affect all stages of timbral listening. We can get the most out of

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203 See KANZIAN 2009.

the wide and representative musical scores, recordings, and literature once psychoacoustics evidence is available. Based on it, or due to individual preferences, simple and more comprehensive modifications to our analytical method can be done, such as weighting the descriptors' factors in the numerisation stages, and changes in the verbal definitions.

◆ **Inaccuracies in the transfer of compositional intention into notation and within performance,** on which analysis will be based. This includes cases when a passage's notation is timbrally ambiguous or the score is not available to us, or when the timbres (or even sound sources) cannot be quite determined based on the recording. On the other hand, we cannot determine all descriptors for a timbre for which instrumental effort is invariable and uninfluenced by intention, such as in electroacoustic music.

◆ Related to the two previous points, we can address all questions of **analysability**. For instance, the passage has to feature enough sounds (at least four), so that its timbral canvas can have enough coordinates that are traversed, to make reliable analytical statements.

◆ Our visualisations may render further results if we deepen connections to **graph theory**, such as GROSS & YELLEN (2004:872–909), who list among others considerations of graph eccentricity, radius, diameter, self-centeredness, automorphism, hull numbers, vertices, and dominating sets.

◆ **Prolongation** of a single timbre or of any state on the noisiness-pitchedness continuum, and durations of timbres are an analytical blind spot. On the one hand, prolongation as a concept (beyond the simple sustain and iteration) is foreign even to atonal music [204]. Thoresen (2015:323–324) also distinguished two kinds of prolongation, explicit (a sound "made to last longer") and implicit ("a sound-event not physically present still exerts an effect on listeners" and their interpretations of even the surrounding sounds), in addition to the conventional definition "the extension of an underlying note (or interval, or chord) by the introduction of additional notes" (THORESEN 2015:55) [205]. Whenever sounds significantly overlap or pause into silence [206], our method would need an added third dimension for time and a ruleset about psychoacoustic masking effects.

◆ Aggregation, masking, and blend as a result of interacting layers [207].

◆ The phenomena of **nonlinearity and emergence** related to Froise and to

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204 For example, Barber's (2015:35ff.) scale-degree condition or embellishment condition for prolongation cannot be reliably fulfilled. A consonance-dissonance condition would have to be replaced by a condition of blending grade, or noisiness total, to distinguish between structural and nonstructural timbres.

205 Thoresen's (2015:303 and passim) specific notational formulas also present which character is prolonged by which other character.

206 On the meanings of musical pauses, see TØNSETH 2015.

207 McADAMS' (2019:213) similar question is "What is the relation between auditory fusion and the perception of timbre? [...] In what way do auditory-scene-analysis principles and acoustic properties contribute to determining whether separate sound events will blend together?". The basics to are found in PEYNIRCIOǦLU et al. 2015.

timbre generally. Many timbral features emerge only when not studied in separation. Conversely, unexpected results in the study of Froise repertoire probably emerged qualitatively and quantitatively: from the linearisation of an essentially nonlinear phenomenon and from the reductive steps taken when we quantify timbre in our method. The developing steps for our methodology are primarily limited by its necessarily superficial engagement with the phenomenon of nonlinearity in noisy sound perception. We can attribute previous literature's avoidance and nonrecognition of Froise and the lack of existing noise analysis methods to the nonlinear elements in sound. Lacking a method, we did seek to accommodate the nonlinearity as far as possible while remaining in a linear framework and not requiring new findings in psychoacoustics. For our purposes, we have also maintained the linearity that makes the noise-pitch continuum. Nonlinear features do not seem to affect the pitched end of the continuum, and diminish in favour of perceptions of chaos when the noise extreme is approached. This continuum remains thus effectively linear [208].

Due to the nonlinearity in Froise listening, the audition of any complex timbre feeds back to the complexity of its preceding timbre, with unpredictable and highly individual results. Going forward should not be done with more topological models to understand timbral space, rather unsurpassably with a study of the psychoacoustic role of nonlinearity in Froise and of chaos in noise. In this sense, the elliptical border between Froise and noise will be a challenge to study, compared to that between Froise and pitch.

◆ further linear models are not a desirable way to continue the study of Froise as a nonlinear phenomenon, since they bring little new perspectives and do not solve the obstacles that our method had. Of numeric taxonomies, our is probably the most comprehensive and applicable to Froise sounds [209]. We warn against ideations that are visual (**ternary diagrams**, triangular charts that could represent the values of noise, Froise, and pitch on separate axes [210]), numeric-categorising (by stacking of our six timbral subtotals to derive morphology classes, which is reflected by the quadrant information in our taxonomy), and

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208 It cannot be excluded that what we deemed to be logical results (the trajectories and strategies that we have listed) are also affected by nonlinearity or inaccuracy effects that have interacted to form misleading patterns and to favour a seemingly logical explanation. This alternative explanation would lead to the conclusion that Froise sounds should not (yet) be studied, which, knowing the increasing presence of these sounds in the repertoire, is unsatisfactory. Nonlinearity in music has been studied by EDGERTON et al. 2003, MUDD 2017, and SADAGOPAN & WANG 2009.

209 "The taxonomic implications of timbre are still a subject under investigation, and may still have the aura of a utopian vision. But the relevance of timbre for *semantic* purposes is established beyond any doubt in 'mainstream' music." (THORESEN 2015:79).

210 See KOWALEWSKI et al. 1995. This would detach from Froise its liminal region and denounce the continuum, although the numeric values themselves are given in that continuum. This graph would indicate a relative independence of Froise, pitch, and noise, yet with some co-dependence since movement in one dimension spells movement in another too. Such a conflicting idea against the notion of a linear continuum of pitch–Froise–noise finds no support from the similar concept continuum order–complexity–chaos promoted by BERTUGLIA & VAIO (2012: passim) either.

phylogeny [211].

◆ **Attributability to a model of language or speech** [212], since as SOLOMOS (2020:241) notes, sound-based music questions any previous links that interval-based music consistently created towards language.

We lack the space to discuss these resources and challenges at length since the challenge is to future theorists, not to our main thesis.

5.2.3. Compositional prospects of Froise analysis

"If the effect of music is to be judged by the listener, then it is essential for anyone writing music or analyzing music not to confuse theoretical identity with perceived identity" (THORESEN 2015:317)

As the **compositional resources** from Froise and from our method, we note:

◆ There is **no strict numeric definition of Froise**. We have given a guidance of the absolute noisiness values –7…+7, or contextually a division of the noisiness values of the used timbres into three equidistant borders. Many works show groupings that include not-quite-Froise sounds that act in the same roles as Froise sounds, or group-based trajectories in which the Froise region is crossed by a large margin. At other times, trajectories are transmitted from a clearly Froise region to a more noisy or pitched region, which can help blur the borders of the sound types even more.

◆ **Trajectories and constellations** provide inexhaustible compositional possibilities and can be transferred to any part of timbral space and any timbral canvas. Likewise do **trajectory strategies**, since small adjustments to them can be made that still retain the characteristics of the strategy.

◆ **The eight trajectory types** we identified can be used compositionally either more consistently than any of the analysed compositions have done, or in combinations. **Timbral "scales"** may be created by repeating a trajectory.

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[211] It could consist of questions as to where a sound gained its noisiness. Some potent questions would concern the use of the frequency region, presence of spectromorphology, stability of frequency regions or peaks, relations of frequencies to each other, relations between harmonic components and inharmonic components.

[212] While the tasks of listening to music and speech are both about information-processing capability and information density, "Probably in music all spectro-temporal components in the signal, even silences, carry information, whereas for speech some spectro-temporal components, like formants, clearly carry more information then [sic!] others, like silences." (BEERENDS 2001:27). Humans have a capability for at least two timbral dimensions already in speech perception: "there is evidence that listeners are able to distinguish more than three independent aspects in comparing vowels of equal pitch and loudness. Since there are two formants needed to distinguish different vowel types, they cannot be arranged on a straight line with perceptual evidence. Furthermore, the same vowel can be more or less sharp, and it can be sung with more or less vibrato [Lerdahl 1987]. All these aspects can be varied independently, […] a structure of at least four dimensions." (MUZZULINI 2006:7). On phonemic listening in music see BURCZYK 2015, FENK-OCZLON 2017, on noise in speech BIDELMAN & YELLAMSETTY 2017.

◆ **Other trajectory strategies** than the five studied may be also feasible.

◆ The timbre-based dialectics represented **dialectical tension–release patterns**, of which two were related to Froise, two to noisiness and nine to other features. They were listed at the end of 4.4.

◆ Different **ways to construct or undermine continuity of timbral space**. This involves a (non-)dialectical use of the noise-pitch continuum, resolution (pixelation) of timbral space, and the use or avoidance of seamless transformations. In addition, in cases that we did not study, Froise can be used with a (conventional) pitch-based dialectic or in a way that does not participate in a dialectic. If a **strong dialectic** between Froise and some other region on the noisiness-pitch continuum does not arise, it may arise in intensity (TIV) or in one of the three dimensions of a signal. If other dialectics were crucial to the functioning of Froise, they were not shown by this analysis method. The noisiness continuum was seen as a more flexible determinant than principles in conventional instrumentation (based on instrumental families or in Penderecki's percussion, the material of an instrument), Lachenmannian and Smalleyan morphologies which do not guide composition with exact sounds enough, or spectral analysis which conventionally addresses the steady features of a pitched sound and not differences in morphology or of noisy sounds.

◆ **Gaps in timbral space**, akin to a *horror vacui* principle in much of interval-based music (a pitch or interval becomes more impactful the longer time it has been absent) [213]. This can contribute to sensations of tension and release [214].

◆ **Our timbral taxonomy as a collection**, which is needed by the method and constitutes in itself a simple timbral instrumentation catalogue or guidebook which hopefully will become very handy for composers. The trajectories have above been presented less pedagogically yet can guide how to relate or blend sound sequences and aggregates taken from the catalogue [215].

◆ Froise can be somewhat easily created by **texturation** [216], as long as the base timbres for the textures are not too far from Froise. This far such situations were shown in changes of articulation when several instrumental layers are present (Furrer, Rădulescu, Sciarrino). There are likely perceptual principles (memory effects, categorical perception effects, effects with pitch) on the surface that determine the function of texturations and layers.

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213 Such emptiness can be unsettling: "If we conceive [...] an impossibility to anchor oneself in fixed points and stabilizing relations, then we are confronted by nothing other than an emptiness, or more precisely a horror vacui." (ABRAHAMSSON 2018:113)

214 A compositional observation of and operation with gaps in timbral space is somewhat common, however not systematic. There are no known principles as to how soon gaps should be filled, how close to the centre of the gap should the "filler" timbre be, and how many gaps should exist at any given moment, does the filling of a timbral gap bear form or reap experiential rewards, and is a timbral scale genuinely being interpolated so that a sensation of a gap results.

215 In addition to this theoretical information, a composer will need a unified notation for these sounds that is not in conflict with their instrumental aetiology.

216 On texture study in music, see GRILL et al. 2011.

◆ The use of Froise as either the **adaptation of voice-leading** into sound-based composition or as simply **musical dramaturgy** is a conceptual choice left to the composer. Similarly for any balance between interval-based and sound-based composition, both of which Froise responds to and that Froise marvellously enables. Froise is central to any music that smoothly traverses interval-based and sound-based composition [217].

◆ Froise may fit well with **other gradations**, such as microintervallic pitch organisation.

◆ The analyses show **which constellations, trajectories, and strategies** in different timbral spaces and on different canvases are likely to work. This can inspire future compositions.

◆ The **ubiquity and centricity of Froise sounds** is likewise a compositional choice that has been seen to strongly characterise a piece. A dialectic with Froise is however possible when the passage has any share of Froise between small and ubiquitous.

◆ There are various ways in which aggregates can overlap, be made to seem either permanent or unique.

◆ How much Froise sounds participate in Gestalts, form-building transformations (in the sense of THORESEN 2015), symmetries, thematisations, and motivisations that emerge in timbral space (a canvas) or in other aspects of musical perception is an open playground for composers.

◆ The **multistability** feature of Froise may be engaged with in compositional contexts, once its factors are known and when the composer can steer the listener's "cognitive control" which "is the ability to control the rate of reversals" and make them less frequent (HANDEL 2019:97) between the noise and pitch percept [218]. A small minority of sounds may remain in the multistable perceptual negotiation for their entire sounding duration.

◆ Lyrics, visuals, spatiality, and other **media can be used in conjunction** with

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[217] In interval-based music, those Froise timbres that provide one clear pitch at a time should be the most applicable to voice-leading, even though multiphonics (many of, if not most of which are Froise) can be woven into interval-based composition. A case in point is the role of Froise from the timpani in tonal repertoire.

[218] On multistability, see KELSO 2012, KUBOVY & YU 2012, SCHWARTZ et al. 2012, WILSON 2012, and WINKLER et al. 2012. HANDEL (2019) presents five types of reversals of the perceived state of a visual stimulus, yet only two for sound, neither of which deals with substance similar to ours. Handel's cases are that "two sounds of different frequencies are recycled" (91) or "if a sound or word is repeated continuously." (HANDEL 2019:92). According to Handel (2019:100), "two theoretical positions have emerged". In what pertains to Froise, the second position would allow the musical use of Froise: "Gestalt theory emphasizes that percepts tend to be the simplest given the actual stimulation. Underlying this notion of *prägnanz* is the belief that the percept follows the operation of a uniform nervous system. Statistical theory on the other hand emphasizes that percepts tend to be the ones most likely to occur in specific situations and that people attend to the most reliable sensations, the Bayesian assumption." (HANDEL 2019: 100).

Froise composition.

◆ Froise sounds **enable particular musical expression** and musical experiences that cannot be achieved by other means. The use of Froise sounds increases compositional choice [219].

◆ If Froise is not separate from the **aesthetics** discourse (to which we have taken a distance), it may integrate with other compositional aesthetics.

◆ Froise forces composers away from an over-reliance on written notation (French "*scripturisme*")[220].

◆ At any point in the compositional process from material to orchestration, a **combinability with pitch-based composition**, which has widely documented tools for composers. This connection may be made particularly via our concepts of blending and "different aggregation states" (ROSSETTI 2017:275).

◆ **Added perspectives from embodied cognition**, as well as other conventional analysis tools.

What must be seen as the **compositional blind points of our method** are that there is no **timbral equivalent to transpositions and modulations**, no matter how often this connection between interval-based and sound-based music has been proposed [221]. This is partly due to the difficulty of establishing clear timbral centres [222]. Even if timbral vectors are perceived, they might not be powerful enough to be perceived saliently. Likewise, our approach does not guide composers as to the **subjective associations and embodied cognition** from timbres, which should play some role in compositional planning, however evasive they are as a topic.

Here we could also mention **compositional intentionality** and (un)planned effects due to the earlier viewpoint of **music as an emergent phenomenon**[223]**.**

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219 "Listening to timbre is entering the gap imposed by the dichotomies of post-Kantian aesthetics. Its meta-acoustic vibration unequivocally proves those binaries misguided. Timbre is not either sound source or sublime ineffability: it is both, *sentiment sonore*. Timbral aesthetics does not present either carnal sensation or cerebral Thingness: it offers both, in *Tonwollust*. Timbral paradoxes are not contradictions, but they are the delightful friction evoked by the most affective and effictive [sic!] of music's vital agents: the ungraspable qualia of sonorous difference." (VAN ELFEREN 2021:207)

220 LEYDON (2012) also speaks of this "ocularcentrism" and FRIZOT (2008) on the effects of notation on music aesthetics.

221 "the patterns designed out of timbre must permit some form of invariance under transformation, like a melody that remains identifiable when it is transposed." (ROADS 2015:xix). Modulation would require the whole relation system of other sounds to also shift according to a new centre timbre; thus modulation in the more specific sense that relies on establishing a new centricity, as opposed to mere transposition, is probably impossible to attain in the timbral context. All timbral modulations would sound as transpositions. This is true of atonal pitch-based music too, and thus modulation may be limited to tonal music.

222 One pitch suffices to establish a tonic on one scalarity in interval-based music, while timbres in sound-based music establish several scalarities and cannot establish one of them as preferential.

223 On the general discourse of intentionality, see FIOCCO 2019.

5.3. Summary and future prospects

5.3.1. Future prospects for analysis and composition

Much of the above sums up our tasks, also those spelled in 3.3.1., and their results. A summary chart of our analytical method is provided in Appendix 5.

Further researchers could take two routes: a **musicological task** to further investigate the role of Froise in the repertoire (which will also help composers), and a **quantitative task** to test the limitations of our analytical method, especially the case of motions on the timbral canvas. The musicological task seems to be qualitative, while the quantitative task is wider in scope. Fascinatingly, the quantitative task holds the future promise of reformulating our analytical method into a compositional method.

For readers who look forward to conducting further research and compositional applications, we recommend the following concrete perspectives:

◆ How to learn **to hear** the timbral functions and dramaturgy in which Froise participates, akin to a timbral solfege found in Smalley's and Thoresen's studies?

◆ How can changes of TTS or of canvas during a piece affect its segmentation? Does a change of canvas without a change of the used TTS, or a change of TTS without a change of canvas, constitute something analogous to modulation or prolongation?

◆ Which of the found dialectics for creating completion are more robust than others and how robust completions would a Froise-based piece need? How do they relate to Gestaltic principles?

◆ Can timbral dramaturgy on the level of an entire piece be simplified into cyclical or recurring dramaturgy, chaining or welding, process or ambient dramaturgy?

◆ How do the evasive nature of Froise sounds and categorical perception affect memorisation processes [224] of the sounds and of musical dramaturgy in this repertoire?

◆ Listeners' expected contextual changes of focus between the entity of a complex sound and the individual complex sound sources that make up that entity. The benefits from aggregative listening to voice-leading.

◆ How much do the values on the timbral canvases emulate the auditive-cognitive results of a piece, and are there many more layers of audition and cognition behind the listening reward from Froise sounds?

◆ What exactly are the novel (cognitive, neurochemical) rewards and

[224] See BRIDGES 2012.

associations that listeners can receive from Froise sounds? How do such reward chronologies compare to rewards from structural form-based listening? [225] Could the effectively same piece (with the same reward dramaturgy) be composed with A) the same timbral constellation, different trajectories? B) the same trajectories, different constellation?

◆ Since musical structure does not automatically equal perceived expression (HALLAM 2009:141 ff.) even in pitch-based music, how far is our timbral voice-leading, as shown in TTS's and dialectics of timbre, from describing the cognitive reward in an average listener's brain? Would two pieces with different timbral collections yet the same dialectic and similarly timed dramaturgy and trajectories be able to sequentially activate the same cognitive-chemical pathways?

◆ What are the differences in following a sound that has a constant pitch and varying noise component versus when the pitch varies and noise does not (disregarding the inherent variation in noise)?

◆ Tricking categorical perception to not perceive any of the borders between the pitch, Froise, and noise regions, by using a steady linear progress in all the noisiness descriptors from either polar extreme.

◆ The relevance of (non-)smoothness and parsimony for voice-leading with Froises. What could replace the principle of parsimony, and on which Gestaltic and psychoacoustic grounds?

◆ Does spectral similarity outweigh morphological similarity in perceptions of whether a dramaturgy is interval-based or sound-based? Can Froise sounds traverse this divide in perceptual focus?

◆ **Compositionally**, what does Froise spell for future guidebooks of instrumentation? Applications of the method's acousmatic approach to electronic playback of instrumental sounds, and even to entirely electronic sounds without instrumental associations.

◆ In addition to specific timbres that emerge from texture (see ANTUNES et al. 2019, CASTRILLÓN's (2020:29–30) "poly-timbral development" with in-between stages of aggregation and texturation, and KOKORAS' 2014 holophony), how to form Froise with non-timbral means?.

◆ In which cases does the first established timbre or timbral aggregate become secondary to some other timbre that is introduced only later? How easily can the first impression be changed?

◆ Can timbral processes happen audibly in one particular descriptor only? Can some descriptors abandon polarity and reflect some cyclical measure of timbre?

◆ **To adjust our method**, how much should the technical effort and range of possibilities on an instrument, that is, a listener's expectation horizon, be present in the taxonomy? Are there any acoustic timbres that do not fit our timbral

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[225] "the point of a composition is the added value of creating a different kind of universe for the listener, [...] sound can become a trap [however]" (PROFANTER 2019: 145).

taxonomy? Do exactly "opposite sounds" exist? Do other complex sounds exist than chords, Froise, and noise? How could the taxonomy be modified to serve sound synthesis, that is electronically constructing and modelling sounds that are deceivingly close to the described sound? [226]

◆ Which compromises are needed to convert between Schaefferian sound types or Thoresenian visual notation and our timbral taxonomy? Are correspondences with the Smalleyan and Lachenmannian typologies necessarily incomplete?

◆ How to make our analytical tool independent of regional, cultural, historical, and contemporary preferences and value statements for certain sounds? [227] By what modifications to make our timbral taxonomy applicable to electronic music where Froise is also commonly found yet the base timbral identity of an instrument has to be abandoned?

◆ How can we study the musical intentions of a composer when using (certain) Froise sounds, and their realisations in a piece? Can similar compositional intentions lead to dissimilar pieces of the Froise repertoire?

◆ How much can the varying pitch organisation solutions in Froise music (as dramaturgically not pitch-based) benefit from the aesthetics and discourse of nomadicity (see BRAIDOTTI 2014) or fragmentariness (LICHTENSTEIN 2009; BOULEZ 2008)?

◆ An academic curriculum could be developed based on Froise, TTS, dialectics, and the general trajectories in timbral space. This would require a wider corpus of repertoire, and possibly sorted and presented by a similar strategy of timbral movement for pedagogic practicality.

5.3.2. Summary

To conclude, we have studied in recent acoustic repertoire the more and more common type of sounds (Froise) that are at a perceptual balance between pitchedness and noisiness. Gradations of noisiness have long been regarded as a crucial compositional operator for this repertoire that has noisy acoustic sounds as its main dramaturgical material. To study Froise as part of the nonlinear and emergent nature of noise we also had to be able to understand noise music-analytically. The analytical method that was developed is a separate tool that brought great synergy to the study of Froise.

At the start of each analysis of the 18 passages, our light, modular, and non-computerised method categorised noisy instrumental timbres for 15 of their most strictly timbral features such as spectromorphology. These features were in keeping with the most pertinent timbral descriptors identified by the literature, and they were further optimised for indicating noisiness in the timbres.

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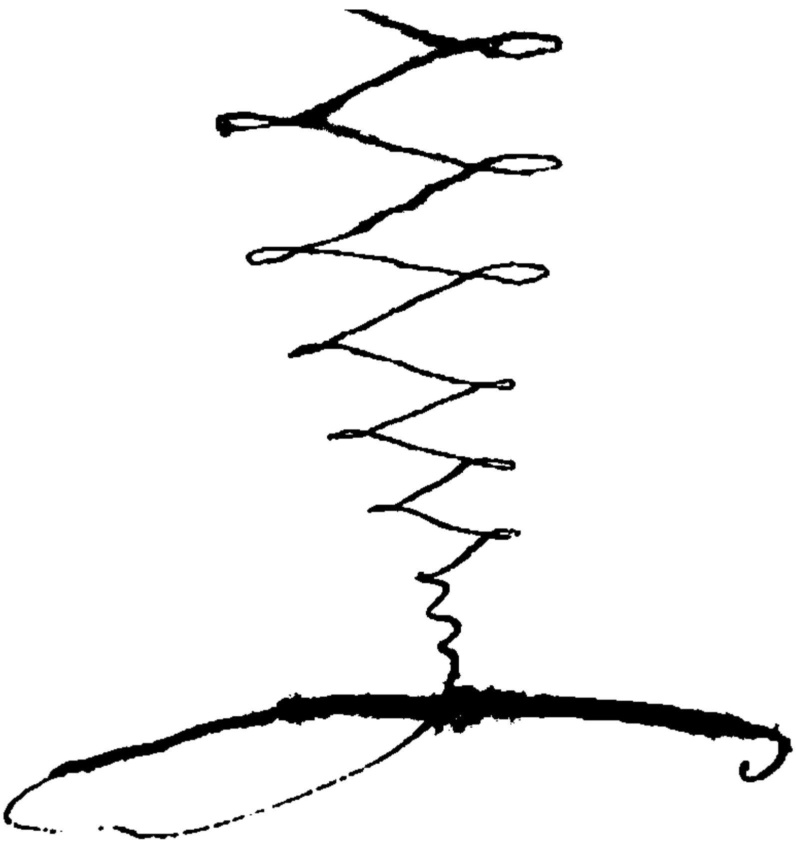
[226] About resynthesis using noise bands and sinusoids see SERRA 1997 and NIELSEN 2012.

[227] This boils down to KLEMPE's (1983:11) fundamental questions of music analysis: What can we say about the piece, and in what way can this be said?

Since composers' growing preference for Froise sounds is enabled by timbral listening, we abstracted timbral spaces (timbral canvases) to emulate the many possible ways of listening. Of the possible presentations, we concentrated on four presentations (timbral canvas versions) from among many. We studied the ways in which Froise sounds proceed in timbral space and found eight specific timbral trajectories. Despite the occasional inaccuracy of our tentative method and the lack of a better one, timbres in these works were seen to move systematically enough in timbral space. When any of the eight trajectories combined in compositional use, they formed strategies on the upper level that can engage with timbral listening strategies. Five such common strategies when using Froise sounds were identified. Since these timbral trajectory strategies operate with degrees of parsimonious movement in how timbres proceed to each other, it has been feasible to understand such sound-based dramaturgy through an earlier (although more limited term) as timbral voice-leading.

While these composers likely did not elaborately plan their music in timbral space, many of their compositional strategies with Froise sounds eventually relied on basic Gestaltic and parsimony principles. In addition, each canvas revealed various timbre-based dialectics that resemble tension–release patterns typical of earlier music. Mostly due to the nonlinear nature of the Froise phenomenon and because timbres in pieces act contextually rather than detachedly, each analytical module has limitations and inaccuracies that may be overcome with advances in psychoacoustics. In addition to introducing a new category of sound, our study provides an urgently needed competent and modifiable tool both for future acoustic composition and analysis of sound-based music, which often centres on Froise.



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The graphics to fill the pages with the late 1600's scribblings are likely by Isac E. Pihlman, a registrar for the Somero parish books in Finland. The FFT charts were made with Reaper and Adobe Audition.

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Bibliography

Musical score and recording sources

The excerpts from **Auvinen**, **Furrer**, and **Zubel** are reprinted in Appendix 4 with kind permission of the composers. The reference for Auvinen are unpublished concert recordings from 2015 and 2021 by Helsinki Chamber Choir, defun Ensemble, and Nils Schweckendiek. The Furrer reference recording was released by KAIROS, 2014. The Zubel recording is by the Seattle Chamber Players and Agata Zubel. Three scores are not permissible to be reproduced here.

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Lachenmann: © 2022 by Breitkopf & Härtel, Wiesbaden. Publication PB 5435. Reference recording by London Sinfonietta & Brad Lubman. **Pesson:** © 2016 by Maison ONA / ONA 0081 / 978-2-37166-080-9, CATCH SONATA, Gérard Pesson, 2016, clarinet, violoncello & prepared piano, 12'. Heard live at a Trio Catch workshop in Budapest in May 2019; reference recording from a concert of Trio Catch in Atmusica, Tours 30.9.2020. **Rădulescu**: Thirteen dreams ago (opus 26) by Horatiu Radulescu ©1978 Copyright Editions Jobert, Paris. Reference recording: Ensemble Köln & Robert HP Platz, 1982.

Romitelli: Several reference recordings used comparatively online.

Saariaho: Copyright © 1994 Chester Music Ltd. Reprinted by Permission of Hal Leonard Europe Ltd. Reference recording by Florent Jodelet and Kaija Saariaho.

Sciarrino: Reference recording released by KAIROS, 2005. Reprinting permissions for the **Czernowin** excerpt would have been too expensive. The score is available in a 2009 edition and sold by Schott Music. Reference recording by Ensemble Nikel. In addition, many pieces can be listened to online and occasionally this includes the scores.

Literary sources

The in-text references pointed to one or two author names per source. Sources are ordered primarily by that first author surname and secondarily by other authors and by year of publication. The academic citation convention here reflects this practical hierarchy. To identify between electronically available sources and the many rare out-of-print publications, the print location information is also given. Where several sources are part of one and the same larger publication, the list may compactly point to the larger publication as a separate entry. Any sources from clearly one of the corresponding baskets of literature (laid out in chapter 2) are given as circled numbers ① to ⑧.

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Appendix 1. Definitions of the spectral descriptors

<table>
<tr><th colspan="4">Name of descriptor</th><th>Abbreviation</th></tr>
<tr><th colspan="2">Pitchedness criteria
(values –2 and –1)</th><th>Froisiness criteria
(value 0)</th><th colspan="2">Noisiness criteria
(values +1 and +2)</th></tr>
<tr><td colspan="4">Brightness or Spectral Centroid (combines strength, register, stability, and competition)</td><td>Br</td></tr>
<tr><td>**–2:** All of these: A strong, high, stable, uncompeted centroid</td><td>**–1:** three of these:
a strong, high, stable, uncompeted centroid</td><td>**0:** When no pitchedness or noisiness steps are fulfilled completely</td><td>**1:** Three of these: a weak, low, fluctuating, competed centroid</td><td>**2:** All of these: a weak, low, fluctuating, competed centroid</td></tr>
<tr><td colspan="4">Amount and dispersal* of simultaneous frequency components, also labelled the opposite of Spectral Flatness</td><td>Di</td></tr>
<tr><td>**–2:** small amount of frequency components and concentrated and at systematic distances</td><td>**–1:** small amount of frequency components or components concentrated at systematic distances</td><td>**0:** pitch region changes rapidly or there is a moderate amount of frequency components, and frequency spacing is neither systematic nor entirely unsystematic</td><td>**1:** quite large amount of frequency components or components are diffused in a quite large frequency space unsystematically</td><td>**2:** large amount of frequency components, diffused in a large frequency space unsystematically</td></tr>
<tr><td colspan="4">Inconsistency of the amount and general positioning of frequency components
[in repeated playing or during sound body or decay; change of elements resists auditive categorisation and thus makes it sound more noisy]</td><td>Afr</td></tr>
<tr><td>**–2:** stable amount and approximate positioning of frequency components</td><td>**–1:** stable amount of frequency components yet changing positioning (by glissandoing for instance)</td><td>**0:** The amount of frequency components cannot be counted, or positioning is stable and amount varies only slightly</td><td>**1:** changing amount of frequency components or changing general registral positioning of frequency components</td><td>**2**: changing amount and general registral positioning of frequency components</td></tr>
</table>

Width of frequency bands				Wb
−2: components have narrow frequency bands	**−1:** stronger narrow components are a majority (pitches) and are bordered by softer noisy frequency bands	**0:** some components have narrow, some wide frequency bands	**1:** most components have wide frequency bands	**2:** components have wide frequency bands
Inconsistency of frequencies, especially fluctuating (fundament) pitch level and dynamic presence				Fr
−2: frequencies of components and their dynamic presence or share in the sound remain steady	**−1:** most frequencies of components and their dynamic presence or share in the sound remain steady	**0:** if sound is percussive without decay possibility, or frequencies move e.g. linearly, or dynamic presence grows/diminishes slowly and gradually	**1:** most frequencies of components are unstable, or frequencies' instability is predictable	**2:** frequencies of components are unstable and unpredictable
Independence of frequency contours				Ifc
−2: frequency contour follows that of another component [homophony is perceived as more pitched], or there is no other component	**−1:** many of the frequency contours follow that of another component	**0:** if sound is percussive or halted without decay possibility or no frequency contours are present	**1:** some components’ frequency contours are independent of each other or of any other component.	**2:** (All) components’ frequency contours are independent of each other. [polyphony inside one sound source is perceived as more noisy]
Dynamic in-stability of frequency bands when held				Dsb

−2: when held or reattacked, components have dynamically steady frequency bands	**−1:** when held or reattacked, most components have dynamically quite steady frequency bands	**0:** if percussive without decay possibility, or if sound cannot be held. Sound is not quite steady nor unstable either.	**1:** when held or reattacked or when decaying, decays naturally	**2:** non-decay based unstability; when held or reattacked or when decaying, components have dynamically unstable frequency bands
Internal and textural independence of dynamic contours.				Idc
−2: dynamic contour follows that of another component or there is no other component inside this sound source	**−1:** dynamic contour mostly follows that of another component	**0:** if sound is percussive or sound body cannot be affected	**1:** at least two dynamic contours of components can be controlled separately while playing within the same sound.	**2:** components' dynamic contours are independent of each other or there are other independent somewhat equally salient layers present
Un-clarity* between attack (noise) and body of sound (pitch). Amount* of attacks *				Ca
−2: small number of attacks and clarity of attack (noise) vs. body of sound (pitch)	**−1:** somewhat clear attack (noise) vs. body of sound (pitch)	**0:** unclear attack or percussive or sound has no body	**1:** many perceivable attacks, e.g. by recoils	**2:** granularity by dense attacks that yet do not quite constitute pitch
Prevalence and role of attacks *				Pa
−2: no attack is present, or attack is extremely short compared to the steady sound state	**−1:** the onset of sound is elliptical or attack is quite short compared to the steady sound state	**0:** slightly unsteady body [borders] of sound	**1:** no steady state of the sound is present, and no new attacks (e.g. a decay)	**2:** no steady state of the sound is present, and there are new attacks

Energy distribution in time *				Ed
−2: soft and regular	**−1:** soft and somewhat irregular or an accented decay	**0:** soft irregular	**1:** loud regular	**2:** loud irregular
The maximum length at which this sound can be achieved				Lm
−2: long infinite	**−1:** long definite, yet sound can be actively held in a way that could affect its morphology. (on wind instruments, circular breathing is not taken into account)	**0:** when instrument physically ends or sound is perceived as perforated enough or sound cannot be held at all	**1:** short or irregular	**2:** very short or very irregular
Non-harmonicity of relationships between frequency components *, also called Inharmonicity				Inh
−2: relationships between frequency components are harmonic (pitchedness)	**−1:** there are no harmonics or not many of them, or there are harmonics and nonharmonic components	**0:** relationships are harmonic to several fundamentals or a fundament that is not present	**1:** relationships between most frequency components are inharmonic (noisiness)	**2:** relationships between frequency components are inharmonic (noisiness)
In-hierarchicity in components' strengths *, both in FFT snapshot and in decay				Ihc
−2: The strengths of components manifest a	**−1:** the strengths of components manifests	**0:** somewhat stable strength proportions. Unstable	**1:** some little differences in components’	**2:** no differences in components’ strengths, no

clear hierarchy (which stays if possible to sustain)	some hierarchy (which mostly stays if possible to sustain)	hierarchy, between even and uneven	strengths at any point in time	hierarchy between the audible peaks. This does not change at any point in time
Sense of noisiness brought about by (extreme) register *				Er
−2: narrow register. Middle register or non-extreme register for the instrument	**−1:** non-extreme register for the instrument yet not narrow	**0:** the instrument or this playing mode only has one register	**1:** close to extreme register, also in terms of the instrument or this playing mode only uses an extreme register	**2:** extreme register, also in terms of the instrument

Two additional descriptors are contextual and depend on the entity of the previous descriptors:

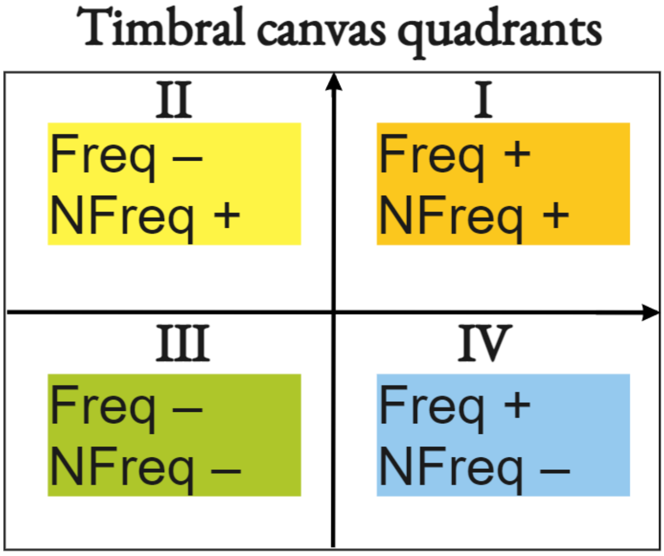
Amount of blend (pitch-based cohesion) and beating (noise-based interference) in combinations of sounds. This can be made by pitched harmony* or temperament*. This descriptor somewhat correlates with the terms Roughness and Sensory Dissonance.				Cbb
−2: more blend than interference in the structure of components	−1:	0:	1:	**2:** more interference than blend in the structure of components

The external effect of room acoustics and obstacles (affects the complexity of the transmitted sound)				Ra
−2: dry	−1:	0:	1:	**2:** reverberant

Some basic labels that we used as part of the descriptors Di, Ca, Pa, Ed, Inh, Ihc, Er, Cbb and Ra (above marked with *) originate in or are inspired by the listing of features by LYYTIKÄINEN (2009).

Appendix 2. Descriptor catalog for common instrumental timbres

Instrumental timbres are listed by their instrument family and alphabetically. The abbreviations of the descriptors and subtotals (repeated below) refer to chapter 3. For ease of imagining the timbres on the respective timbral canvas comparison, the quadrants in the subtotals are here coloured using this pattern, with the example of the Freq–NFreq canvas:



Subtotals:
Temp: Afr, Dsb, Ifc, Ca, Lm, Pa, Fr, Idc, Ed.
NTemp: Wb, Br, Er, Inh, Di, Ihc.
Freq: Wb, Br, Er, Inh, Di, Dsb, Ihc, Afr, Ifc, Ca, Pa, Fr.
NFreq: Lm, Idc, Ed.
Amp: Di, Ihc, Pa, Dsb, Fr, Idc, Ed.
NAmp: Wb, Br, Er, Inh, Afr, Ifc, Ca, Lm.
TIV: timbral internal variance (from all descriptors).
Noisiness total: sum of all descriptors.

Most timbres in the quadrants II and IV are Froise, since the equilibrium of positive and negative proceeds from the upper left corner via the origo (middle) to the lower right corner. Froise sounds are also found in quadrants I and III when they are near this line. This chart is given for the Freq–NFreq comparison yet these notions apply similarly to all three subtotal canvases. Since further connections between timbres might be made by similarities in these quadrants, the values below are coloured with these shadings. If one or both values are zero, the quadrant cannot be determined.

This taxonomy may be completed at a later occasion since it misses many common sounds that were absent in the repertoire study. In the best case, these lists can be combined. If the tables are viewed on software such as Excel, timbres from all instruments can be sorted separately, for example according to each subtotal, TIV, or noisiness total. This facilitates finding interesting yet similar combinations of timbres.

Please refer simultaneously to the definitions of the descriptors in App. 1 to arrive (in some cases) at your own values that will be more applicable to your work and perception of these timbres. Also note that this method combines well with pitch-based analysis and voice-leading with fundaments or spectral components. Note that the bowed string instrument abbreviations developed for the Furrer and Rădulescu pieces have values of descriptor Er that describe playing in the extremely high register.

Woodwinds

noisiness total	TIV	instrument	sound / playing mode	Br	Di	Afr	Wb	Fr	Ifc	Dsb	Idc	Ca	Pa	Ed	Lm	Inh	Ihc	Er	Temp	NTemp	Freq	NFreq	Amp	NAmp
-1	0.596	flute	air only	0	1	1	1	-1	-1	0	-1	0	0	-1	-1	1	0	0	-4	3	2	-3	-2	1
2	1.316	flute	air, low, long, cresc.-dim.	2	1	1	1	0	-1	2	-1	-1	-2	0	-1	1	0	0	-3	5	4	-2	0	2
-8	1.316	flute	airy, spitting embouchure ("spucken, wenig Ton")	0	-1	-1	-1	-2	-2	0	0	-2	1	-1	2	-1	1	-1	-5	-3	-9	1	-2	-6
1	0.996	flute	airy bisb. stacc. (second octave)	0	0	2	0	0	0	0	0	0	0	-1	2	-1	1	-2	3	-2	0	1	0	1
-3	1.093	flute	airy pitch (soffio)	0	1	1	1	0	-1	1	-1	-1	-2	-2	-1	1	0	0	-6	3	1	-4	-3	0
-7	0.782	flute	bisb. & gliss., f diminuendo	0	0	1	0	1	-2	-1	-2	0	0	-1	-1	-1	0	-1	-5	-2	-3	-4	-3	-4
-8	1.582	flute	bisb. ord.	-1	0	1	-1	1	-2	-1	-2	1	2	-1	-1	-2	0	-2	-2	-6	-4	-4	-1	-7
-2	1.049	flute	closed embouchure vowel sweep/gliss.	1	1	-1	1	0	1	-1	-1	-2	-1	-1	-1	1	0	1	-7	5	1	-3	-3	1
-6	1.173	flute	dyadic multiphonic, airy (soffio)	1	0	-2	1	-2	-2	-1	1	0	0	-1	-1	1	0	-1	-8	2	-5	-1	-3	-3
-3	1.093	flute	fl. soffio, airy pitch	0	1	1	1	0	-1	1	-1	-1	-2	-2	-1	1	0	0	-6	3	1	-4	-3	0
5	0.756	flute	flutes (alto, in C, bass): fast airy pitch sequence, legato, f	1	1	1	0	0	-1	0	1	1	2	0	-1	1	0	-1	3	2	5	0	4	1
-1	1.396	flute	flz. ord.	0	0	1	0	-1	1	-1	-2	2	2	-1	-1	1	-1	-1	0	-1	3	-4	-4	3
0	2.133	flute	flz. ord., extreme highest register, ff	-2	0	-2	0	-1	0	0	-2	2	2	2	-1	1	-1	2	0	0	1	-1	0	0
-1	0.862	flute	inhale through instrument, low air noise, vowel cavity "a"	1	0	-1	1	1	-1	-1	-2	0	0	0	-1	1	1	0	-5	4	2	-3	-1	0
8	0.516	flute	jet whistle, mf	0	1	2	0	1	0	0	0	0	0	2	1	1	0	0	6	2	5	3	4	4
3	1.227	flute	key clicks	1	0	-1	-1	0	0	1	-2	0	2	0	1	2	1	-1	1	2	4	-1	2	1
-1	1.262	flute	low, almost no pitch ("1/5K") [soffio estremo], ppp	1	1	1	1	1	-1	1	-1	-1	-2	-2	-1	1	0	0	-5	4	3	-4	-2	1
-15	0.533	flute	multiphonic stable solid pitched (Zubel: "freely chosen for the dynamic")	0	-1	-2	1	-2	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-12	-3	-12	-3	-8	-7
-21	0.773	flute	narrow gliss. from g3 down, dimin.	-2	-2	-1	-2	0	-2	-1	-2	-2	-2	-2	-1	-1	-2	1	-13	-8	-16	-5	-11	-10
-22	0.382	flute	ord., almost no vibr.	-1	-2	-1	-2	0	-2	-1	-2	-2	-2	-2	-1	-1	-2	-1	-13	-9	-17	-5	-11	-11
-6	2.240	flute	overblown split harmonics (short fff)	0	-1	0	-2	-2	-2	1	-2	-2	0	2	2	-1	-1	2	-3	-3	-8	2	-3	-3

-8	0.782	flute	pizz.	-1	-1	-2	-2	0	0	0	0	0	1	-1	1	-1	-1	-1	-1	-7	-8	0	-2	-6
1	0.996	flute	soffio bisb. stacc. (second octave)	0	0	2	0	0	0	0	0	0	0	-1	2	-1	1	-2	3	-2	0	1	0	1
9	0.907	flute	speak/whisper into flute in own rapid pulse "d k", avoid pitch, vary fingering	2	1	2	1	1	0	-1	0	1	2	0	-1	1	0	0	4	5	10	-1	3	6
-8	1.316	flute	spitting airy embouchure (pitch e2)	0	-1	-1	-1	-2	-2	0	0	-2	1	-1	2	-1	1	-1	-5	-3	-9	1	-2	-6
9	0.773	flute	tongue ram, f	0	0	2	0	0	0	0	0	0	0	2	2	1	0	2	6	3	5	4	2	7
0	1.067	flute	whistle tone (same fingering, wobbly result)	1	1	1	-1	1	1	-1	-2	0	0	-1	-1	1	-1	1	-2	2	4	-4	-3	3
-12	1.227	flute	whistle tone (stable)	0	0	-2	-1	-2	1	-1	-2	-2	-2	-1	-1	1	-1	1	-12	0	-8	-4	-9	-3
12	1.360	bass flute	exhaling and inhaling through instrument with continuous keycliks	2	2	2	1	1	-1	2	1	1	2	0	-2	1	0	0	6	6	13	-1	8	4
10	1.156	bass flute	freely, scream through flute with continuous keyclicks	1	1	2	0	1	-1	2	1	1	2	2	-1	-1	0	0	9	1	8	2	9	1
6	0.773	bass flute	irregular key clicks, active	1	0	0	-1	0	0	1	0	2	2	0	0	1	1	-1	5	1	6	0	4	2
-17	1.049	bass flute	low register ord. ppp	0	-2	-1	-1	-1	-2	-1	-2	-1	-1	-2	-1	-2	-2	2	-12	-5	-12	-5	-11	-6
-14	0.862	bass flute	mid-high register ord. p, short legato pitches	0	0	-1	0	0	-1	-1	-2	-2	-1	-1	1	-2	-2	-2	-8	-6	-12	-2	-7	-7
1	0.996	bass flute	scream through flute text in brackets ≈ as low as possible, f	1	0	1	0	1	-1	1	-1	0	-1	2	-1	-1	1	-1	1	0	1	0	3	-2
3	0.960	oboe	air (through reed), low, long, cresc.-dim.	2	0	0	1	0	0	2	-1	-1	-1	0	-1	1	1	0	-2	5	5	-2	1	2
-8	1.449	oboe	flz.	-1	-1	-2	-1	-1	-2	0	1	2	2	-1	-1	-1	-1	-1	-2	-6	-7	-1	-1	-7
-7	1.316	oboe	legato bisb. & gliss.	0	0	1	-2	1	-2	-1	-2	0	0	2	-1	-1	-1	-1	-2	-5	-6	-1	-1	-6
-7	1.316	oboe	multiphonic (in Bauckholt's Atempause)	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-1	2	2	1	-10	3	-3	-4	-5	-2
-12	0.827	oboe	ord. low, short, pp	0	-1	-1	-2	-2	0	0	0	-1	0	-1	-1	-2	-2	1	-6	-6	-10	-2	-6	-6
-18	0.693	oboe	ord. stacc.	-1	-1	-1	-2	-2	-2	-1	-1	-1	0	1	-1	-2	-2	-2	-8	-10	-17	-1	-6	-12
1	0.862	oboe	stacc. bisb. & gliss.	0	0	1	-2	0	0	0	0	0	0	1	2	-1	1	-1	4	-3	-2	3	2	-1
-7	1.182	clarinet	"pizzicato", mp	0	-2	-1	-1	0	0	0	0	0	-1	-1	2	-2	1	-2	-1	-6	-8	1	-3	-4
-4	0.596	clarinet	air only	0	1	0	1	-1	-1	-1	-1	0	0	-1	-1	1	-1	0	-6	2	-1	-3	-4	0

0	0.667	clarinet	air, low, long, cresc.-dim.	1	0	1	1	-1	0	-1	-1	0	-1	0	-1	1	1	0	-4	4	2	-2	-3	3
-2	0.916	clarinet	airy, accented, short	1	1	0	0	0	0	0	0	0	-2	-1	1	-1	1	-2	-2	0	-2	0	-1	-1
-6	0.907	clarinet	airy, low	1	0	0	0	-1	1	-1	1	0	-1	-2	-1	-1	0	-2	-4	-2	-4	-2	-4	-2
-4	0.862	clarinet	airy, low, stacc., pp	0	0	-2	0	0	0	0	0	-1	-1	-1	2	-1	-1	1	-3	-1	-5	1	-3	-1
-9	1.573	clarinet	bisb. ord.	-1	0	1	-2	-1	-2	-1	-2	1	2	-1	-1	-1	1	-2	-4	-5	-5	-4	-2	-7
8	0.649	clarinet	fast sequence of key clicks from high to low keys, mf, no pitch	1	0	2	0	1	0	0	0	1	2	0	0	1	1	-1	6	2	8	0	4	4
-6	1.440	clarinet	flz. ord., mf, middle register	-1	0	0	0	-1	-1	-1	1	2	2	-2	-1	-1	-1	-2	-1	-5	-4	-2	-2	-4
0	1.600	clarinet	flz., air only	1	1	-1	1	-1	1	-1	-1	2	2	-2	-1	1	-1	-1	-2	2	4	-4	-3	3
1	1.129	clarinet	flz., airy low pitch	1	0	0	0	-1	1	-1	1	2	2	-1	-1	-1	0	-1	2	-1	2	-1	0	1
-3	0.827	clarinet	flz.., fast scale upwards, pp, cresc.	0	1	1	0	-1	-1	-1	-1	2	0	-1	-1	0	0	-1	-3	0	0	-3	-3	0
3	0.827	clarinet	key clicks (continuous)	1	-1	-1	0	0	0	0	0	0	2	0	0	2	1	-1	1	2	3	0	2	1
-5	1.556	clarinet	legato bisb. & gliss.	0	0	2	-2	1	-2	-1	-2	0	0	2	-1	0	-1	-1	-1	-4	-4	-1	-1	-4
-17	0.916	clarinet	low register ord. ppp	-1	-2	-1	-1	-1	-2	-1	-2	-1	-1	-2	-1	-1	-2	2	-12	-5	-12	-5	-11	-6
-7	1.182	clarinet	Multiphonic (Zubel: "freely chosen for the dynamic")	1	-1	0	-1	-2	-1	-1	-1	0	-2	0	-1	2	1	-1	-8	1	-5	-2	-6	-1
-23	0.249	clarinet	ord., non vibr.	-1	-2	-2	-2	-1	-2	-2	-2	-1	-1	-2	-1	-1	-2	-1	-14	-9	-18	-5	-12	-11
-12	0.427	clarinet	ord., pp	0	0	0	0	-1	-1	-1	-1	-1	-1	-2	-1	-1	0	-2	-9	-3	-8	-4	-6	-6
-1	0.862	clarinet	ord., pp, fast scale upwards, legato	0	1	1	0	-1	-1	0	-1	2	0	-1	-1	0	1	-1	-2	1	2	-3	-1	0
-9	1.973	clarinet	overblow, unstable highest register (held)	0	-2	-2	-2	1	-1	1	-2	-2	-2	1	-1	-1	1	2	-7	-2	-7	-2	-2	-7
-9	0.773	clarinet	short low, ppp	0	-2	-2	0	-1	-1	0	-1	0	-1	-1	1	-1	-1	1	-6	-3	-8	-1	-7	-2
-1	0.596	clarinet	slap, f, middle register	0	0	0	0	-1	0	0	0	0	0	1	1	-1	1	-2	1	-2	-3	2	1	-2
-6	1.440	clarinet	squeak (short, high)	0	-2	-2	-2	-2	0	0	0	0	0	1	2	-1	-1	1	-1	-5	-9	3	-4	-2

0	0.667	clarinet	stacc. soffio bisb. "chiavi alte dei trilli" (mid-high)	0	1	1	0	0	0	1	0	0	0	0	1	-1	-1	-2	3	-3	-1	1	1	-1
7	1.582	clarinet	trem. between two air sounds	2	1	0	0	2	-1	2	-1	2	2	-1	-1	1	0	-1	4	3	10	-3	5	2
-6	1.573	bass clarinet	fast regular bisb. trill, high register	-1	-1	1	-1	-1	-2	-1	-2	1	2	-1	-1	-1	0	2	-4	-2	-2	-4	-4	-2
-8	1.849	bass clarinet	fast regular trill, high register	0	-1	1	-1	-1	-2	-2	-2	1	2	-1	-1	-1	-2	2	-5	-3	-4	-4	-7	-1
7	0.782	bass clarinet	irregular key clicks, active	1	0	0	0	0	0	0	0	2	2	0	0	2	1	-1	4	3	7	0	3	4
2	0.916	bass clarinet	M slap tongue	0	0	-1	-2	0	0	0	0	0	1	1	2	-1	1	1	3	-1	-1	3	3	-1
-8	0.782	bass clarinet	Multiphonic f#-c-g < >. layers overlapping with both bass clarinets	0	-1	0	0	-2	-1	-1	-2	0	-1	0	-1	1	1	-1	-8	0	-5	-3	-6	-2
3	0.427	bass clarinet	slap tongue	1	0	0	0	-1	0	0	0	0	0	1	1	-1	1	1	1	2	1	2	1	2
-2	1.316	bass clarinet	soffio, low and mid reg.	2	0	0	0	-1	1	-1	1	-1	-2	-2	-1	1	0	1	-6	4	0	-2	-5	3
-5	1.022	contrabass-clarinet	1 stacc. overblown pitch, ff	-1	-1	-2	0	0	0	0	0	0	-2	2	0	-1	-1	1	-2	-3	-7	2	-2	-3
7	1.582	contrabass-clarinet	flz., slightly airy, low, rapidly changing fingerings, legato, p	2	0	1	0	2	-1	2	1	2	2	0	-1	-1	-1	-1	8	-1	7	0	6	1
9	0.773	contrabass-clarinet	keyclicks, rapid, continuous	2	0	1	0	1	0	0	0	2	2	0	0	1	1	-1	6	3	9	0	4	5
2	1.049	contrabass-clarinet	low, aggressive, fanatic, intoxicated murmur, through instrument	1	0	0	0	1	-1	2	-1	0	0	2	-1	-1	-1	1	2	0	2	0	3	-1
9	1.307	contrabass-clarinet	noise through instrument, with key clicks and voice (ad lib.), fff	2	1	1	0	1	0	0	0	2	2	2	-2	1	0	-1	6	3	9	0	6	3
7	1.982	contrabass-clarinet	noise with voice (scream) with continuous key clicks [freely shout vowels into instrument while changing fingerings	0	0	2	0	2	-1	2	1	2	-1	2	-1	-2	-1	2	8	-1	5	2	5	2
0	0.533	bassoon	"pseudo-slap" by hitting the bocal on instrument without reed (cork opening) by hand, p	0	0	2	0	0	0	0	0	0	-1	-1	0	-1	1	0	0	0	1	-1	-1	1
0	1.067	bassoon	bocal (without reed or rest of instrument), air, high overtones by overblowing	0	0	2	0	2	-1	-2	-1	0	0	0	-1	1	0	0	-1	1	2	-2	-1	1
-8	1.316	bassoon	breathe out through instrument and bocal without reed (low, non-fork fingerings)	1	1	-2	1	-1	-2	-1	-2	0	0	-2	-1	1	-1	0	-11	3	-3	-5	-6	-2
1	1.396	bassoon	flz. air only, low	1	1	0	0	-1	1	-1	-1	2	2	-2	0	1	-1	-1	0	1	4	-3	-3	4
-6	1.440	bassoon	legato bisb. & gliss.	1	0	1	-2	1	-2	-1	-2	0	0	2	-1	-1	-1	-1	-2	-4	-5	-1	-1	-5
-8	0.782	bassoon	multiphonic (not particularly beating), ppp	1	0	0	0	-2	-1	-1	-2	0	-1	0	-1	1	-1	-1	-8	0	-5	-3	-7	-1

-23	0.249	bassoon	ord., mp, minimal vibr.	-1	-1	-2	-2	-1	-1	-1	-2	-2	-2	-2	-1	-2	-2	-1	-14	-9	-18	-5	-11	-12
-23	0.382	bassoon	ord., pp	0	-2	-2	-2	-1	-1	-1	-2	-2	-2	-2	-1	-2	-2	-1	-14	-9	-18	-5	-12	-11
-7	1.316	bassoon	sub-range fundament multiphonic, f	1	0	0	0	-2	-1	-1	-2	0	-1	1	-1	-2	-1	2	-7	0	-5	-2	-6	-1
1	1.129	bassoon	tongue on bocal	-1	-1	-1	0	0	-1	1	-1	1	2	-1	2	1	0	0	2	-1	1	0	0	1
-10	1.022	bassoon	without reed, blow into bocal with instrument, inhale or exhale, tight (normal) embouchure, (low,	1	0	-2	0	-1	-2	-1	-2	0	0	-2	-1	1	-1	0	-11	1	-5	-5	-7	-3
-21	0.240	contrabassoon / contraforte	ord., mp, minimal vibr.	-1	-2	-2	-2	-1	-1	-1	-2	-1	-1	-2	-1	-1	-2	-1	-12	-9	-16	-5	-11	-10
-9	1.173	contrabassoon / contraforte	without reed, blow into bocal with instrument, inhale or exhale, overblown overtone ("stable,	1	0	-2	1	-1	-2	-1	-2	0	0	-2	-1	1	-1	0	-11	2	-4	-5	-7	-2
-10	1.289	tenor saxophone	gliss.,mp cresc., middle register	0	0	1	-2	0	-1	2	-2	-1	-2	0	-1	-2	-1	-1	-4	-6	-7	-3	-3	-7
-11	0.996	tenor saxophone	multiphonic, middle-high, (steady components) not consonant, p	0	-1	-2	-1	-2	-1	-1	-1	-1	-1	-1	-1	2	1	-1	-11	0	-8	-3	-6	-5
-10	1.156	tenor saxophone	multiphonic, middle-low, (steady components), not consonant, p	1	-1	-2	-1	-2	-1	-1	-1	-1	-1	-1	-1	2	1	-1	-11	1	-7	-3	-6	-4
-20	0.622	tenor saxophone	ord., low. mf	-1	-1	-2	-2	-1	-1	-1	-2	-1	-2	-2	-1	-2	-2	1	-13	-7	-15	-5	-11	-9
-7	1.849	tenor saxophone	rapid pitches, f	0	0	-2	-2	0	-1	0	-2	1	2	2	0	-2	-1	-2	0	-7	-7	0	1	-8
2	0.649	tenor saxophone	slap tone, low, ff	-1	0	0	0	-1	0	0	0	0	0	1	1	-1	1	2	1	1	0	2	1	1
1	0.862	tenor saxophone	uncontrollable whistle tone while fundament pitch is audible	1	0	-1	-1	2	1	1	-1	0	0	0	0	-1	-1	1	2	-1	2	-1	1	0
-1	1.662	cb-recorder	exhaled trill (a minor third) pitch, low, ppp	2	0	-1	-1	1	-1	2	-2	1	2	0	-1	-1	-1	-1	1	-2	2	-3	2	-3
8	0.916	cb-recorder	airy exhale with moving filter, espirare "suono del vento" - chiudere le chiavi della mano destra e	2	1	0	0	2	0	2	1	0	1	0	-1	1	0	-1	5	3	8	0	7	1
-3	1.093	cb-recorder	airy pitch exhale with moving filter, espirare "suono del vento" - chiudere le chiavi della mano	1	0	0	1	0	-1	2	-2	0	-1	-1	-1	1	-1	-1	-4	1	1	-4	-3	0
-4	0.996	cb-recorder	airy pitch inhale "inspirare"	1	1	0	1	-1	0	-1	-1	-1	-1	-1	-1	2	-1	-1	-7	3	-1	-3	-5	1
-5	0.889	cb-recorder	articulated narrow glissando downwards by going from open to closed aperture, airy, p	0	0	-1	-1	0	-1	0	-1	1	2	-1	0	-1	0	-2	-1	-4	-3	-2	0	-5
1	1.529	cb-recorder	exhaled trill (a minor third or a microtonally narrow minor third), airy pitch	2	1	-1	-1	1	-1	2	-1	1	2	0	-1	-1	-1	-1	2	-1	3	-2	4	-3
4	1.262	cb-recorder	flatterzunge & gliss., airy low pitch	1	1	-1	0	0	-1	0	-1	2	2	0	-1	-1	1	2	0	4	6	-2	3	1
5	1.422	cb-recorder	flatterzunge & narrow glissando downwards by going from open to closed aperture, airy, pp	1	2	1	0	1	1	0	-1	2	2	0	-1	-1	0	-2	5	0	7	-2	4	1
17	1.049	cb-recorder	flatterzunge & rapid trill, airy low pitch	2	2	2	1	1	-1	2	1	2	2	0	-1	1	1	2	8	9	17	0	9	8
0	1.600	cb-recorder	Flatterzunge with pitch	-1	0	-2	0	1	-1	2	1	2	2	-1	-1	-1	0	-1	3	-3	1	-1	5	-5

-1	1.796	cb-recorder	gliss. & trem. (a fifth), airy low breathy pitch	2	0	-1	0	-1	-1	0	-2	2	2	-1	-1	-1	-1	2	-3	2	3	-4	-3	2
-3	1.627	cb-recorder	gliss. & trem. (a fifth), with pitch	1	-1	-1	-1	-1	-1	0	-2	2	2	0	-1	-1	-1	2	-2	-1	0	-3	-3	0
3	0.560	cb-recorder	inhaled constant pitch, tip of tongue, fast short attacks	1	0	0	0	0	0	0	0	1	2	0	0	1	-1	-1	3	0	3	0	1	2
7	1.449	cb-recorder	inhaled trill (a minor third), not particularly pitched	2	-1	-1	1	2	1	2	-1	1	2	0	-1	1	-1	0	5	2	9	-2	3	4
-5	0.889	cb-recorder	narrow glissando downwards by diminishing embouchure pressure to minimum, high register, "calando di fiato"	0	0	-1	0	0	-1	1	-2	-1	-1	-1	0	-1	0	2	-6	1	-2	-3	-3	-2
11	1.396	cb-recorder	overblown harmonics " gliss." up and down, simultaneously tremolo fingerings, mp	0	2	2	0	1	-1	2	1	2	2	0	-1	-1	0	2	8	3	11	0	8	3
7	1.049	cb-recorder	pitched glissando (up) of overblown harmonics, tip of tongue	1	0	1	0	1	-1	2	0	1	2	0	0	-1	-1	2	6	1	7	0	4	3
4	0.862	cb-recorder	play (low) and hum in unison, with vibrato	0	0	1	0	1	-1	2	1	0	0	0	-1	-1	0	2	3	1	4	0	4	0
1	0.996	cb-recorder	play and hum in unison, without vibrato	0	-1	0	0	0	-1	2	1	0	0	-1	-1	-1	1	2	0	1	2	-1	2	-1
-4	0.729	cb-recorder	play and hum a minor second apart, without vibrato	1	0	-2	0	-1	0	-1	1	0	1	0	-1	0	-1	-1	-3	-1	-4	0	-1	-3
-9	1.307	cb-recorder	play and hum above at a blending interval (a harmonic), p	0	-1	-2	-2	-1	1	2	1	-1	-1	0	-1	-2	-1	-1	-2	-7	-9	0	-1	-8
-3	0.693	cb-recorder	play with airhole completely closed, high descending glissando with the rush of air (Romitelli' s marking * probably indicates underpressure)	0	-1	1	-1	0	-1	0	0	0	-1	0	0	-1	-1	2	-1	-2	-3	0	-3	0
2	0.516	cb-recorder	slap, very low register, f	0	0	0	0	0	0	0	0	0	0	-1	1	-1	1	2	0	2	2	0	0	2
-2	0.649	cb-recorder	sweeping long sound, gradually open aperture to create descending harmonics, natural accent occurs, " aprire gradualmente il labium per produrre degli armonici discendenti"	0	0	1	-1	1	-1	1	0	-1	1	-1	0	-1	-1	0	1	-3	-1	-1	1	-3
4	1.396	cb-recorder	trem. (a fifth), low register, flatterzunge, f	2	1	-1	0	1	-1	2	1	1	2	0	-1	-1	-1	-1	4	0	4	0	6	-2
-20	0.356	ocarina	ord.	-1	-2	-2	0	-1	-1	-1	-1	-1	-2	-2	-1	-1	-2	-2	-12	-8	-16	-4	-11	-9
2	0.916	ob. / cl. / fg.	air suck	0	1	0	1	1	-1	-1	-1	0	1	0	-1	2	1	-1	-2	4	4	-2	2	0
3	0.827	cl., bcl., ob. fg.	key clicks (continuous)	1	-1	-1	0	0	0	0	0	0	2	0	0	2	1	-1	1	2	3	0	2	1
-12	1.627	bfl. & cl. as a	low register ord. ppp	0	-1	-1	0	-1	2	-1	-2	-1	-1	-2	-2	-2	-2	2	-9	-3	-6	-6	-10	-2
-2	0.649	ob. / fg.	stacc. on bocal	0	0	0	0	-1	-1	0	0	0	2	-1	-1	1	0	-1	-2	0	0	-2	0	-2
9	0.773	2bfl + 1fl.	tongue ram + air accent "t"	0	0	2	0	2	0	0	0	0	2	0	2	1	0	0	8	1	7	2	4	5

Brass

noisiness total	TIV	instrument	sound / playing mode	Br	Di	Afr	Wb	Fr	Ifc	Dsb	Idc	Ca	Pa	Ed	Lm	Inh	Ihc	Er	Temp	NTemp	Freq	NFreq	Amp	NAmp
-2	0.649	brass (generally)	blow towards the mouthpiece from a distance of ca. 5 cm	0	0	0	1	1	-1	-1	-2	0	0	0	0	-1	1	0	-3	1	0	-2	-1	-1
-4	1.129	horn	air	1	1	-1	0	-1	-1	-1	-2	0	-1	-1	-1	1	2	0	-9	5	0	-4	-3	-1
-4	0.729	horn	air noise, closed, ppppp	1	1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	1	1	0	-8	4	-1	-3	-3	-1
2	1.182	horn	air noise, gliss. with mouth cavity, closed, pppp	1	1	2	0	0	-1	2	-1	-1	-1	-1	-1	1	1	0	-2	4	5	-3	1	1
9	1.173	horn	air noise, move all valves (inhale or exhale)	1	0	2	0	1	-1	2	-1	1	2	0	-1	2	1	0	5	4	11	-2	5	4
-6	0.640	horn	air, all valves open (inhale or exhale)	0	1	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	0	-8	2	-3	-3	-3	-3
3	1.627	horn	air, cresc., long	0	1	2	1	0	1	0	-2	-1	-2	0	-1	2	2	0	-3	6	6	-3	-1	4
-5	0.489	horn	cor. stopped, short, pp	0	0	0	-1	0	0	0	-1	-1	1	-1	1	-1	-1	-1	-1	-4	-4	-1	-2	-3
-24	0.240	horn	ord.	-1	-2	-2	-2	-1	-1	-1	-2	-2	-2	-2	-1	-2	-2	-1	-14	-10	-19	-5	-12	-12
-16	0.862	horn	ord., fff	-1	0	0	0	-1	-2	-2	-2	-1	-2	1	-1	-1	-2	-2	-10	-6	-14	-2	-8	-8
-23	0.249	horn	ord., mid register, ff	-1	-1	-2	-2	-1	-1	-1	-2	-2	-2	-2	-1	-2	-2	-1	-14	-9	-18	-5	-11	-12
-23	0.382	horn	ord., mid register, pp	0	-2	-2	-2	-1	-1	-1	-2	-2	-2	-2	-1	-2	-2	-1	-14	-9	-18	-5	-12	-11
-16	0.329	horn	straight mute	-1	-1	-2	-1	-1	-1	0	-1	0	-1	-2	-1	-1	-2	-1	-9	-7	-12	-4	-8	-8
-2	1.716	trombone	air flz.	2	1	-1	1	-1	-1	-1	-2	2	2	-1	-1	-1	-1	0	-4	2	2	-4	-3	1
-1	0.996	trombone	air wawa descresc.	1	0	0	0	-1	-1	-1	-1	0	-1	0	-1	2	2	0	-6	5	1	-2	-2	1
-5	0.622	trombone	air, all valves open (inhale or exhale), mf, short	0	1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	1	1	0	-8	3	-2	-3	-3	-2
3	1.227	trombone	air, cresc., long	0	1	2	1	0	1	0	-1	-1	-2	0	-1	2	1	0	-2	5	5	-2	-1	4
-15	0.400	trombone	con sordino (plunger), mf, mid-low register	0	-1	-2	0	-2	-1	-1	-1	0	-1	-2	-1	-1	-1	-1	-11	-4	-11	-4	-9	-6
-7	1.316	trombone	flz. ord.	-2	-1	-1	-1	-1	-1	0	1	2	2	-1	-1	-1	-1	-1	0	-7	-6	-1	-1	-6
-7	0.516	trombone	harmon mute, air, processes between closed and open, pp	1	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	1	0	-1	-8	1	-4	-3	-5	-2
-16	0.329	trombone	harmon mute, closed, mp	0	-1	-2	-1	-1	-1	-2	-1	-1	0	-1	-1	-1	-1	-2	-10	-6	-13	-3	-7	-9
-5	1.289	trombone	harmon mute, flz.	0	0	-2	-1	-1	-1	0	1	2	2	-1	-1	-1	-1	-1	-1	-4	-4	-1	0	-5
2	1.316	trombone	harmon mute, flz., air	1	1	0	1	-1	-1	0	-2	2	2	0	-1	1	-1	0	-1	3	5	-3	-1	3

-23	0.382	trombone	ord.	0	-2	-2	-2	-2	-1	-1	-2	-2	-2	-2	-1	-2	-1	-1	-15	-8	-18	-5	-12	-11
-17	0.782	trombone	ord., fff	-1	-1	0	0	-1	-2	-2	-2	-1	-2	1	-1	-1	-2	-2	-10	-7	-15	-2	-9	-8
-1	0.862	trombone	unpitched air with reversed mouthpiece held on instrument (at zero distance), with microphone amplified into a piano resonance	0	1	0	0	-1	0	-1	-1	-1	1	-1	-1	2	1	0	-5	4	2	-3	-1	0
-19	0.329	trombone	with harmon mute	-1	-1	-2	-1	-2	-1	-1	-1	0	-2	-2	-1	-1	-2	-1	-12	-7	-15	-4	-11	-8
5	1.422	trombone tuba	stacc. pop at mouthpiece	0	0	-1	1	-2	-2	0	0	1	2	1	2	1	1	1	1	4	2	3	2	3
-7	0.382	trumpet	wawa ord. descresc.	0	0	0	0	-1	-1	-1	-1	0	-1	-1	-1	1	0	-1	-7	0	-4	-3	-5	-2
-4	0.862	trumpet	air, all valves open (inhale or exhale)	0	1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	1	2	0	-8	4	-1	-3	-2	-2
2	1.049	trumpet	air, cresc., long	0	1	2	1	0	1	0	-1	-1	-2	0	-1	1	1	0	-2	4	4	-2	-1	3
7	0.649	trumpet	bright air sound, low, short, as loud as possible	2	1	0	1	0	0	0	0	0	-1	0	2	1	1	0	1	6	5	2	1	6
1	1.129	trumpet	fast repetition double tongued, unpitched articulated air, bell in the air	0	-1	1	0	-1	-1	0	-1	1	2	-1	-1	2	1	0	-1	2	4	-3	-1	2
-13	0.516	trumpet	harmon mute f2 stacc	-1	0	-1	-2	-1	-1	-2	-1	-1	-1	0	-1	1	-1	-1	-9	-4	-11	-2	-6	-7
8	1.449	trumpet	harmon mute, closed with hand, air noise, gliss. using mouth cavity, move all valves	1	-1	2	0	2	-1	2	1	0	0	-1	-1	2	2	0	4	4	9	-1	5	3
-12	0.427	trumpet	harmon mute, closed, pp	0	-1	0	0	-1	-1	-2	-1	-1	0	0	-1	-1	-1	-2	-7	-5	-10	-2	-6	-6
8	1.582	trumpet	harmon mute, open, air noise, gliss. using mouth cavity, move all valves	1	-1	2	0	2	-1	2	-1	1	2	-1	-1	2	1	0	5	3	11	-3	4	4
-1	0.996	trumpet	harmon, air, closed, pp	0	-1	0	0	1	-1	2	-1	0	0	-1	-1	2	-1	0	-1	0	2	-3	-1	0
-9	0.773	trumpet	low, short pitch, ppp	-1	0	-2	-2	0	0	0	-1	-1	-1	-1	1	-1	-1	1	-5	-4	-8	-1	-4	-5
-19	0.862	trumpet	ord., fff	-1	-2	0	0	-1	-2	-2	-2	-1	-2	1	-1	-2	-2	-2	-10	-9	-17	-2	-10	-9
-6	0.907	tuba	air, all valves open	1	1	0	1	-1	-1	-1	-1	-1	-2	-1	-1	1	-1	0	-9	3	-3	-3	-6	0
-4	0.862	tuba	air, all valves open (inhale or exhale), mf, short	0	2	0	0	-1	-1	-1	-1	-1	-1	-1	-1	1	1	0	-8	4	-1	-3	-2	-2
4	1.396	tuba	air, cresc., long	0	2	2	1	0	1	0	-1	-1	-2	0	-1	2	1	0	-2	6	6	-2	0	4
-17	0.916	tuba	ord., fff	0	-2	0	0	-1	-2	-2	-2	-1	-2	1	-1	-1	-2	-2	-10	-7	-15	-2	-10	-7
10	1.156	tuba	air noise, move all valves, p, closed with hand	1	0	2	1	1	-1	2	-1	1	2	0	-1	2	1	0	5	5	12	-2	5	5

Percussion and objects

noisiness total	TIV	instrument	sound / playing mode	Br	Di	Afr	Wb	Fr	Ifc	Dsb	Idc	Ca	Pa	Ed	Lm	Inh	Ihc	Er	Temp	NTemp	Freq	NFreq	Amp	NAmp
8	0.649	"Aufzieh klang"	with a large metal chain over a piece of metal	0	1	0	1	1	-1	1	-1	1	2	1	0	1	1	0	4	4	8	0	6	2
-5	0.889	2 styrofoam	rub vertically slowly, ppp	0	1	0	-1	-1	0	-1	-1	0	0	-1	-2	2	-1	0	-6	1	-1	-4	-4	-1
6	1.307	aluminium foil	rub very slowly, perforated sound, ppp	1	0	1	0	1	0	2	-1	1	2	0	-2	2	-1	0	4	2	9	-3	3	3
9	0.773	bamboo tree	hit, l.v., mf	0	1	2	0	1	0	2	0	1	2	-1	0	1	0	0	7	2	10	-1	5	4
7	1.049	bass drum	"FSHB" with inner part of hand and fingertips, rub with both hands, gliss.	1	0	1	1	1	1	2	-1	0	1	0	-2	2	0	0	3	4	10	-3	3	4
17	1.182	bass drum	with inner part of hand and fingertips "FSHB" ("mit dem Handballen und den Fingerspitzen") rub with both hands, two pitches gliss.	2	2	1	1	1	1	2	2	2	2	0	-2	2	1	0	9	8	17	0	10	7
-4	0.462	bongos	ord., mf	0	0	-2	-1	0	0	0	0	0	1	0	0	-1	-1	0	-1	-3	-4	0	0	-4
3	0.960	cabasa	ord. individual attacks	0	1	0	1	-1	-1	-1	-1	1	1	1	-1	2	1	0	-2	5	4	-1	1	2
7	0.649	chinese cymbal	chinese cymbal, handheld, hit, p and abrupt percussive damping	1	1	1	0	0	0	2	0	0	1	0	2	0	-1	0	6	1	5	2	3	4
-1	0.729	chinese drum (mediu	wooden beater on skin	1	0	-2	-1	0	1	1	0	0	1	0	0	-1	-1	0	1	-2	-1	0	1	-2
1	1.529	clicker	down - up	1	0	-2	-1	-1	-1	0	0	0	2	2	2	-1	-1	1	2	-1	-3	4	2	-1
-3	1.227	cowbell, almglocken	hit, mf, l.v.	0	-2	-2	0	1	-1	1	0	0	1	-1	2	-1	-1	0	1	-4	-4	1	-1	-2
-9	1.573	crotales	arco l.v., high, ff	-2	-2	-2	0	-2	0	1	-2	0	-1	2	0	-1	-1	1	-4	-5	-9	0	-5	-4
2	1.182	crotales	metal beater hit, l.v.	-2	0	0	0	-1	0	1	-1	-1	1	2	0	1	0	2	1	1	1	1	2	0
7	0.249	cymbal	arco, one bowing l.v., mf	0	1	1	1	1	0	1	0	0	0	0	0	1	1	0	3	4	7	0	4	3
15	1.333	cymbal	arco, trem.	1	2	2	2	0	0	1	1	2	2	0	-2	2	2	0	6	9	16	-1	8	7
6	2.373	cymbal	high pressured bowing	-2	0	-2	0	0	0	2	-1	2	2	2	-2	2	1	2	3	3	7	-1	6	0
7	1.049	cymbal	ord., 1 mallet hit l.v., mf	2	1	0	1	1	-1	1	2	0	-1	0	0	2	-1	0	2	5	5	2	3	4
9	1.307	cymbal	trem., soft mallets, (soft rapid) damping regularly with flesh of fingers	2	1	1	0	2	0	2	-1	2	2	0	0	0	-1	-1	8	1	10	-1	5	4
7	1.849	cymbal	ord, mallets trem. ff	2	1	0	0	-1	1	1	-1	2	2	2	-2	2	-1	-1	4	3	8	-1	3	4

16	0.862	cymbal	with sizzle, mallets trem. ff	1	1	0	1	2	1	1	2	2	2	2	0	2	-1	0	12	4	12	4	9	7
8	0.649	cymbal	with sizzle, soft mallet, 1 hit, pp, l.v.	1	0	0	0	0	0	1	2	1	1	-1	0	2	1	0	4	4	7	1	4	4
11	1.396	cymbal	with sizzle, soft mallets, trem., pp	1	0	1	0	1	1	2	2	2	2	0	-2	2	-1	0	9	2	11	0	6	5
-10	0.889	flexatone	arco, almost non vibr., l.v., p	1	-2	-2	0	-1	0	1	-2	-1	-1	-1	0	-1	-1	0	-7	-3	-7	-3	-7	-3
10	1.156	flowerpaper (flower wrap paper)	ppp, rub (fast or slow)	1	1	0	0	1	0	2	2	1	2	0	-2	2	0	0	6	4	10	0	8	2
4	0.329	frame drum	fingertips ("FS") hit, mf	1	0	1	0	1	0	1	0	0	0	0	0	1	-1	0	3	1	4	0	1	3
7	1.316	frame drum (50 cm)	rub with inner part of hand and fingertips change between edge and middle, ppp ("mit dem Handballen und den Fingerspitzen")	2	1	-1	1	1	1	2	-1	0	0	0	-2	2	1	0	0	7	10	-3	4	3
1	1.129	frog guiro	wipe, with wooden resonant stick, mf	0	0	0	-1	0	-1	2	-1	2	2	0	0	-1	-1	0	4	-3	2	-1	2	-1
-1	0.596	glass bottle	blow air	1	1	0	-1	0	0	1	-1	0	0	-1	-1	1	-1	0	-2	1	2	-3	-1	0
-2	0.649	glass can	one hit inside with wooden mallet, mf	0	0	1	0	0	0	1	0	-2	1	-1	0	-1	-1	0	0	-2	-1	-1	0	-2
12	1.360	glass chimes (circular)	hit & l.v.	1	2	2	-2	1	2	1	-1	1	2	2	0	1	0	0	10	2	11	1	7	5
8	0.916	gong (medium	soft beater, l.v., ff	0	2	1	0	1	1	1	0	0	-2	2	0	1	1	0	4	4	6	2	5	3
1	0.729	gong (medium register)	soft beater, l.v., p	1	1	0	-1	1	1	1	0	0	-2	0	0	-1	0	0	1	0	1	0	1	0
7	1.182	gran cassa	gran cassa trem. / soft mallets	0	2	1	1	1	1	1	-1	1	0	-1	-2	2	1	0	1	6	11	-4	3	4
2	1.449	gran cassa	muted, hit with mallet	-1	2	-1	1	0	1	1	-1	-1	1	-2	-1	2	1	0	-3	5	6	-4	2	0
6	0.640	gran cassa	ord., 1 soft mallet hit, l.v., mf	0	2	0	0	0	0	1	0	0	1	-1	0	2	1	0	1	5	7	-1	4	2
7	1.182	gran cassa	trem. / soft mallets	0	2	1	1	1	1	1	-1	1	0	-1	-2	2	1	0	1	6	11	-4	3	4
-9	0.773	gran cassa	wipe with styrofoam	0	1	-1	1	0	-1	-1	-2	0	-1	-1	-2	-1	-1	0	-9	0	-4	-5	-5	-4
7	1.182	Greaseproof paper	("Butterbrotfolie") ppp, rub	1	0	1	0	1	0	2	-1	1	2	0	-2	2	0	0	4	3	10	-3	4	3
-4	0.996	guero	ord., one wipe	-1	0	-1	1	1	-2	-1	-1	1	1	0	1	-1	-1	-1	-1	-3	-4	0	-1	-3

5	1.022	jingle bells set (big, complex sound)	drop once supported by string, l.v.	0	0	0	-1	2	0	2	0	1	0	-1	2	1	-1	0	6	-1	4	1	2	3
3	1.093	large drum	large drum with brushes [" Fell mit Bürste gestrichen"]	0	0	1	1	0	-1	2	-1	0	0	0	-2	2	1	0	-1	4	6	-3	2	1
14	0.729	large spring drum	draw, l.v., ff	2	2	2	0	1	1	1	0	0	1	2	0	2	0	0	8	6	12	2	7	7
-4	0.862	log drum	log drum	0	-1	-1	0	-1	-2	-1	0	-1	1	-1	1	1	1	0	-5	1	-4	0	-2	-2
8	1.449	marimba	2 hands, two glissandos simultaneously with fingers, palms, or nails, ppp	1	1	2	-1	2	1	2	1	2	0	0	-2	0	0	-1	8	0	9	-1	6	2
-8	1.316	marimba	ord. hit, ff, l.v., soft mallet	-1	-1	0	-1	1	-2	1	-2	-1	0	2	0	-1	-2	-1	-1	-7	-8	0	-1	-7
-1	0.729	metal plate	yarn beater, l.v., p...mf	-1	1	0	-1	1	1	1	0	0	-2	0	0	-1	0	0	1	-2	-1	0	1	-2
14	0.996	metallic washboard	wipe with block of wood, f	0	0	1	1	2	1	2	-1	2	2	2	0	2	0	0	11	3	13	1	7	7
9	1.173	ocean drum	rotate slowly (ord.), pp	2	1	0	1	1	1	2	-1	1	0	0	-2	2	1	0	2	7	12	-3	4	5
0	0.667	perc.	hit cymbal on timpani, resonate with pedal	0	1	-1	0	1	-1	1	-1	0	0	0	-1	1	1	-1	-2	2	2	-2	3	-3
4	0.596	plate bells	at edge, leather-covered mallet, l.v., ppp	1	0	0	1	0	1	1	0	0	1	-2	0	1	0	0	1	3	6	-2	0	4
2	0.649	plate bells	in the middle, leather-covered mallet, l.v., pp	1	1	0	0	0	1	1	0	0	1	-2	0	-1	0	0	1	1	4	-2	1	1
17	0.649	rainstick	turn, ord., f	1	2	1	0	2	0	2	2	1	2	2	0	1	1	0	12	5	13	4	13	4
6	1.707	ratchet	ord., continuous, medium speed, f	0	1	0	0	1	0	2	-2	2	2	2	-2	1	-1	0	5	1	8	-2	5	1
3	1.093	ratchet (high)	strongly suspended, ff	-1	0	0	0	1	0	0	-2	0	1	2	2	1	-1	0	4	-1	1	2	1	2
6	1.040	ratchet (low)	strongly suspended, ff	0	1	0	1	1	0	0	-2	0	1	2	2	1	-1	0	4	2	4	2	2	4
5	1.022	ratchet (medium)	strongly suspended, ff, one hit	0	1	0	0	1	0	0	-2	0	1	2	2	1	-1	0	4	1	3	2	2	3
-12	1.360	recorder	ord., non vibr., high, f	-1	-1	-2	-1	-1	-1	-1	-2	-2	-1	2	-1	-1	-1	2	-9	-3	-11	-1	-5	-7
10	0.756	round shaker with handle	shake once, mf	0	1	1	1	2	0	2	0	1	0	-1	0	2	1	0	5	5	11	-1	5	5
3	1.360	sandpaper blocks (semi-coarse)	rubbing, steady, slow, mf	1	1	1	1	0	1	-1	-1	2	0	-1	-2	2	-1	0	-1	4	7	-4	-3	6

11	0.596	shell tree	hit, l.v., mf	0	1	2	0	1	0	2	0	1	2	0	0	1	1	0	8 3	11 0	7 4
-4	1.129	siren whistle	f, ord. (let pitch fall with decay)	-1	0	-1	-1	0	-1	1	-2	0	1	2	-1	-1	-1	1	-1 -3	-3 -1	1 -5
3	0.960	skin with brush	wipe	1	0	0	1	1	-1	1	-1	1	1	0	-1	2	-1	-1	1 2	5 -2	1 2
17	1.449	snare dr.	superball wiping, snare on	0	2	2	1	2	0	2	2	2	2	2	-2	2	0	0	12 5	15 2	12 5
2	1.849	snare dr. trem.	trem.	0	1	-2	1	1	-1	-1	-1	2	2	1	-2	2	-1	0	-1 3	4 -2	2 0
9	0.640	snare drum	hit ff	0	0	0	1	0	0	0	0	0	1	2	2	2	1	0	5 4	5 4	4 5
7	1.449	spring coil	one hit with metal beater, l.v.	2	1	1	0	1	0	2	1	-1	-1	2	-2	1	-1	1	3 4	6 1	5 2
3	1.360	stirring xylophone	rotating hits with wooden mallet, mf	0	0	1	0	0	-1	-1	-1	2	2	2	-2	1	0	0	2 1	4 -1	2 1
0	0.933	tambourine	hit once (skin and jingles), pp...mf	0	1	-2	0	1	1	1	0	0	-2	-1	0	1	0	0	-2 2	1 -1	0 0
12	1.360	tambourine	trem. (jingles), mf	0	0	0	0	1	2	2	2	2	2	2	-2	1	0	0	11 1	10 2	9 3
7	0.649	tamtam	tamtam played ppp, short, l.v.	-1	2	0	0	1	1	1	1	0	1	0	-1	1	1	0	4 3	7 0	7 0
13	0.649	tamtam	metal beater hit on edge and l.v. mf	1	2	1	1	1	1	2	0	0	1	1	-1	2	1	0	6 7	13 0	8 5
14	1.129	tamtam	metal beater on edge trem. (continuous)	0	1	1	1	1	1	2	2	2	2	2	-2	1	0	0	11 3	12 2	10 4
15	0.667	tamtam	ord., ff	1	2	1	1	1	1	1	2	0	1	2	-1	2	1	0	8 7	12 3	10 5
8	0.516	tamtam	played ppp, short, l.v. (Sciarrino)	-1	2	0	0	1	1	1	1	0	1	0	0	1	1	0	5 3	7 1	7 1
14	0.462	tamtam	tamtam / metal beater hit on edge and l.v. mf	1	2	1	1	1	1	2	0	0	1	1	0	2	1	0	7 7	13 1	8 6
14	0.596	tamtam	tamtam / metal beater on edge	1	2	1	1	1	1	2	1	0	1	1	-1	2	1	0	7 7	13 1	9 5
7	0.649	tamtam	tamtam played pp (Sciarrino)	-1	2	0	0	1	1	1	1	0	1	0	-1	1	1	0	4 3	7 0	7 0
6	0.773	tamtam	tamtam played pp, damped soon	-1	2	1	0	1	0	0	0	0	1	0	2	1	-1	0	5 1	4 2	3 3
7	0.782	tamtam	with superball, l.v.	2	0	1	0	-1	1	2	1	0	1	0	0	-1	1	0	5 2	6 1	4 3
6	0.907	tamtam	with superball, l.v.	2	0	1	0	-1	1	2	1	0	1	0	-1	-1	1	0	4 2	6 0	4 2

12	0.827	thunder sheet, suspended	shaken shortly, l.v., f	2	0	1	0	2	1	1	-1	0	1	2	2	1	0	0	9	3	9	3	5	7
7	1.049	Tibetan bowl	wooden beater, hit once, l.v.	0	1	2	0	2	1	1	-1	-1	1	2	-1	0	0	0	6	1	7	0	6	1
7	0.382	timp.	*(Tibetan) bowl on timpani skin, arco*	1	0	2	0	1	0	1	0	0	1	0	0	1	0	0	5	2	7	0	3	4
11	1.262	timp.	rub low timpani with fingertips and inner part of both hands ("FSHB"), ppp	1	1	1	0	1	-1	2	2	2	2	0	-2	1	1	0	7	4	11	0	9	2
7	0.382	timp. & (Tibetan) bowl	(Tibetan) bowl on timpani skin, arco	1	0	2	0	1	0	1	0	0	1	0	0	1	0	0	5	2	7	0	3	4
-2	1.449	timpani	low trem., pp	0	1	1	0	-1	0	0	0	2	2	-2	-2	-1	-1	-1	0	-2	2	-4	-1	-1
3	2.160	timpani	low trill or tremolo, 2 or more pitches, pp	2	2	2	0	1	-1	0	0	2	2	-2	-2	-1	-1	-1	2	1	7	-4	2	1
7	1.049	timpani	soft beater, l.v., mf...ff	2	1	2	0	-1	0	1	0	-1	1	2	0	1	0	-1	4	3	5	2	4	3
3	0.960	timpani	timpani with brushes [" Fell mit Bürste gestrichen"]	0	1	1	1	0	-1	2	-1	0	0	0	-2	1	1	0	-1	4	6	-3	3	0
6	0.640	tomtom	hit with medium mallet, mf, l.v.	1	0	0	0	1	-1	1	-1	0	1	0	2	1	1	0	3	3	5	1	3	3
0	1.200	triangle	metal beater, l.v., mf...ff	-1	1	-2	-1	1	0	1	0	0	-2	2	0	1	0	0	0	0	-2	2	3	-3
-6	1.040	vibraphone	bow on middle register key, motor on, ped., l.v., switch motor off gradually	-1	-1	-2	0	1	0	2	0	-1	0	0	0	-1	-1	-2	0	-6	-6	0	1	-7
-7	1.049	vibraphone	bow on middle register key/bar, motor off, ped., l.v.	-1	-1	-2	0	0	0	2	0	-1	1	-1	0	-1	-1	-2	-1	-6	-6	-1	0	-7
-10	1.022	vibraphone	motor on, arco, 1 pitch, l.v. (by pedal)	-1	-2	-2	-1	0	0	2	-1	0	-1	-1	0	-1	0	-2	-3	-7	-8	-2	-3	-7
-5	1.022	vibraphone	motor on, arco, 2 pitches, l.v. (by pedal)	0	0	-2	-1	0	0	2	-1	0	-1	-1	0	0	1	-2	-3	-2	-3	-2	0	-5
-16	0.729	vibraphone	vibraphone, soft mallets, motor off, ped.	-1	-1	0	-2	-1	-2	1	-2	-2	0	-1	-1	-2	-1	-1	-8	-8	-12	-4	-5	-11
6	0.907	vibraslap	with hand, l.v.	1	0	-2	-1	0	1	1	0	1	1	2	0	1	1	0	4	2	4	2	5	1
15	0.933	waterphone (large)	arco on several metal bars, mf, l.v., turn slowly for resonance	1	1	2	0	2	0	2	2	2	2	0	0	1	1	-1	12	3	13	2	10	5
7	0.649	whip	f	0	1	0	1	0	0	0	0	0	1	2	1	2	-1	0	4	3	4	3	3	4
0	0.667	woodblocks	ord.	0	-1	-2	0	0	0	0	0	0	1	-1	1	1	1	0	-1	1	0	0	0	0
3	0.693	wooden table surface [Kante mit Holzstab]	soft hits with stick [low = Schaft, high = Spitze] , pp, followed by abrupt percussive damping	1	1	1	0	0	0	0	0	0	-1	-1	1	2	-1	0	0	3	3	0	-2	5

Plucked strings

noisiness total	TIV	instrument	sound / playing mode	Br	Di	Afr	Wb	Fr	Ifc	Dsb	Idc	Ca	Pa	Ed	Lm	Inh	Ihc	Er	Temp	NTemp	Freq	NFreq	Amp	NAmp
-6	1.040	e-guitar	gliss., mp, cresc. (by fader), low register	0	0	-1	-1	1	-1	2	-1	-1	-1	0	1	-2	-1	-1	-1	-5	-6	0	0	-6
4	1.129	e-guitar	high flageolet and whammy bar hit, l.v., mf	0	0	2	0	1	-1	2	0	1	2	-1	0	-1	0	-1	6	-2	5	-1	4	0
-6	1.440	e-guitar	high pitch repetition, pp	-1	-1	-2	-1	1	0	0	0	1	2	-1	-2	-2	-1	1	-1	-5	-3	-3	0	-6
6	0.773	e-guitar	hit strings lightly with palm, gliss. with bottle neck and with whammy bar, pp	2	0	2	0	1	-1	1	1	0	0	0	0	1	0	-1	4	2	5	1	3	3
1	0.729	e-guitar	muted half-flageolet pressure, ff, high	1	0	0	0	0	0	1	-1	0	-1	2	0	1	-1	-1	1	0	0	1	0	1
7	1.316	e-guitar	muted half-flageolet pressure, rapid irregular trem., ff, high	1	1	1	0	0	0	2	0	1	2	2	-2	1	-1	-1	6	1	7	0	6	1
1	0.996	e-guitar	muted heavily with palm above the bridge pick up, ff	1	0	1	1	0	0	1	-1	-1	-1	2	-1	1	-1	-1	0	1	1	0	0	1
-4	1.396	e-guitar	rapid pitches, some remain ringing, f	0	0	-2	0	0	-1	0	-2	0	2	2	0	-1	0	-2	-1	-3	-4	0	2	-6
-1	0.596	harp	(nonaccented) gliss. with the tuning key/fork metal part, along one string, accented decay	1	0	-1	0	0	-1	1	1	0	0	-1	1	-1	0	-1	0	-1	-2	1	1	-2
-11	0.462	harp	2 high flageolets, l.v., pp	-1	-1	-2	-1	-1	0	1	0	-1	-1	-1	0	-1	-1	-1	-5	-6	-10	-1	-4	-7
-20	0.756	harp	à table [Prés de la table]	-2	-2	-1	-1	-2	-2	0	-2	-1	-2	1	-1	-2	-1	-2	-10	-10	-18	-2	-8	-12
17	1.049	harp	cluster of four low strings, rattle and damp, ff	1	1	2	0	2	2	2	-1	1	2	2	1	2	1	-1	13	4	15	2	9	8
1	0.329	harp	fingertips ("FS"), one hit on wooden resonating table "auf den Holz des Resonanztisches" f or ff	0	0	1	-1	0	0	0	0	0	1	-1	0	1	0	0	1	0	2	-1	0	1
14	0.862	harp	gliss wide range, l.v. with pedal buzz	1	2	0	0	1	2	2	0	1	2	2	0	1	1	-1	10	4	12	2	10	4
3	0.427	harp	hit cluster of strings with fingertips and inner part of both hands ("HBFS"), while damped by other	1	0	1	0	1	0	0	0	0	0	-1	1	1	0	-1	2	1	3	0	0	3
2	0.249	harp	hit string (or narrow cluster of strings) and damp it with its upper neighbour string (Andre:	0	0	1	0	0	0	0	0	1	0	-1	0	1	0	0	1	1	3	-1	-1	3
-6	1.173	harp	low, two enharmonically unison neighbouring strings, l.v., ff	0	-1	-2	-1	0	-1	1	0	-2	1	2	0	-1	-1	-1	-1	-5	-8	2	2	-8
8	0.916	harp	one rapid swipe with hard credit card (or similar object) on strings, damped, ff	0	1	-1	1	0	0	2	-1	0	1	2	0	2	1	0	3	5	7	1	6	2
-15	0.933	harp	pitch alternation (c4 - d4)	-2	-2	-1	-1	0	-2	-1	-2	-1	-2	1	-1	-1	-1	1	-9	-6	-13	-2	-7	-8
-3	0.827	harp	up-down swipe with finger	0	0	-1	0	0	-1	1	-2	1	1	-1	0	1	-1	-1	-2	-1	0	-3	-2	-1

Other instrumental groupings

noisiness total	TIV	instrument	sound / playing mode	Br	Di	Afr	Wb	Fr	Ifc	Dsb	Idc	Ca	Pa	Ed	Lm	Inh	Ihc	Er	Temp	NTemp	Freq	NFreq	Amp	NAmp
5	0.756	water stream	(in Bauckholt)	1	0	0	0	1	1	1	1	1	1	0	-2	1	0	-1	4	1	6	-1	4	1
29	0.062	electronic	white noise	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	18	11	23	6	14	15
-30	0.000	electronic	sine tone	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-18	-12	-24	-6	-14	-16
-11	0.862	accordion	legato wide ff quintuplet figure based on seconds, unisons, sevenths and ninths	-1	0	-2	0	0	-1	0	-1	0	0	1	-2	-2	-2	-1	-5	-6	-9	-2	-2	-9
5	0.889	accordion	change to/from unison and microtonal 50 cent interval < >	0	0	1	0	0	1	-1	2	0	0	1	-2	1	1	1	2	3	4	1	3	2
10	0.622	accordion	button wipes (r.hand) linearly, mf	1	1	0	0	0	0	2	0	2	2	0	0	1	1	0	6	4	10	0	6	4
2	1.716	accordion	bellow shake (horizontal or with the corners of the instrument rhyhmically), one middle-register pitch, f	-1	-1	0	0	1	0	2	-1	2	2	2	0	-1	-1	-2	8	-6	1	1	4	-2
-8	1.049	accordion	acc. legato pp figure based on octaves, ninths, unisons, and seconds	1	-1	1	-2	1	-2	0	-1	0	0	0	-2	-1	-1	-1	-3	-5	-5	-3	-2	-6
-15	0.933	celesta	ord., low	0	-1	-2	-1	-2	-2	1	-1	-2	-2	-1	-1	-1	-1	1	-12	-3	-12	-3	-7	-8
2	2.116	organ	half-registered	1	2	1	0	-1	-2	-1	-2	1	-1	1	-2	2	2	1	-6	8	5	-3	0	2
3	0.293	pianoforte	up pedal accent (no shoe sound; closes pedal)	0	0	0	1	0	0	0	0	0	1	-1	1	1	0	0	1	2	3	0	0	3
-1	1.662	pianoforte	una corda, pp, pitch repetition, mid-register, ped.	1	1	-2	0	0	0	2	-2	1	2	0	0	-1	-1	-2	1	-2	1	-2	2	-3
-2	1.582	pianoforte	una corda, pp, pitch repetition, high register, ped.	0	1	-2	0	0	0	2	-2	1	2	0	0	-1	-1	-2	1	-3	0	-2	2	-4
2	1.182	pianoforte	two nearby glissandos on keys, 2 hands, middle-high register, mf	0	0	1	-2	0	-1	0	1	2	2	0	-1	0	1	-1	4	-2	2	0	4	-2
7	0.782	pianoforte	spoon on tuning pins, wipe/slide, f, non ped.	1	1	-1	1	0	-1	0	-1	1	1	2	0	1	1	1	1	6	6	1	4	3
9	1.307	pianoforte	spoon on tuning pins, wipe/slide, f, 1/2 ped.	2	1	0	1	1	1	2	-1	0	0	2	-2	2	0	0	3	6	10	-1	5	4
-7	1.049	pianoforte	slightly damped (by preparation), low, p	1	-2	-2	0	0	-1	0	-1	0	0	-1	2	-1	-1	-1	-3	-4	-7	0	-5	-2
2	1.582	pianoforte	slide rubber tyre on steel strings, resulting pitch around the 14th partial, with pedal, f	-1	-1	2	-2	0	-1	2	-1	0	0	2	1	1	-1	1	5	-3	0	2	1	1
6	1.173	pianoforte	slide coin (flat side) along a low string slowly, mf, pedal	2	1	1	1	1	-1	2	-1	0	0	0	-2	1	1	0	0	6	9	-3	4	2
-8	1.049	pianoforte	short string between tuning pin and agraffe (untuned part), pizz. with finger, l.v., mf	0	-1	-2	0	-1	-1	1	-2	-2	1	0	1	-1	-1	0	-5	-3	-7	-1	-3	-5

-9	0.907	pianoforte	short string between tuning pin and agraffe (untuned part), pizz. with finger, l.v., mf	0	-1	-2	0	-1	-1	1	-2	-2	1	0	0	-1	-1	0	-6	-3	-7	-2	-3	-6
-10	0.889	pianoforte	short string at back (untuned part), pizz. with finger, l.v., mf	-1	-1	-2	0	-1	-1	1	-2	-2	1	0	0	-1	-1	0	-6	-4	-8	-2	-3	-7
2	0.782	pianoforte	rub a spoon on tuning pins, mf, 1/2 ped.	1	0	0	0	1	1	0	-1	0	0	0	-2	2	0	0	-1	3	5	-3	0	2
8	0.782	pianoforte	press and hold middle register key, string prepared with light metal chain with small rings, mf	1	0	1	0	0	0	2	0	1	2	2	0	-1	0	0	8	0	6	2	6	2
9	0.640	pianoforte	press and hold low register key, string prepared with a sheet of paper on top, mf	0	1	1	1	1	0	2	0	1	2	1	0	-1	0	0	8	1	8	1	7	2
-2	1.582	pianoforte	pp, pitch repetition, mid-register	0	0	-2	0	1	0	2	-2	1	2	0	0	-1	-1	-2	2	-4	0	-2	2	-4
1	1.662	pianoforte	pp, pitch repetition, high register	-1	0	-2	0	1	0	2	-2	1	2	0	0	-1	-1	2	2	-1	3	-2	2	-1
12	0.960	pianoforte	Pedal accent, raise pedal slowly	1	1	0	2	1	2	1	2	-1	1	-1	0	1	2	0	5	7	11	1	7	5
-4	2.062	pianoforte	ord., rapid repetition of a pitch, with pedal, f	-1	0	-2	0	-1	0	2	-2	2	2	1	-2	-1	0	-2	0	-4	-1	-3	2	-6
-2	1.449	pianoforte	ord., high, short, fff, ped.	-1	0	-2	0	-2	-2	1	0	-1	1	1	0	1	0	2	-4	2	-3	1	1	-3
-15	2.133	pianoforte	ord., high, ff	-2	-1	-2	-2	-2	-2	1	-2	-2	-2	2	0	-1	-2	2	-9	-6	-15	0	-6	-9
-21	0.773	pianoforte	ord., held, without pedal, p...pp	-1	-1	-2	-2	-2	-2	1	-2	-2	-2	-1	0	-1	-2	-2	-12	-9	-18	-3	-9	-12
4	1.129	pianoforte	ord., gliss., mid-register, pp, cresc.	0	1	1	0	1	-1	2	-2	2	0	0	0	0	1	-1	3	1	6	-2	3	1
-3	1.493	pianoforte	ord., accented short attack, middle register, fff, Ped.	-1	1	0	-1	-1	-2	2	0	-2	-1	2	0	1	0	-1	-2	-1	-5	2	3	-6
-11	1.262	pianoforte	ord., accented short attack, fff, sostenuto Pedal held from earlier with selected resonating pitches	0	0	-2	-1	-1	-2	1	-1	-2	-2	2	0	-1	-1	-1	-7	-4	-12	1	-2	-9
3	0.960	pianoforte	muted, middle-high register, mf	1	0	-2	1	0	0	1	0	0	1	0	2	1	-1	-1	2	1	1	2	1	2
5	1.156	pianoforte	muted, middle-high register, ff	0	1	-2	1	0	0	1	0	0	1	2	2	1	-1	-1	4	1	1	4	4	1
-8	0.916	pianoforte	multiphonic, simple, individual strong flageolet	-1	0	1	-1	-2	0	-1	0	-1	0	-2	0	1	-2	0	-5	-3	-6	-2	-7	-1
-6	1.307	pianoforte	multiphonic on low string, complex proportion and sound, with ped.	2	-1	0	-1	-2	0	-1	0	-1	-2	0	-2	0	1	1	-8	2	-4	-2	-5	-1
-3	1.227	pianoforte	mid-high, loosely damped pitches (preparation), mp	0	-2	1	0	1	0	0	0	-2	1	-1	2	-1	-1	-1	2	-5	-4	1	-2	-1

-5	1.022	pianoforte	mid register damped with finger, ped., mf	-1	0	-2	0	1	1	1	0	-2	1	-1	0	-1	-1	-1	-1	-4	-4	-1	1	-6
15	0.933	pianoforte	medium speed scratch with plectrum on a low monochord string, audible attacks on each slot of winding, "node progression", pedal, mf	1	2	2	0	2	0	0	2	1	2	2	0	1	1	-1	11	4	11	4	11	4
-7	1.316	pianoforte	low register damped string, with ped.	1	-2	-2	0	-2	-2	1	-1	0	-1	0	-1	1	0	1	-8	1	-5	-2	-5	-2
-5	1.156	pianoforte	low register chord, ped., pp	2	0	-2	0	-2	-1	1	0	-1	-1	0	-1	1	0	-1	-7	2	-4	-1	-2	-3
1	0.329	pianoforte	knock with knuckles on opened keyboard lid, no pedal, mf	0	0	0	-1	0	0	0	0	0	1	0	1	1	-1	0	2	-1	0	1	0	1
-3	0.960	pianoforte	hit mid-low register key ff, release, and immediately lower pedal to resonate the decay (post-pedaling)	1	1	-2	1	1	0	1	0	-1	-1	-1	0	-1	-1	-1	-3	0	-2	-1	0	-3
13	0.782	pianoforte	hit metal rod on two lowest strings (minor 2nd) and immediately release, ped., ff	1	1	1	0	1	0	2	0	-1	1	2	0	2	1	2	6	7	11	2	8	5
6	0.507	pianoforte	hit metal body with plastic hammer, ped., bright, mf	0	1	0	0	1	0	1	0	0	1	-1	0	2	1	0	2	4	7	-1	4	2
8	0.516	pianoforte	hit metal body with plastic hammer, ped. (or sostenuto pedal selected resonating pitches), dark	1	1	0	0	1	0	1	0	0	1	-1	0	2	1	1	2	6	9	-1	4	4
-1	1.529	pianoforte	hit keys (cluster) and wipe glass on corresponding steel strings, accented onset, with pedal	1	0	2	-1	1	1	1	-2	-2	-1	-1	1	1	-1	-1	0	-1	1	-2	-3	2
8	0.782	pianoforte	hit keys (cluster of white and black keys), low, mf, ped.	0	1	0	0	2	0	2	0	-1	1	0	0	1	0	2	4	4	8	0	6	2
3	1.493	pianoforte	hit crosswise metal bars with hard mallet, with pedal	2	1	1	1	0	1	-1	-1	-1	-2	-1	-1	1	2	1	-5	8	6	-3	-2	5
5	1.156	pianoforte	highest octave prepared with scotch tape, f	1	0	-2	1	0	0	1	-1	0	0	1	2	2	-1	1	1	4	3	2	0	5
-2	1.449	pianoforte	high, short, fff, ped.	-1	0	-2	0	-2	-2	1	0	-1	1	1	0	1	0	2	-4	2	-3	1	1	-3
12	1.227	pianoforte	high cluster non-linear gliss., ppp	0	1	2	0	2	1	2	1	2	0	0	-2	1	0	2	8	4	13	-1	6	6
7	1.316	pianoforte	glissando on low strings with both hands,with ped., f	1	1	1	0	1	0	2	-2	0	0	2	-1	2	1	-1	3	4	8	-1	5	2
16	0.996	pianoforte	glissando on low strings (dampers down) with both hands, without ped., f possibile	2	1	2	0	1	1	2	0	2	2	2	0	2	0	-1	12	4	14	2	8	8
-11	0.996	pianoforte	flageolet 3rd harmonic partial (on steel strings, tenor range). pedaled, mf	0	-1	-2	-1	-1	-2	2	0	-1	-2	0	-1	-1	0	-1	-7	-4	-10	-1	-2	-9
12	0.960	pianoforte	down pedal accent (no shoe sound; activates pedal) and hold pedal	1	1	0	2	1	2	1	2	-1	1	-1	0	1	2	0	5	7	11	1	7	5

Human voice

noisiness total	TIV	sound / playing mode	Br	Di	Afr	Wb	Fr	Ifc	Dsb	Idc	Ca	Pa	Ed	Lm	Inh	Ihc	Er	Temp	NTemp	Freq	NFreq	Amp	NAmp
2	0.916	" ž"	1	1	-2	1	-1	0	-1	1	0	0	1	0	1	1	-1	-2	4	0	2	2	0
-3	1.227	whistle & hum multiphonic	1	0	-1	1	-1	-2	-1	-2	1	0	1	-1	-1	1	1	-6	3	-1	-2	-2	-1
-6	1.440	whisper, steady sound	1	0	-2	1	-2	-1	0	-1	1	-2	-2	-1	1	1	0	-10	4	-2	-4	-6	0
3	1.760	whisper "šu" gliss., mf	2	0	2	2	0	1	2	-1	-1	-2	-1	-1	1	0	-1	-1	4	6	-3	-2	5
-1	2.729	whisper "š"	2	2	-2	2	-2	-1	-1	-2	0	-2	1	-1	2	2	-1	-10	9	1	-2	-2	1
2	2.382	whisper "s"	2	2	-2	1	-2	0	-2	1	0	-2	0	-1	2	2	1	-8	10	2	0	-1	3
-6	1.573	voice only, humming, narrow glissando down, pppp	0	0	2	0	1	-1	2	-2	-1	-2	-2	-1	-1	0	-1	-4	-2	-1	-5	-3	-3
8	1.716	vocal fry	-2	1	1	2	2	-1	1	0	1	2	1	-2	0	0	2	5	3	9	-1	7	1
4	1.396	very high humming with "r" and mouth closed	-1	1	0	0	-1	1	-1	1	2	2	-1	-1	-1	1	2	2	2	5	-1	2	2
3	1.227	varying guttural consonants, imitating pencil writing	0	1	2	1	1	-1	2	-2	0	0	0	-1	1	0	-1	1	2	6	-3	2	1
5	0.622	trem. using cheek and mouth cavity (cheek firmly in hand, no slapping sound)	0	0	2	0	0	0	0	0	1	2	0	0	1	-1	0	5	0	5	0	1	4
3	1.227	tongue click, secco, noise prepared type	1	1	-1	-1	0	0	0	0	-2	2	1	2	0	-1	1	2	1	0	3	3	0
-11	1.529	tongue click, pitched type	1	-1	-1	-2	-1	-1	-2	-2	-2	-2	1	2	0	-1	0	-8	-3	-12	1	-8	-3
3	1.093	spoken & sung (Sprechgesang), mf	0	0	2	0	2	-1	2	-1	0	1	0	0	0	-1	-1	5	-2	4	-1	3	0
10	1.689	solo inhaling, fast, wild, air noises	1	1	2	1	1	-1	2	-2	2	2	0	-1	2	1	-1	5	5	13	-3	5	5
11	1.796	solo exhaling, fast, wild, air noises	2	1	2	1	1	-1	2	-2	2	2	0	-1	2	1	-1	5	6	14	-3	5	6
1	1.929	snoring (inhale) "pig/snoring sound effect"	2	0	1	0	0	-1	2	-2	2	2	-2	-1	-1	-1	0	1	0	6	-5	-1	2
-9	1.440	screaming or shouting, held, highest possible	-1	0	1	0	0	-1	1	-2	-2	-2	2	-1	-2	-1	-1	-4	-5	-8	-1	-2	-7
2	2.382	"s"	2	2	-2	1	-2	0	-2	1	0	-2	0	-1	2	2	1	-8	10	2	0	-1	3
2	1.449	rr pitched, low	1	0	-2	0	-1	1	-1	1	2	2	-1	-1	1	1	-1	0	2	3	-1	1	1
11	1.396	rapid "tk" repetition, alternating inhaling or exhaling, f	1	1	0	1	2	0	2	-2	2	2	2	0	1	0	-1	8	3	11	0	7	4
0	1.867	rapid "tk" repetition while inhaling (includes gliss.), ff and diminuendo	2	0	-1	-1	0	-1	2	-2	2	2	-1	-1	1	-1	-1	0	0	4	-4	0	0
-14	0.996	overtone singing	1	-1	0	-2	0	0	-1	-1	-2	-2	0	-2	-2	-2	0	-8	-6	-11	-3	-7	-7

-20	0.489	ord. singing	-2	0	-2	-1	0	-2	-1	-2	-2	-2	-1	-1	-2	-1	-1	-13	-7	-16	-4	-7	-13
-10	0.889	ord. baritone (Sciarrino)	-1	-1	-2	-1	1	-2	1	-1	-1	-1	0	-1	-1	-1	1	-6	-4	-8	-2	-2	-8
-5	1.422	long exhaled hum downwards, as if relieved	0	0	2	0	1	-1	2	-2	-1	-2	-1	-1	-1	0	-1	-3	-2	-1	-4	-2	-3
-9	1.040	I (voiceless)	0	2	0	0	-1	-1	-1	-2	-1	-1	-2	-1	1	-1	-1	-10	1	-4	-5	-6	-3
3	1.627	irregular rapid inhale and exhale without pitch, "orgastic"	2	0	1	-1	1	-1	2	-2	1	2	0	-1	1	-1	-1	3	0	6	-3	2	1
3	0.827	hmph (low sound of frowning or frustration)	-1	2	0	0	0	0	0	0	0	1	0	2	-1	-1	1	3	0	1	2	2	1
3	1.093	hit chest & sing	0	0	1	0	1	1	1	-1	-2	2	1	1	-1	-1	0	5	-2	2	1	3	0
1	1.662	finger at lip tremolo	0	1	1	1	1	0	-1	0	-2	0	0	-2	2	2	-2	-3	4	3	-2	3	-2
-1	0.862	fast almost whispered	0	0	-2	1	1	-1	0	-1	1	-1	0	-1	1	1	0	-4	3	1	-2	0	-1
-18	0.693	falsetto, vowel, mf, minimal vibrato	-2	-1	-2	-1	-1	-2	-1	-2	-2	-2	0	-1	-1	-1	1	-13	-5	-15	-3	-8	-10
-3	1.093	burst of exhaled air with relaxed mouth („ gehaucht") and mouth cavity formed for vowel u	0	0	1	1	0	-1	1	-2	-2	0	-1	-1	1	1	-1	-5	2	1	-4	-1	-2
-1	1.396	burst of exhaled air with relaxed mouth („ gehaucht") and mouth cavity formed for vowel a	0	1	1	1	0	-1	1	-2	-2	0	-1	-1	2	1	-1	-5	4	3	-4	0	-1
-4	1.262	airy singing	0	1	1	1	0	-1	1	-1	-1	-2	-2	-2	1	0	0	-7	3	1	-5	-3	-1
1	1.529	air, lower lip	1	1	1	1	1	-1	-1	-1	2	-2	-1	-2	1	1	0	-4	5	5	-4	-2	3
2	1.316	(audible) inhale h(o)	0	1	1	1	0	-1	2	-2	0	0	-1	-1	2	1	-1	-2	4	6	-4	1	1
3	1.360	(audible) exhale h(o)	1	1	1	1	0	-1	2	-2	0	0	-1	-1	2	1	-1	-2	5	7	-4	1	2
8	1.182	"v" or "f" (voiceless), mf	1	2	2	1	1	1	2	-1	0	-1	0	-1	1	1	-1	3	5	10	-2	4	4
9	0.507	"rk" unpitched, short, f	1	0	2	1	0	0	0	0	0	0	1	1	2	1	0	4	5	7	2	2	7
1	1.796	"r" unpitched, low	0	1	-2	0	-1	1	-1	-1	2	2	0	-1	2	1	-2	-1	2	3	-2	1	0
1	1.396	"r" pitched, low	1	0	-2	0	-1	1	-1	1	2	2	-1	-1	1	0	-1	0	1	2	-1	0	1
-5	1.156	"h" unvoiced, gliss. (vocal cavity gliss.), with stable pitch-noise balance, accented	1	1	1	0	0	-1	1	-1	-2	-2	-1	-1	1	-1	-1	-6	1	-2	-3	-3	-2
-8	1.182	"h" unvoiced, gliss. (vocal cavity gliss.), with stable pitch-noise balance	1	1	-1	0	0	-1	1	-1	-2	-2	-2	-1	1	-1	-1	-9	1	-4	-4	-4	-4
1	0.862	"dh" low	0	1	1	0	0	0	0	0	0	-2	-1	2	1	-1	0	0	1	0	1	-3	4

Bowed strings and generalised string corpus

noisiness total	TIV	instrument	sound / playing mode	Br	Di	Afr	Wb	Fr	Ifc	Dsb	Idc	Ca	Pa	Ed	Lm	Inh	Ihc	Er	Temp	NTemp	Freq	NFreq	Amp	NAmp
7	0.916	violin	two strings, from pont. draw bow along string all the way through fingerboard, pppp	1	1	1	2	1	-1	2	1	0	0	0	-1	1	0	-1	3	4	7	0	5	2
15	0.933	violin	two strings, extreme bow pressure and perforation, one bow fff = F00002	2	2	1	1	2	-1	2	1	2	2	0	0	1	0	0	9	6	14	1	9	6
-3	1.227	violin	trem. behind bridge, mf	0	1	-1	0	-1	-2	0	-1	2	2	0	0	-1	-1	-1	-1	-2	-2	-1	0	-3
-1	1.262	violin	several flag. multiphonics, molto pont., vary grip intervals	1	0	2	-1	0	1	-1	2	-1	0	0	-2	-1	0	-1	1	-2	-1	0	1	-2
5	0.889	violin	punta d' arco, pont. = 000i00Ppn	0	0	1	-1	2	-1	0	-1	1	2	0	1	0	0	1	5	0	5	0	3	2
3	0.827	violin	punta d' arco, ord. = 000i00pn	0	0	1	-1	1	-1	-1	-1	1	2	0	1	0	0	1	3	0	3	0	1	2
8	0.782	violin	pressured bowing, towards bridge	2	1	0	1	1	-1	1	1	1	1	0	-1	1	1	-1	3	5	8	0	6	2
3	1.227	violin	pont. molto (or poco), high finger position on string (near bow), flageolet, -5BD, 1/5D, pp	0	1	0	0	-1	1	2	-1	0	0	-1	-1	2	-1	2	-1	4	6	-3	-1	4
-8	0.782	violin	pizz. ord. l.v.	0	-1	-2	-1	0	0	1	0	-2	1	-1	0	-1	-1	-1	-3	-5	-7	-1	-1	-7
3	0.827	violin	pizz. nut with plectrum (section, not unison)	0	1	-1	-1	1	0	0	0	-1	1	-1	2	1	0	1	1	2	2	1	2	1
-5	1.022	violin	pizz. harmonic, l.v., f	-1	-1	-2	-1	0	0	1	0	-1	1	2	0	-1	-1	-1	1	-6	-7	2	2	-7
-19	0.729	violin	ord., punta, pp, one bow length	-1	0	-2	-1	-1	-1	-2	1	-2	-2	-2	-1	-2	-2	-1	-12	-7	-17	-2	-8	-11
-24	0.373	violin	ord., mf, one long bow, non vibr.	-2	-1	-2	0	-2	-1	-2	-1	-2	-2	-2	-1	-2	-2	-2	-15	-9	-20	-4	-12	-12
12	1.227	violin	one bow, near bridge (molto pont.), flautando with extremely loose bow pressure (-5BD), very	2	1	1	1	2	1	2	2	-1	-1	0	-1	2	1	0	5	7	11	1	7	5
2	0.916	violin	legno batt. (pitch f3)	1	1	-1	-1	-1	0	0	-1	1	1	0	2	1	0	-1	1	1	1	1	0	2
2	0.649	violin	high pizz. (secco)	0	0	-2	-1	0	0	0	0	0	1	1	1	1	0	1	1	1	0	2	2	0
2	0.516	violin	hard plectrum, accented hit on open A string (secco), on fingerboard (damp immediately)	0	0	1	-1	0	0	0	0	0	1	0	2	-1	0	0	4	-2	0	2	1	1
-11	0.729	violin	flageolet vibrato, p	0	0	-1	-1	1	-1	-1	-1	-1	-1	-2	-2	-1	-1	1	-9	-2	-6	-5	-5	-6
-12	1.893	violin	flag. flaut. sul tasto	1	-2	-2	-2	-2	0	1	-2	-1	-1	-2	-2	-1	1	2	-11	-1	-6	-6	-7	-5
-3	1.093	violin	fast trem. open string vs. flageolet, mf	0	0	2	0	0	-1	2	-1	0	0	0	-2	-1	-1	-1	0	-3	0	-3	0	-3
11	0.862	violin	extreme bow pressure (+5BD) near bridge, draw bow along string in region between	1	1	1	1	1	-1	2	-1	2	2	0	0	1	0	1	6	5	12	-1	5	6
-5	1.022	violin	col legno, two strings, draw bow from ponticello towards fingerboard, ppp	-1	-1	-2	-1	0	0	1	0	-1	1	2	0	-1	-1	-1	1	-6	-7	2	2	-7

-12	1.627	violin	bow vibr.	0	-1	0	-2	-2	-2	1	-2	1	2	-1	-2	-1	-1	-2	-5	-7	-7	-5	-4	-8
1	0.596	violin	behind bridge, one staccato accented and stopped bow, mp	0	-1	0	0	1	0	0	0	0	1	0	2	-1	-1	0	4	-3	-1	2	0	1
6	0.640	violin	Bartok pizz.	1	1	0	0	0	0	0	0	0	0	2	2	1	-1	0	4	2	2	4	2	4
-12	1.493	violin	artif.harmonic flag. with vibr.	0	-2	1	1	1	-2	-1	-2	-2	-2	-2	-1	-1	-1	1	-10	-2	-7	-5	-9	-3
-2	1.316	violin	arco gettato / battuto, f	0	0	-2	0	-1	0	0	0	1	2	2	0	-2	-1	-1	2	-4	-4	2	2	-4
-1	0.462	violin (section)	accented pizz. fluido (left hand plucks, flat bow handle slides on string), quite long	0	0	1	0	0	-1	1	-1	-1	0	-1	0	1	0	0	-2	1	1	-2	-1	0
7	0.782	violin	1/2 col legno, two strings, from pont. draw bow along string all the way through fingerboard, pppp	1	1	1	1	1	1	2	1	0	-1	0	-1	1	0	-1	4	3	7	0	4	3
-20	1.022	viola	vla. high short separated onsets pppp (m. 7)	-2	-2	-2	-2	-2	-1	-1	-1	-1	-2	-2	-1	-1	-2	2	-13	-7	-16	-4	-12	-8
11	1.396	viola	vla. high pressured trem. short separated onsets	0	1	2	0	2	1	0	-1	2	2	2	-2	1	0	1	8	3	12	-1	6	5
15	0.933	viola	two strings, extreme bow pressure and perforation, one bow fff = f00002	2	2	1	1	2	-1	2	1	2	2	0	0	1	0	0	9	6	14	1	9	6
-8	0.782	viola	two strings, extreme bow pressure and perforation, one bow fff = f00002	0	0	0	-2	1	-1	-1	-1	-1	-2	-1	-1	0	0	1	-7	-1	-5	-3	-4	-4
5	1.022	viola	scratch tone (pressione), p	2	1	0	1	0	0	0	-1	1	-1	1	-1	2	1	-1	-1	6	6	-1	1	4
-11	1.396	viola	ord., repeated, high drifting (directed) sound, wobbling pitch (Furrer)	-1	-1	-1	1	1	-2	0	-2	-1	-1	-1	-2	-2	-1	2	-9	-2	-6	-5	-5	-6
12	1.227	viola	one bow, near bridge (molto pont.), flautando with extremely loose bow pressure (-5BD), very loose finger pressure with grip between bow and fingerboard, ppp	2	1	1	1	2	1	2	2	-1	-1	0	-1	2	1	0	5	7	11	1	7	5
-2	1.049	viola	legno batt., (pitch d0)	-1	0	-1	-1	-1	0	0	0	-1	2	0	2	-1	-1	1	1	-3	-4	2	0	-2
15	0.933	viola	col legno, draw bow along two strings, from ponticello towards fingerboard, ppp	2	2	1	1	2	-1	2	1	2	2	0	0	1	0	0	9	6	14	1	9	6
-2	0.916	viola	bow on stringholder, one bow	0	-2	0	0	-1	1	2	-1	0	-1	0	-1	1	0	0	-1	-1	0	-2	-3	1
7	0.782	viola	bow on stringholder, col legno	2	1	0	1	1	1	2	-1	0	0	0	-1	1	0	0	2	5	9	-2	3	4
5	0.622	viola	bow on stringholder, 1/2 col legno	1	0	0	1	1	1	2	-1	0	0	0	-1	1	0	0	2	3	7	-2	2	3
-6	1.040	viola	arco on tailpiece, string hair	0	0	-2	1	-1	0	-1	-1	0	-2	-1	-1	2	0	0	-9	3	-3	-3	-6	0
-3	1.227	viola	2 pitches flag. [f00002], ppp cresc. to f	0	0	1	-2	1	-1	0	-1	-1	-2	2	-1	0	0	1	-2	-1	-3	0	0	-3

-2	1.049	viola	legno batt. (pitch d0)	-1	0	-1	-1	-1	0	0	0	-1	2	0	2	-1	-1	1	1	-3	-4	2	0	-2
-10	0.889	cello	vibr., pont., f, several bowings	0	0	1	0	0	-1	-1	-2	-1	-2	1	-2	-1	-1	-1	-7	-3	-7	-3	-5	-5
-5	0.622	cello	vc. wide glissando down from high position, mf	0	0	-1	0	1	-2	0	-1	-1	1	0	-1	0	0	-1	-4	-1	-3	-2	1	-6
-9	0.773	cello	vc. flag. dim.	-1	-1	0	-2	-1	-2	0	-1	0	-1	-1	-1	0	1	1	-7	-2	-6	-3	-4	-5
-8	0.782	cello	two strings, flageolets, p = f00002	0	0	0	-2	1	-1	-1	-1	-1	-2	-1	-1	0	0	1	-7	-1	-5	-3	-4	-4
15	0.667	cello	trem. gliss. upwards, pont., mf	1	1	2	0	0	1	2	2	2	2	0	0	1	1	0	11	4	13	2	8	7
4	1.129	cello	trem. gliss. upwards, ord., mf	0	0	1	0	0	-1	2	-1	2	2	1	0	-1	-1	0	6	-2	4	0	3	1
0	1.067	cello	trem. behind the bridge, sequence of strings I to IV, non-ponticello to ponticello, mf (Pesson m. 184 & 194)	1	1	-1	0	0	-1	0	-1	2	2	0	-1	-1	0	-1	0	0	2	-2	2	-2
10	1.022	cello	seagull gliss. pont. fast trem.	1	1	2	1	0	1	-1	1	2	2	-1	-1	1	1	0	5	5	11	-1	3	7
2	0.649	cello	seagull gliss. ord.	1	0	2	0	0	1	-1	-1	0	1	0	-1	0	0	0	1	1	4	-2	-1	3
2	0.916	cello	rapid sequence of pizz. flageolets, p	0	0	-1	0	1	0	2	0	1	2	0	0	-1	-1	-1	5	-3	2	0	4	-2
-1	0.862	cello	poco pressione, mf	1	1	0	0	-1	1	0	-1	-1	0	0	-2	1	1	-1	-4	3	2	-3	0	-1
3	0.693	cello	pizz., damped, low, p	1	-1	0	-1	0	0	0	0	0	1	0	2	1	1	-1	3	0	1	2	1	2
-14	0.729	cello	pizz. high harmonic, l.v., f	-2	-2	-2	-1	-1	0	1	0	-1	-1	-1	0	-1	-1	-2	-5	-9	-13	-1	-5	-9
-7	0.649	cello	pizz. harmonic, l.v., f	0	0	-2	-1	-1	0	1	0	-1	1	-1	0	-1	-1	-1	-3	-4	-6	-1	-1	-6
2	0.649	cello	pizz. behind the bridge, p...mf	0	-1	0	0	1	0	1	0	0	1	0	2	-1	-1	0	5	-3	0	2	1	1
-23	0.382	cello	ord., mf, one long bow, non vibr.	-1	-1	-2	0	-2	-1	-2	-1	-2	-2	-2	-1	-2	-2	-2	-15	-8	-19	-4	-12	-11
-8	0.516	cello	on endpin, 1/2 col legno, gliss., ppppp	0	-1	1	0	-1	0	-1	-2	0	0	-1	-1	-1	-1	0	-5	-3	-4	-4	-7	-1
3	1.093	cello	natural harmonics gliss., one bow, mf	0	0	-1	-1	1	2	2	2	0	0	0	-1	-1	0	0	5	-2	2	1	5	-2

-9	0.640	cello	Multiphonic arco, mf, one bow	1	1	-2	0	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	0	-9	0	-6	-3	-5	-4
5	1.289	cello	low double stop, trem., gliss. on one of the pitches, mf	2	0	-1	0	0	1	0	1	2	2	0	-2	0	1	-1	3	2	6	-1	4	1
4	0.729	cello	hit with finger (low D)	1	0	0	0	1	0	1	-1	0	1	-1	1	-1	0	2	2	2	5	-1	1	3
-5	0.756	cello	high left hand pizz., l.v., mf	-1	-1	0	-1	0	0	1	0	-2	1	-1	0	-1	-1	1	-1	-4	-4	-1	-1	-4
-12	0.427	cello	high flageolet, accented stacc.	-1	-1	0	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	0	-2	-6	-6	-9	-3	-4	-8
3	0.960	cello	flag. trem. on high position	0	1	0	0	1	-1	0	-1	0	2	0	-2	1	1	1	-1	4	6	-3	4	-1
-12	0.827	cello	flag. high (non trem.)	-1	-1	0	-2	1	-2	-1	-1	-1	-2	-1	-1	-1	0	1	-8	-4	-9	-3	-5	-7
-11	0.729	cello	flag. high (non trem.) = f00001	-1	-1	0	-2	1	-1	-1	-1	-1	-2	-1	-1	-1	0	1	-7	-4	-8	-3	-5	-6
13	0.916	cello	fast flageolets, legato, through all four strings, ord. to pont., mf	0	1	2	0	1	1	2	2	2	2	0	0	1	0	-1	12	1	11	2	8	5
11	1.129	cello	damped strings, one fast arpeggio pizz.	2	1	0	0	0	1	2	0	2	2	-1	1	2	0	-1	7	4	11	0	4	7
4	0.329	cello	damped strings, arco, mf, short attack and release	1	1	0	0	0	0	1	0	-1	1	0	0	1	0	0	1	3	4	0	3	1
5	0.622	cello	damped strings, arco, mf, short	1	1	0	0	0	0	1	0	-1	1	-1	1	2	0	0	1	4	5	0	2	3
0	0.800	cello	damped pizz., tasto	0	-1	-1	-1	0	0	0	0	1	1	0	2	-1	1	-1	3	-3	-2	2	1	-1
13	1.316	cello	con pressione ultimo (scratch "tone")	2	2	1	2	1	1	0	-1	1	-2	2	0	1	2	1	3	10	12	1	4	9
4	0.862	cello	col legno battuto, fully resonant string, l.v., mf	0	0	2	0	1	-1	1	0	0	1	0	2	-1	0	-1	6	-2	2	2	3	1
-3	1.627	cello	bow vibrato impulses, within a glissando, p	1	0	1	-1	1	-1	1	-1	1	2	0	-2	-2	-1	-2	2	-5	0	-3	2	-5
9	1.307	cello	bow strings at nut (pegbox), ppp	1	0	2	0	2	1	2	-1	1	2	0	-2	1	0	0	7	2	12	-3	5	4
6	1.040	cello	bow on stringholder, flautando or almost no bow pressure (-5BD), one bow, gliss. from end of stringholder towards strings	2	0	1	1	0	1	2	-1	0	-1	0	-1	2	0	0	1	5	8	-2	0	6
2	1.049	cello	bow on stringholder, flautando or almost no bow pressure (-5BD), one bow	1	-1	0	1	-1	1	2	-1	0	-1	0	-1	2	0	0	-1	3	4	-2	-2	4

9	1.307	cello	bow hair, ppp rotating circular bow	1	0	2	0	2	1	2	-1	1	2	0	-2	1	0	0	7	2	12	-3	5	4
9	0.773	cello	batt./tapping on damped strings	1	1	0	0	0	0	0	0	0	1	2	2	2	1	-1	5	4	5	4	5	4
-7	1.316	cello	batt./tap (not damped) and release	0	-1	-2	-1	-1	1	2	1	-1	1	-1	-1	-1	-1	-2	-1	-6	-6	-1	0	-7
-8	1.449	cello	batt./tap (not damped) and release	0	-1	-2	-2	-1	1	2	1	-1	1	-1	-1	-1	-1	-2	-1	-7	-7	-1	0	-8
6	0.907	cello	arco pont., rapid sequence of separately bowed flag. pitches, mp	0	0	2	0	2	-1	0	0	1	2	0	0	1	0	-1	6	0	6	0	4	2
-13	0.916	cello	arco pont. molto	0	0	0	-1	-2	1	-1	-2	-2	-2	-2	-1	-1	0	0	-11	-2	-8	-5	-9	-4
0	1.067	cello	arco gettato / battuto, f	0	0	-2	0	-1	0	0	0	1	2	2	0	-1	0	-1	2	-2	-2	2	3	-3
-13	0.516	cello	arco behind bridge, pont. punta	-1	1	-1	0	-1	-2	-1	-1	-2	-1	-1	-1	-1	0	-1	-11	-2	-10	-3	-4	-9
10	0.756	cello	2 strings, trem., gliss. upwards, mf	*0*	*0*	*2*	*0*	*1*	*1*	*0*	*1*	*2*	*2*	*1*	*0*	*0*	*1*	*-1*	10	0	8	2	6	4
11	0.729	cello	2 strings, pont., gliss. upwards, trem., mf	1	1	2	0	1	1	0	1	2	2	0	0	0	1	-1	9	2	10	1	6	5
-15	0.800	cello	2 pitches, low, pp	0	0	-2	-1	-1	-1	-2	-1	-2	-2	-2	-1	0	-1	1	-14	-1	-11	-4	-9	-6
-8	0.782	cello	2 flageolets, p = f00002	0	0	0	-2	1	-1	-1	-1	-1	-2	-1	-1	0	0	1	-7	-1	-5	-3	-4	-4
3	1.493	cello	legno batt. (pitch e2)	0	0	-1	1	-2	-2	0	0	1	2	1	2	1	-1	1	1	2	0	3	0	3
-10	1.156	double bass	repetition in pulse, a multiphonic (E/20. & 21.)	-2	-1	-1	-1	-2	-1	-2	-1	0	-1	0	-1	0	1	2	-9	-1	-8	-2	-6	-4
-12	0.693	double bass	pizz. harmonic, l.v., f	0	-2	-2	-1	-1	0	1	0	-1	-1	-1	0	-1	-1	-2	-5	-7	-11	-1	-5	-7
-9	0.640	double bass	pizz. behind bridge	-1	-1	-2	-2	0	0	0	0	0	1	-1	0	-1	-1	-1	-2	-7	-8	-1	-2	-7
-18	0.693	double bass	gliss. dim.	-1	0	-2	-2	-1	-2	-1	-1	-2	-2	-1	-2	-1	-1	1	-14	-4	-14	-4	-7	-11
-12	1.493	double bass	flag. flaut. sul tasto	1	-1	-1	-2	-2	-2	1	-2	-1	-1	-1	-2	-1	0	2	-11	-1	-7	-5	-6	-6
5	0.756	double bass	extreme bow pressure (+5/5BD), extreme finger pressure (5/5D), between bridge and stringholder, finger position close to bridge (near bow), bow position closer to stringholder, ppp	1	0	0	1	1	0	0	2	-1	1	0	-1	1	1	-1	2	3	4	1	5	0
11	0.996	double bass	draw bow along string, one bow, ppp	2	1	1	1	1	-1	2	-1	2	2	0	0	1	0	0	6	5	12	-1	5	6

3	1.360	double bass	col legno gliss., ppp	1	2	-2	1	1	-1	2	-1	0	1	0	-1	1	-1	0	-1	4	5	-2	4	-1
-12	1.493	double bass	cb. flag. flaut. sul tasto	1	-1	-1	-2	-2	-2	1	-2	-1	-1	-1	-2	-1	0	2	-11	-1	-7	-5	-6	-6
-1	0.996	double bass	bow on stringholder, one bow	1	-2	0	0	-1	1	2	-1	0	-1	0	-1	1	0	0	-1	0	1	-2	-3	2
9	0.640	double bass	Bartok pizz., l.v., non-open string	0	0	1	1	0	0	0	0	0	1	2	2	2	0	0	6	3	5	4	3	6
-5	1.022	double bass	arco on tailpiece, string hair	1	1	-2	1	-1	0	-1	-1	0	-2	-1	-1	1	0	0	-9	4	-2	-3	-5	0
7	1.182	double bass	1/2 col legno, two strings, extreme flautando (-5BD), bow from end of fingerboard toward bridge, ppp	2	2	1	1	1	-1	2	1	-1	-1	0	-1	1	0	0	1	6	7	0	5	2
0	0.667	double bass	1/2 col legno, gliss., ppp	1	1	-1	0	1	-1	0	1	0	1	0	-1	-1	0	-1	0	0	0	0	4	-4
14	0.862	double bass	1/2 col legno, draw bow over two strings	2	1	1	1	2	-1	2	1	2	2	0	0	1	0	0	9	5	13	1	8	6
2	0.916	double bass	1/2 col legno on stringholder, extremely small bow pressure or flautando (-5BD), ppp	1	-1	0	1	1	1	2	-1	-1	-1	0	-1	1	0	0	0	2	4	-2	0	2
-3	0.693	double bass	"harmonic scanning", pont., several bowings	1	0	1	-1	0	-1	1	-1	0	-1	-1	-1	-1	1	0	-3	0	0	-3	-1	-2
-3	0.827	double bass	up-down swipe with finger	1	0	-1	0	0	-1	1	-2	0	1	-1	0	1	-1	-1	-3	0	0	-3	-2	-1
1	0.729	vc., vl., cb.	steady repetition of 2 pitches, pp, pont. =000r02PP	0	0	0	-1	0	1	0	-1	1	2	-1	0	0	-1	1	2	-1	3	-2	-1	2
-2	0.649	vc., vl., cb.	short pitch, pont., pp	0	0	0	-1	0	0	0	-1	-1	1	-1	2	-1	0	0	0	-2	-2	0	-1	-1
-8	0.782	vl., vla., vc.	pizz. ord. l.v.	0	-1	-2	-1	0	0	1	0	-2	1	-1	0	-1	-1	-1	-3	-5	-7	-1	-1	-7
3	0.827	vl., vc.	pizz. nut with plectrum (section, not unison)	0	1	-1	-1	1	0	0	0	-1	1	-1	2	1	0	1	1	2	2	1	2	1
3	0.560	vl., vla.	pizz. behind the bridge, p...mf	0	-1	0	0	1	0	1	0	0	1	0	2	-1	0	0	5	-2	1	2	2	1
-15	0.667	strings / archi	ord., double stop, rather fast gliss., one bow, mf, middle register	0	0	-1	0	0	-1	-2	-2	-2	-2	-2	-1	0	-1	-1	-13	-2	-10	-5	-9	-6
-23	0.249	strings / archi	ord., "basic average sound", one bow, mf, middle register, almost no vibr.	-1	-1	-2	-1	-1	-1	-2	-2	-2	-2	-2	-1	-2	-2	-1	-15	-8	-18	-5	-12	-11
-1	1.396	vl., vla., vc.	ord. pitch repetition, in fast or medium pulse. high pitch	-1	1	-1	0	-1	-1	-2	-1	1	1	0	2	0	-1	2	-2	1	-2	1	-3	2
9	0.640	vl., vla., vc., cb.	open string Bartok pizz. with all strings damped ("aSd"), short accented, low	0	0	1	1	0	0	0	0	0	1	2	2	2	0	0	6	3	5	4	3	6
-13	0.649	vla. vc.	flag. pizz. l.v., high, mp...f	-1	-2	-2	-1	-1	0	1	0	-1	-1	-1	0	-1	-1	-2	-5	-8	-12	-1	-5	-8
6	1.173	vl., vla., vc.	fast repetition of high scratch tone (pressione)	0	1	0	1	1	-2	1	-1	0	1	0	-1	2	1	2	-1	7	8	-2	4	2

3	1.227	strings / archi	double stop, trem. rather fast gliss., mf, middle register	1	0	1	0	1	-1	0	-1	2	2	0	-2	1	0	-1	2	1	6	-3	2	1
12	1.493	strings / archi	con poco pressione, double stop, trem. rather fast gliss., mf, middle register	1	1	2	1	2	1	2	-1	2	2	0	-2	1	1	-1	8	4	15	-3	7	5
-6	1.040	viola violin	arco on tailpiece, string hair	0	0	-2	1	-1	0	-1	-1	0	-2	-1	-1	2	0	0	-9	3	-3	-3	-6	0
-7	0.782	cb..vc., vla.	activated tuning fork, resonate on bridge	-1	-1	-2	0	1	-1	1	0	-1	-1	-1	1	-1	-1	0	-3	-4	-7	0	-2	-5
-9	0.773	vla., vc., cb.	2 pitches, to pont., ppp to p	0	0	1	0	0	-1	0	-2	-2	-2	0	-1	0	-1	-1	-7	-2	-6	-3	-5	-4
8	0.782	strings	pressured bowing, towards bridge	2	1	0	1	1	-1	1	1	1	1	0	-1	1	1	-1	3	5	8	0	6	2
-11	1.396	strings	high drifting (directed) sound, wobbling pitch	-1	-1	-1	1	1	-2	0	-2	-1	-1	-1	-2	-2	-1	2	-9	-2	-6	-5	-5	-6
-20	1.022	strings	high short separated onsets pppp	-2	-2	-2	-2	-2	-1	-1	-1	-1	-2	-2	-1	-1	-2	2	-13	-7	-16	-4	-12	-8
11	1.396	strings	high pressured trem. short separated onsets	0	1	2	0	2	1	0	-1	2	2	2	-2	1	0	1	8	3	12	-1	6	5
-1	1.396	strings	000r01 = STANDARD	-1	1	-1	0	-1	-1	-2	-1	1	1	0	2	0	-1	2	-2	1	-2	1	-3	2
19	0.729	strings	100i01PPLL	1	1	1	1	2	0	2	-1	2	2	2	2	2	1	1	12	7	16	3	9	10
19	0.596	strings	110i01TVLLpnh	1	1	1	1	1	1	2	-1	2	2	2	2	2	1	1	12	7	16	3	8	11
18	0.693	strings	F00i01PPLLf	1	1	1	1	2	0	2	-1	2	2	2	2	1	1	1	12	6	15	3	9	9
18	0.693	strings	110i01TVLLpnf 110i01TVLLpno	1	1	1	1	1	0	2	-1	2	2	2	2	2	1	1	11	7	15	3	8	10
17	1.049	strings	111i01	1	2	1	1	1	-1	2	-1	2	2	2	2	2	0	1	10	7	14	3	8	9
17	0.782	strings	110i01TVLLpnf 110i01TVLLpnh 110i01TVLLpno 110i01	1	1	1	1	1	0	2	-1	2	2	2	2	2	0	1	11	6	14	3	7	10
17	0.649	strings	F00i01TLLf	1	1	1	1	1	0	2	-1	2	2	2	2	1	1	1	11	6	14	3	8	9
17	0.649	strings	100i01TLL 100i01TTVLLpn	1	1	1	1	1	0	2	-1	2	2	1	2	2	1	1	10	7	15	2	7	10
17	0.382	strings	120i01TmLLf 120i01TmLL	1	1	0	1	1	1	2	1	2	2	1	0	2	1	1	10	7	15	2	9	8

17	0.782	110i01TVLLpnf 110i01TVLLpnh 110i01TVLLpno 110i01	1	1	1	1	1	0	2	-1	2	2	2	2	2	0	1	11	6	14	3	7	10
17	0.649	F00i01TLLf	1	1	1	1	1	0	2	-1	2	2	2	2	1	1	1	11	6	14	3	8	9
17	0.649	100i01TLL 100i01TTVLLpn	1	1	1	1	1	0	2	-1	2	2	1	2	2	1	1	10	7	15	2	7	10
17	0.382	120i01TmLLf 120i01TmLL	1	1	0	1	1	1	2	1	2	2	1	0	2	1	1	10	7	15	2	9	8
16	0.729	101r11 120r02	1	1	1	1	1	0	2	-1	2	2	2	1	2	0	1	10	6	14	2	7	9
16	0.462	120i01TmLLf 120i01TmLL 120i01	1	1	0	1	1	1	2	1	2	2	1	0	2	0	1	10	6	14	2	8	8
15	1.333	101i01	1	1	1	1	1	-1	2	-2	2	2	2	2	2	0	1	9	6	13	2	6	9
15	1.067	100i01PPLL 100i01TTVLLpn 100i01 100i01TLL	1	1	1	1	1	0	2	-2	2	2	1	2	2	0	1	9	6	14	1	5	10
15	0.933	100r01PPVLLpn	1	1	1	1	2	-1	2	-1	2	2	1	0	2	1	1	8	7	15	0	8	7
15	0.933	100i02 101i11 110i02 120i11 120i01 111i01	1	1	1	1	1	-1	2	-1	2	2	1	2	2	0	1	9	6	13	2	6	9
15	0.667	F00r01PPVf	1	1	1	1	2	0	2	-1	2	2	1	1	1	0	1	10	5	14	1	7	8
15	0.533	F00r02TTpnLL	1	1	1	1	1	0	2	-1	2	2	1	1	1	1	1	9	6	14	1	7	8
14	1.262	101i01	1	1	1	1	1	-1	2	-2	2	2	1	2	2	0	1	8	6	13	1	5	9
14	0.996	101r01	1	1	1	1	1	0	2	-2	2	2	1	1	2	0	1	8	6	14	0	5	9
14	0.862	120r02; 120r01 110r02; 110r01 110r01 101r11 120r01; 120r11 110r02; 110r04	1	1	1	1	1	-1	2	-1	2	2	1	1	2	0	1	8	6	13	1	6	8
14	0.862	110002TLL	1	1	1	1	1	0	2	-1	2	2	1	-1	2	1	1	7	7	15	-1	7	7

13	1.182	100r01 101r01	1	1	1	1	1	-1	2	-2	2	2	1	1	2	0	1	7	6	13	0	5	8
13	1.049	100001PVVV flaut.	1	1	0	1	2	0	2	-2	2	1	1	1	2	0	1	7	6	13	0	5	8
13	0.916	110r01	1	1	1	1	1	-1	2	-1	2	2	1	0	2	0	1	7	6	13	0	6	7
13	0.916	110002 110002TLL	1	1	1	1	1	0	2	-1	2	2	1	-1	2	0	1	7	6	14	-1	6	7
13	0.916	100001TTVtlLL	1	1	0	1	1	0	2	-1	2	1	2	-1	2	1	1	6	7	13	0	7	6
13	0.916	100001PVpnLL 100001PVLL	1	1	0	1	2	0	2	-1	2	1	1	-1	2	1	1	6	7	14	-1	7	6
13	0.649	F00002PVVV	1	1	0	1	2	0	2	-1	2	1	1	1	1	0	1	8	5	12	1	6	7
12	1.227	100r01PPVLLpn 100r01	1	1	1	1	1	-1	2	-2	2	2	1	0	2	0	1	6	6	13	-1	5	7
12	0.827	F00001PVpnLL F00001PVLL F00001PPLLf F00001PPLLf	1	1	0	1	2	0	2	-1	2	1	1	-1	1	1	1	6	6	13	-1	7	5
12	0.560	F00002TTVVV	1	1	0	1	1	0	2	-1	2	1	1	1	1	0	1	7	5	11	1	5	7
11	0.862	F00002PV	1	1	0	1	2	0	2	-1	2	1	1	-1	1	0	1	6	5	12	-1	6	5
11	0.729	F00001TLLf F00001TVLLpnf F00001TLLf	1	1	0	1	1	0	2	-1	2	1	1	-1	1	1	1	5	6	12	-1	6	5

10	1.822	000i01PPVVV 000i01PVVV	0	1	1	-1	2	-1	0	-2	2	2	2	2	-1	2	1	8	2	8	2	7	3
10	1.289	f00i02PVVV flaut. f00i02PV flaut.	0	1	1	-1	2	-1	0	-1	2	2	2	2	0	0	1	9	1	7	3	6	4
10	1.156	100001TTVtlLL 100001 100001PVLL 100001PVpnLL 100001PVVV flaut. 100001PVpnLL	1	1	0	1	1	0	2	-2	2	1	1	-1	2	0	1	4	6	12	-2	4	6
10	0.756	F00001PVpnLLf F00002PVmLL	1	1	0	1	2	0	2	-1	0	1	1	-1	1	1	1	4	6	11	-1	7	3
10	0.756	F00000TV F00002TTV F00001TVf	1	1	0	1	1	0	2	-1	2	1	1	-1	1	0	1	5	5	11	-1	5	5
9	1.307	100001	1	1	0	1	1	-1	2	-2	2	1	1	-1	2	0	1	3	6	11	-2	4	5
9	1.040	00b002PLL	1	1	-2	0	2	1	2	1	0	1	0	-1	1	1	1	4	5	9	0	8	1
8	1.182	f00i02TTVVV flaut. f00i02TTV flaut.	0	0	1	-1	1	-1	0	-1	2	2	2	2	0	0	1	8	0	5	3	4	4
7	1.182	00b000PLL	1	1	-2	0	2	1	2	1	0	1	0	-1	1	1	-1	4	3	7	0	8	-1
7	0.916	00b002TTLL 00b002TLL	1	1	-2	0	1	1	2	1	0	1	0	-1	0	1	1	3	4	7	0	7	0
6	1.307	f00i02TTVVV flaut. f00i02PVVV flaut. f00i02TTV flaut. f00i02PV flaut. f00i02	0	0	1	-1	-1	-1	0	-1	2	2	2	2	0	0	1	6	0	3	3	2	4
6	0.773	f00000TTLL	1	1	0	0	1	-1	2	-1	0	1	0	-1	1	1	1	1	5	8	-2	5	1
5	0.889	000i00Ppn, (Lachenmann) punta d’ arco, pont.	0	0	1	-1	2	-1	0	-1	1	2	0	1	0	0	1	5	0	5	0	3	2

4	1.262	f01i10	0	0	1	-1	1	-1	0	-1	2	2	-1	2	-1	0	1	5	-1	4	0	1	3
4	1.262	011i01	1	0	1	-1	0	-1	0	-1	2	2	-1	2	0	-1	1	4	0	4	0	-1	5
4	1.129	000002TTLL	1	1	-2	0	1	-1	2	-1	0	1	0	-1	1	1	1	-1	5	6	-2	5	-1
4	1.129	00b002TLL	1	1	-2	0	-1	1	2	1	0	1	0	-1	1	1	-1	1	3	4	0	5	-1
4	1.129	020i11	0	0	1	-1	0	-1	0	-1	2	2	-1	2	0	0	1	4	0	4	0	0	4
3	1.493	010i04 010i02	1	0	1	-1	0	-1	0	-1	2	2	-2	2	0	-1	1	3	0	4	-1	-2	5
3	1.360	f01i00	0	-1	1	-1	1	-1	0	-1	2	2	-1	2	-1	0	1	5	-2	3	0	0	3
3	0.827	000i00pn (Lachenmann) punta d’ arco, ord.	0	0	1	-1	1	-1	-1	-1	1	2	0	1	0	0	1	3	0	3	0	1	2
2	1.716	011i01 010i01	1	0	1	-1	0	-1	0	-1	2	2	-2	2	0	-2	1	3	-1	3	-1	-3	5
2	1.449	000202 000302	0	0	1	-1	0	-1	0	-1	2	2	-2	2	0	-1	1	3	-1	3	-1	-2	4
2	1.449	001i11	0	0	1	-1	0	-1	0	-1	2	2	-1	2	-2	0	1	4	-2	2	0	0	2
2	1.182	000001TTVVV flaut.	1	1	-2	0	1	-1	2	-1	0	1	0	-1	1	1	-1	-1	3	4	-2	5	-3
2	1.182	000000TTLL	1	1	-2	0	1	-1	2	-1	0	1	0	-1	1	1	-1	-1	3	4	-2	5	-3
2	0.916	f01r10	0	0	1	-1	1	-1	0	-1	1	2	-1	1	-1	0	1	3	-1	3	-1	1	1
2	0.916	f00r02	0	0	1	-1	1	-1	-1	-1	1	2	-1	1	0	0	1	2	0	3	-1	0	2
2	0.782	020r11; 020r12	0	0	1	-1	0	-1	0	-1	1	2	-1	1	0	0	1	2	0	3	-1	0	2
1	1.662	020i01	0	0	1	-1	0	-1	0	-1	2	2	-2	2	0	-2	1	3	-2	2	-1	-3	4
1	1.129	010r02 010r04	1	0	1	-1	0	-1	0	-1	1	2	-2	1	0	-1	1	1	0	3	-2	-2	3
1	0.996	f00r01 f01r00	0	-1	1	-1	1	-1	0	-1	1	2	-1	1	-1	0	1	3	-2	2	-1	0	1
0	1.333	010r01	1	0	1	-1	0	-1	0	-1	1	2	-2	1	0	-2	1	1	-1	2	-2	-3	3
0	1.067	f00r00	0	-1	1	-1	1	-1	-1	-1	1	2	-1	1	-1	0	1	2	-2	1	-1	-1	1
0	1.067	010r01	1	0	1	-1	0	-1	0	-1	1	2	-2	0	0	-1	1	0	0	3	-3	-2	2
0	1.067	000r11 001r11	0	0	1	-1	0	-1	0	-1	1	2	-1	1	-2	0	1	2	-2	1	-1	0	0

0	1.067	f00r01	0	-1	1	-1	1	-1	-1	-1	1	2	-1	1	-1	0	1	2	-2	1	-1	-1	1
0	1.067	020r02	0	0	1	-1	0	-1	0	-1	1	2	-2	1	0	-1	1	1	-1	2	-2	-2	2
0	1.067	001r11 000r11	0	0	1	-1	0	-1	0	-1	1	2	-1	1	-2	0	1	2	-2	1	-1	0	0
0	0.800	020r02	0	0	1	-1	0	-1	0	-1	1	2	-1	0	0	-1	1	1	-1	2	-2	-1	1
0	0.800	000r02	0	0	0	-1	0	-1	0	-1	1	2	-1	1	0	-1	1	1	-1	1	-1	-1	1
-1	1.396	f00r11	-2	0	1	-1	1	-2	0	-1	1	2	-1	1	-1	0	1	2	-3	0	-1	1	-2
-1	1.396	f00i00	0	-1	1	-1	1	-1	0	-1	2	-2	-1	2	-1	0	1	1	-2	-1	0	-4	3
-1	1.129	000r02	0	0	1	-1	0	-1	-1	-1	1	2	-2	1	0	-1	1	0	-1	1	-2	-3	2
-2	1.582	000i10	0	0	0	-1	0	-1	0	-1	2	2	-1	2	-2	0	-2	3	-5	-2	0	0	-2
-2	1.182	010004	1	0	1	-1	-1	-1	0	-1	1	2	-2	-1	0	-1	1	-2	0	2	-4	-3	1
-3	2.160	001i01 000i01	0	-1	1	-1	0	-1	0	-2	2	2	-2	2	-2	-2	1	2	-5	-1	-2	-5	2
-3	1.493	001r01	0	-1	1	-1	0	0	0	-2	1	2	-1	1	-2	-2	1	2	-5	-1	-2	-4	1
-3	1.227	000r10	0	0	1	-1	0	-1	0	-1	1	2	-1	1	-2	0	-2	2	-5	-2	-1	0	-3
-3	1.093	f00001PPVVV f00001PVVV flaut. f00001PVVV flaut.	0	1	0	-1	2	-1	0	-1	-1	-2	-1	1	-1	0	1	-3	0	-2	-1	-1	-2
-3	0.693	f00002TTVVV	0	0	0	-1	1	-1	0	-1	0	-2	-1	1	0	0	1	-3	0	-2	-1	-3	0
-3	0.427	f01010	0	0	0	-1	1	-1	0	-1	0	0	-1	0	-1	0	1	-2	-1	-1	-2	-1	-2
-4	2.196	000i01 000i01PPVVV 000i01PVVV	0	-1	1	-1	-1	-1	0	-2	2	2	-2	2	-2	-2	1	1	-5	-2	-2	-6	2
-4	0.729	f00001TVVV flaut.	0	-1	0	-1	1	-1	0	-1	0	-2	-1	1	0	0	1	-3	-1	-3	-1	-4	0
-5	1.689	001r01	0	-1	1	-1	0	-1	0	-2	1	2	-2	1	-2	-2	1	0	-5	-2	-3	-5	0
-5	1.422	000002PVVV 000002PPVVV 000002TTVVV 000002TTVVV	0	1	-2	-1	2	-1	0	-1	-1	-2	-2	1	0	0	1	-6	1	-3	-2	-2	-3
-5	1.289	020i01	-1	-1	-1	-1	0	-1	0	-1	2	2	-1	0	-1	-2	1	0	-5	-3	-2	-3	-2

-5	1.022	f00001PVVV	0	1	0	-1	2	-1	0	-1	-1	-2	-1	-1	-1	0	1	-5	0	-2	-3	-1	-4
-5	0.489	f01000	-1	-1	0	-1	1	-1	0	-1	0	0	-1	0	-1	0	1	-2	-3	-3	-2	-2	-3
-6	2.240	000i00 000i00Ppn quasi trem punta d’ arco, pont. 000i00pn quasi trem punta d’ arco, ord. (Lachenmann)	0	-1	1	-1	0	-1	0	-2	2	2	-2	2	-2	-2	-2	2	-8	-4	-2	-5	-1
-6	0.507	f00010	0	0	0	-1	1	-1	0	-1	-1	-1	-1	-1	-1	0	1	-5	-1	-3	-3	-2	-4
-7	1.182	020r01 (unison from two strings)	-1	-1	-1	-1	0	-1	0	-1	1	2	-2	0	-1	-2	1	-2	-5	-4	-3	-4	-3
-8	0.782	f00002 f00002TTVVV	0	0	0	-2	1	-1	-1	-1	-1	-2	-1	-1	0	0	1	-7	-1	-5	-3	-4	-4
-8	0.516	001010	0	0	0	-1	0	-1	0	-1	0	0	-1	0	-2	0	-2	-3	-5	-6	-2	-2	-6
-9	1.707	000r00	0	-1	1	-1	0	-1	-1	-2	1	2	-2	1	-2	-2	-2	-1	-8	-6	-3	-6	-3
-9	0.640	Multiphonic	1	1	-2	0	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	0	-9	0	-6	-3	-5	-4
-11	0.729	f00001PVVV f00001PPVVV f00001PVVV flaut. f00001PVVV flaut. f00001TVVV flaut. f00001	-1	-1	0	-2	1	-1	-1	-1	-1	-2	-1	-1	-1	0	1	-7	-4	-8	-3	-5	-6
-11	0.462	000010	0	0	0	-1	0	-1	0	-1	-1	-1	-1	-1	-2	0	-2	-6	-5	-8	-3	-3	-8
-12	0.827	f00000 f00000TTLL	-2	-1	0	-1	1	-2	-1	-1	-1	-2	-1	-1	-1	0	1	-8	-4	-9	-3	-5	-7
-12	0.827	001001	-1	-1	-2	-1	-1	0	0	-2	0	0	-1	0	-2	-2	1	-6	-6	-9	-3	-7	-5
-13	0.782	f00001	-2	-1	-2	-1	1	-1	-1	-1	-1	-2	-1	-1	-1	0	1	-9	-4	-10	-3	-5	-8
-14	0.862	001001	-1	-1	-2	-1	-1	-1	0	-2	0	0	-2	0	-2	-2	1	-8	-6	-10	-4	-8	-6
-15	0.800	000002	0	0	-2	-1	-1	-1	-2	-1	-2	-2	-2	-1	0	-1	1	-14	-1	-11	-4	-9	-6
-16	0.729	001000	-1	-1	-2	-1	0	-1	0	-2	0	0	-2	0	-2	-2	-2	-7	-9	-12	-4	-7	-9
-21	0.640	000001 (= ord.) 000001TTVVV flaut.	-1	-1	-2	-1	-1	-1	-2	-2	-2	-2	-2	-1	-2	-2	1	-15	-6	-16	-5	-12	-9

Appendix 3. Visual representation of the 15 descriptors

This presentation of the 15 descriptors follows no particular order or grouping (such as the Temp, Freq, Amp subtotals). This visualisation can help readers who are familiar with FFT-based analysis locate the spectral information in our spectral descriptors of noisiness.

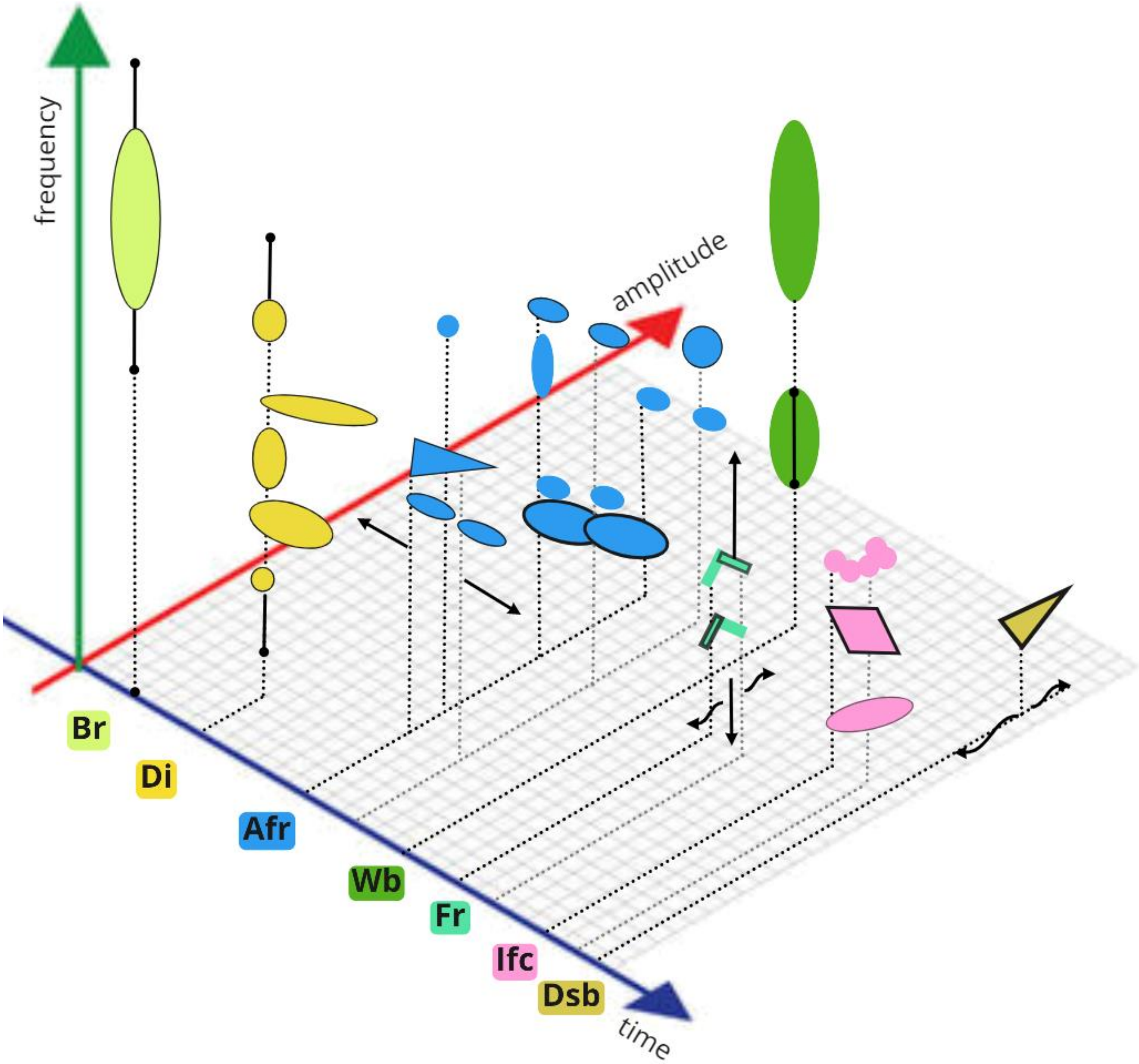


Fig. App. 3.-1. Seven of the spectrotemporal descriptors (Br, Di, Afr, Wb, Fr, Ifc, Dsb) demonstrated in spectrotemporal space (formed by the three dimensions frequency and amplitude in time).

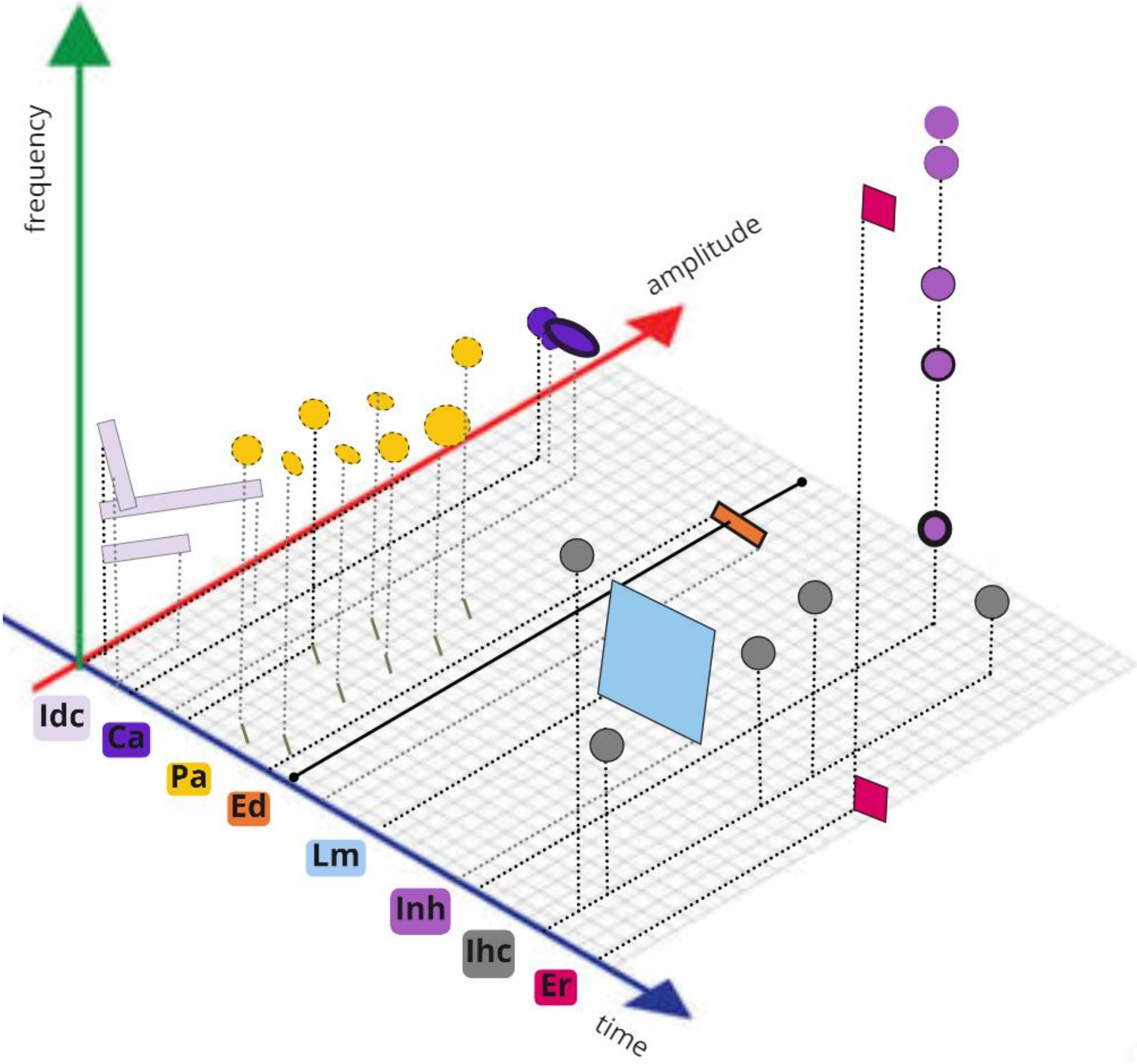
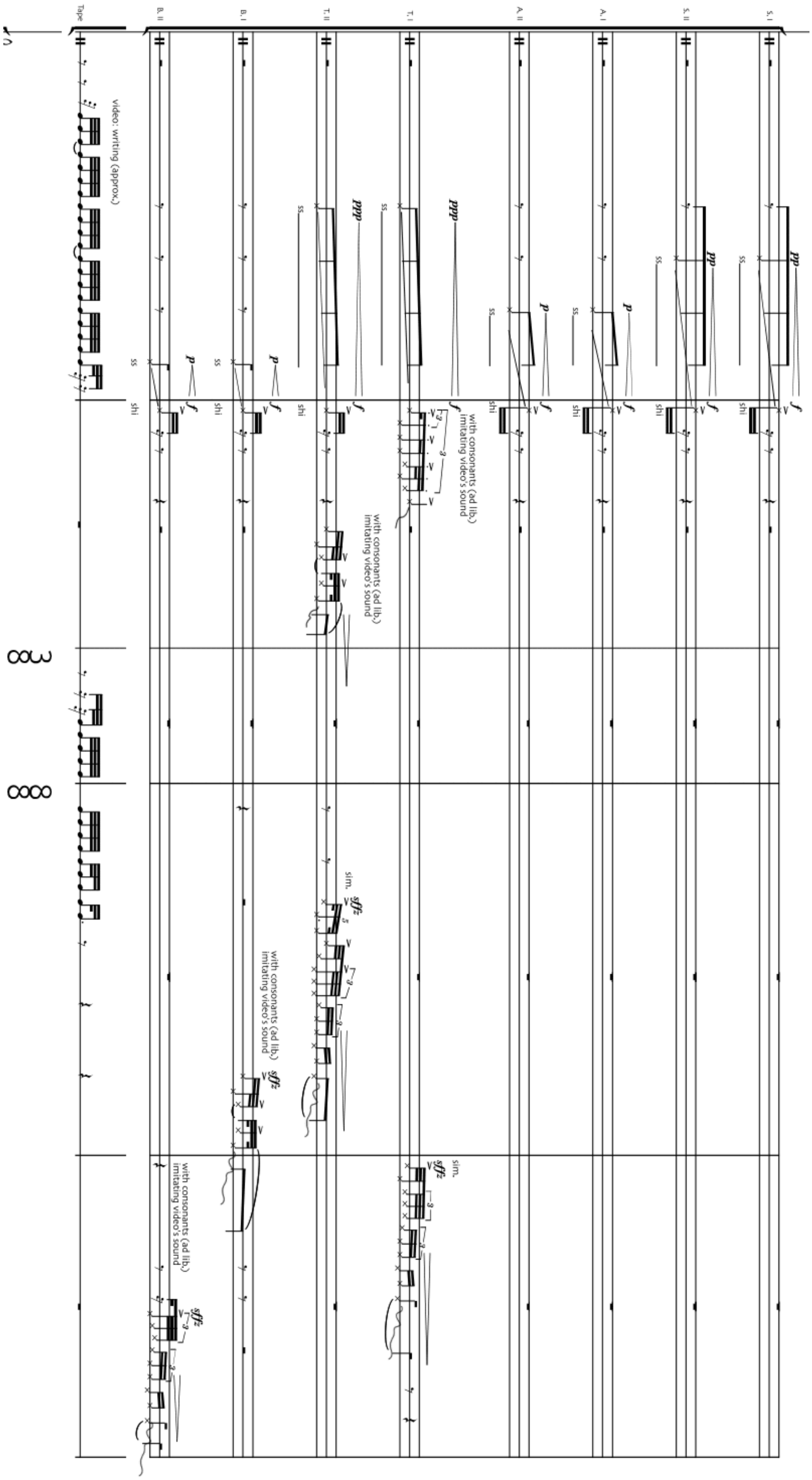


Fig. App. 3.-2. The remaining eight spectrotemporal descriptors (Idc, Ca, Pa, Ed, Lm, Inh, Ihc, Er) demonstrated in spectrotemporal space (formed by the three dimensions frequency and amplitude in time).

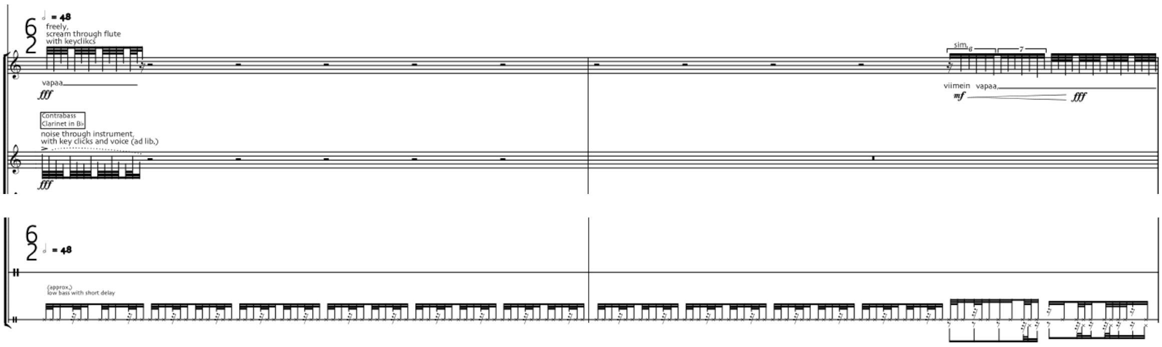
Appendix 4. Score examples

The Figures Fig. App. 4.-a…n are labelled after the composer.

a) **Auvinen**, the beginning of segment 1, excerpt:

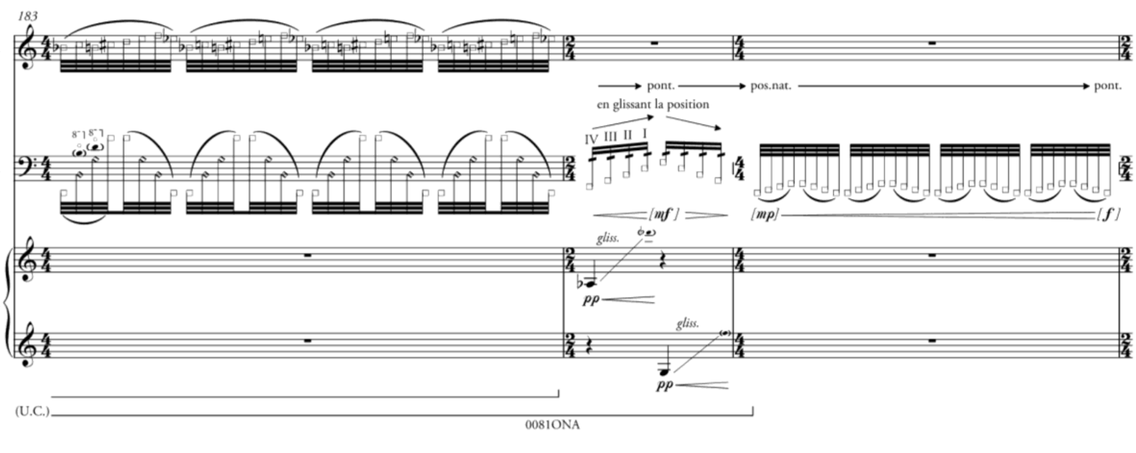


b) The beginning of segment 2, excerpt:



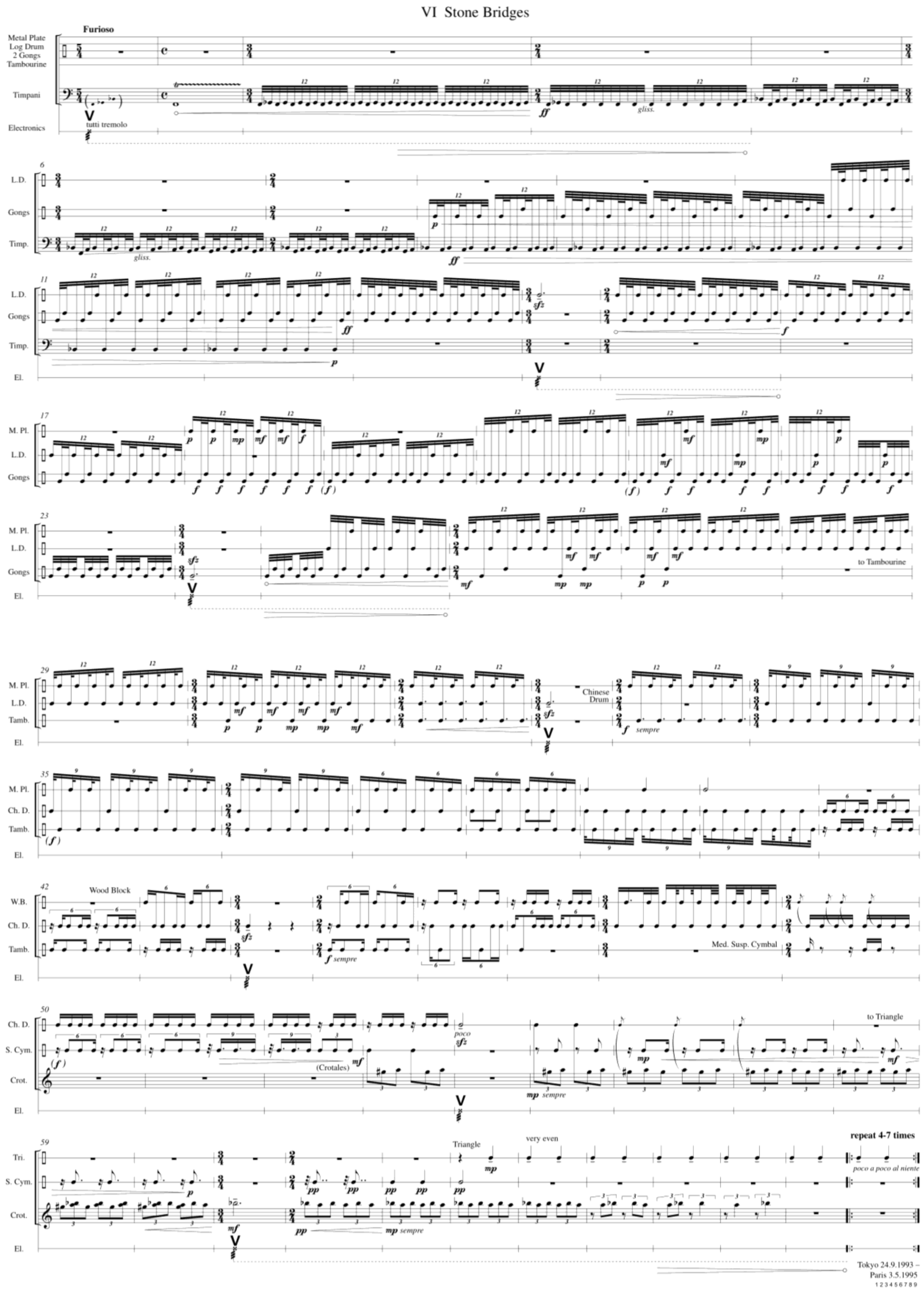
c) The beginning of segment 3, excerpt:

d) **Pesson**, the whole analysed passage:

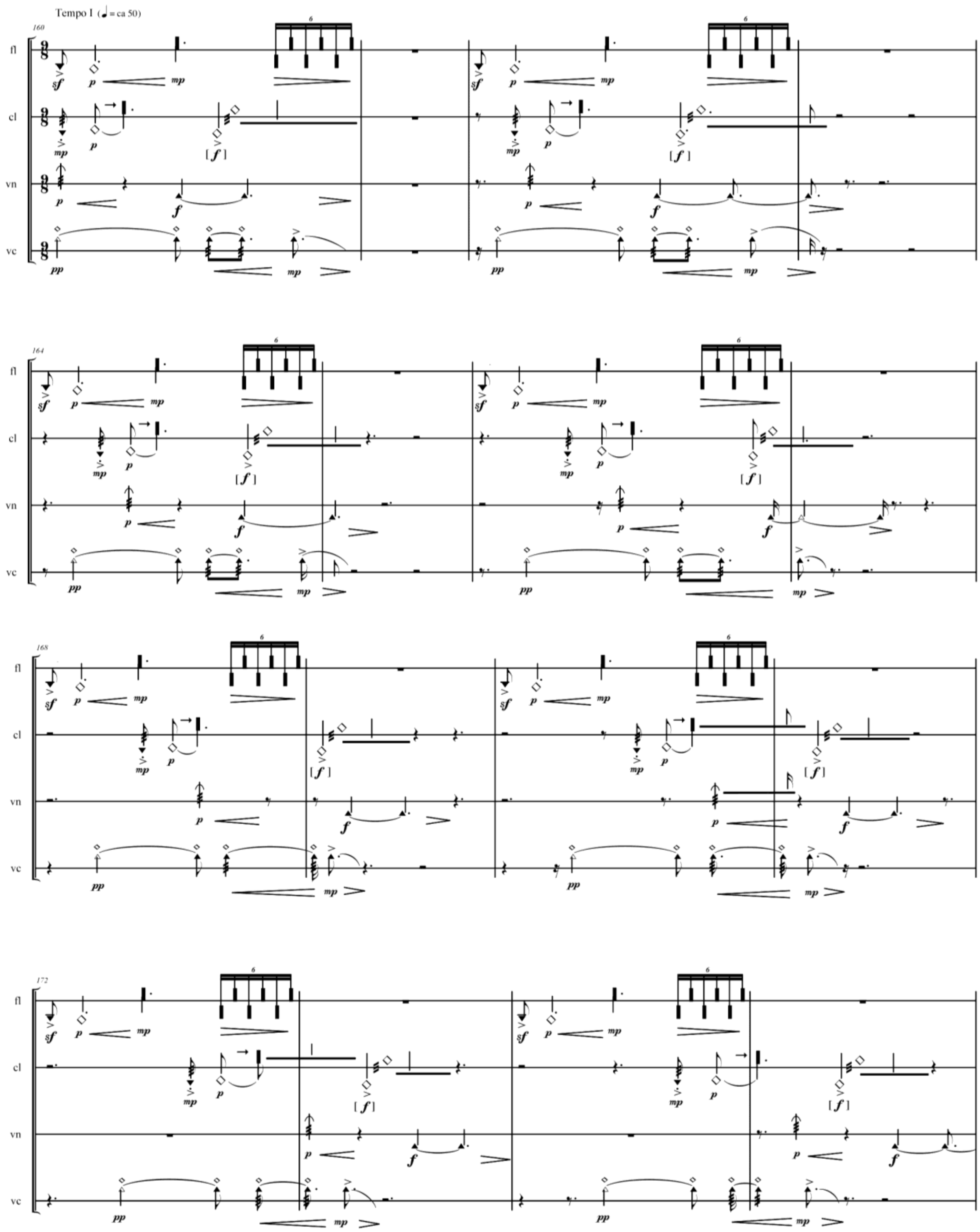


* a) fermer la main sur les cordes
b) pizz. arpégé cordes étouffées en changeant la position
c) relâcher la main

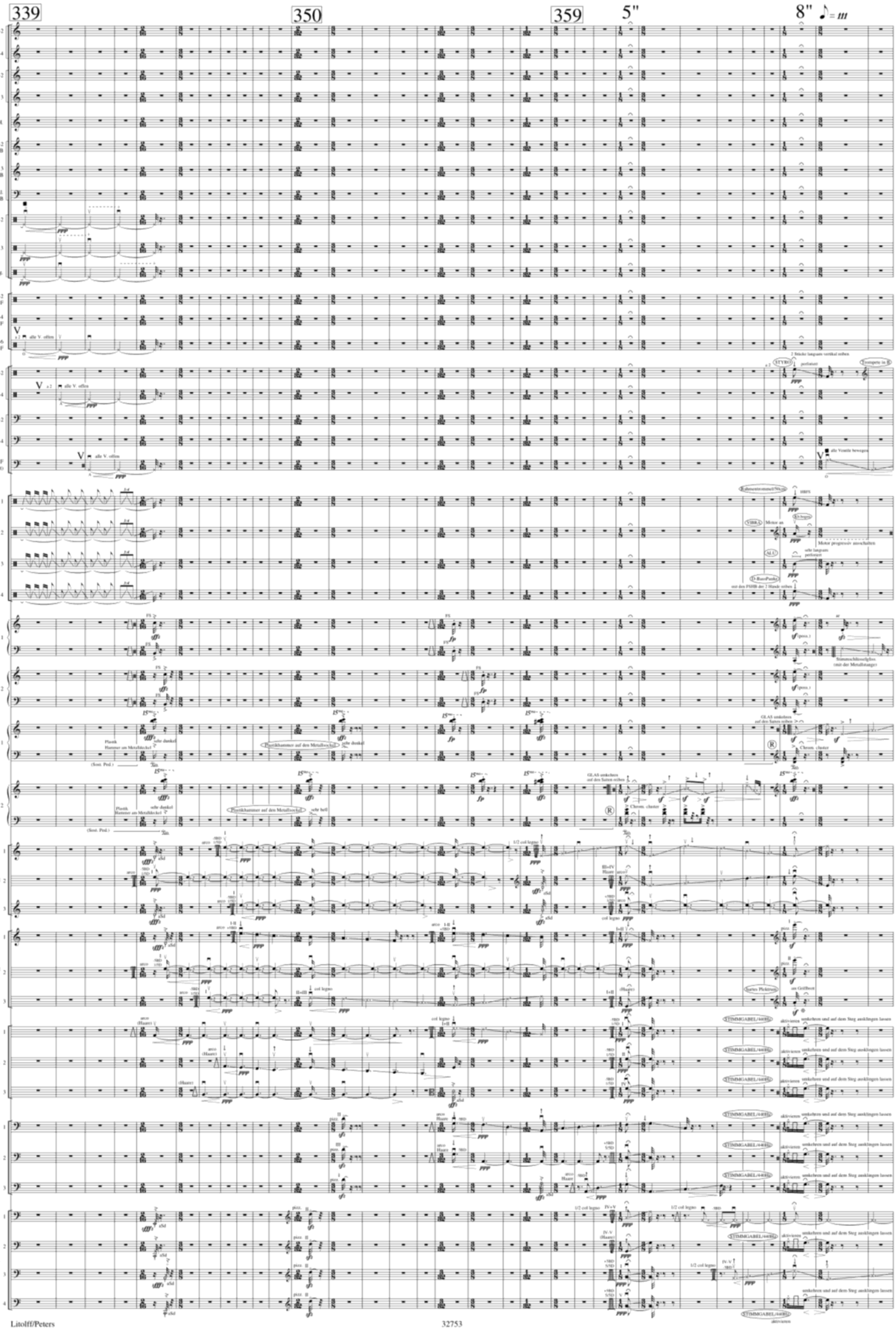
e) **Saariaho**, the entire movement.

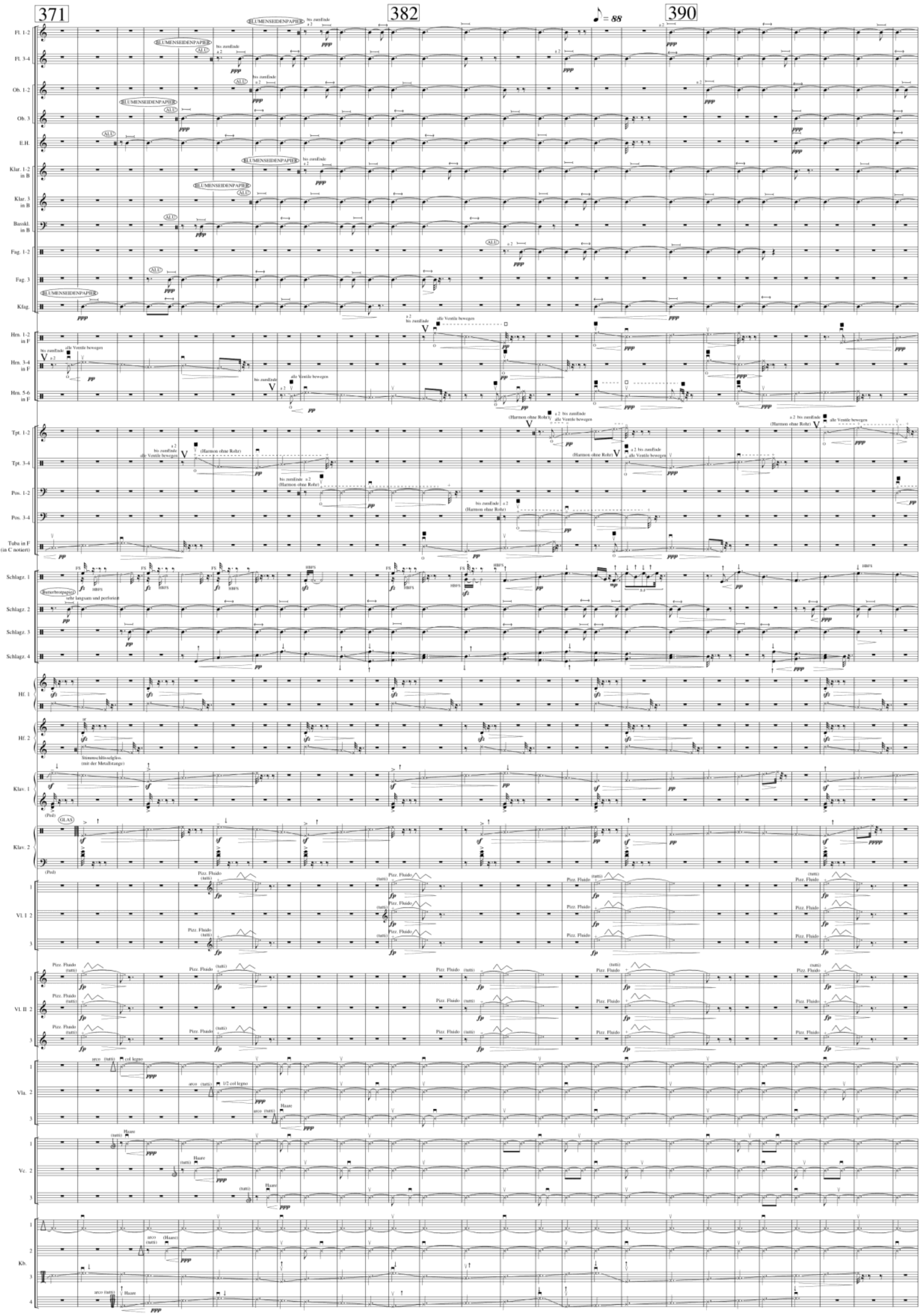


f) **Zubel**, excerpt from the beginning.

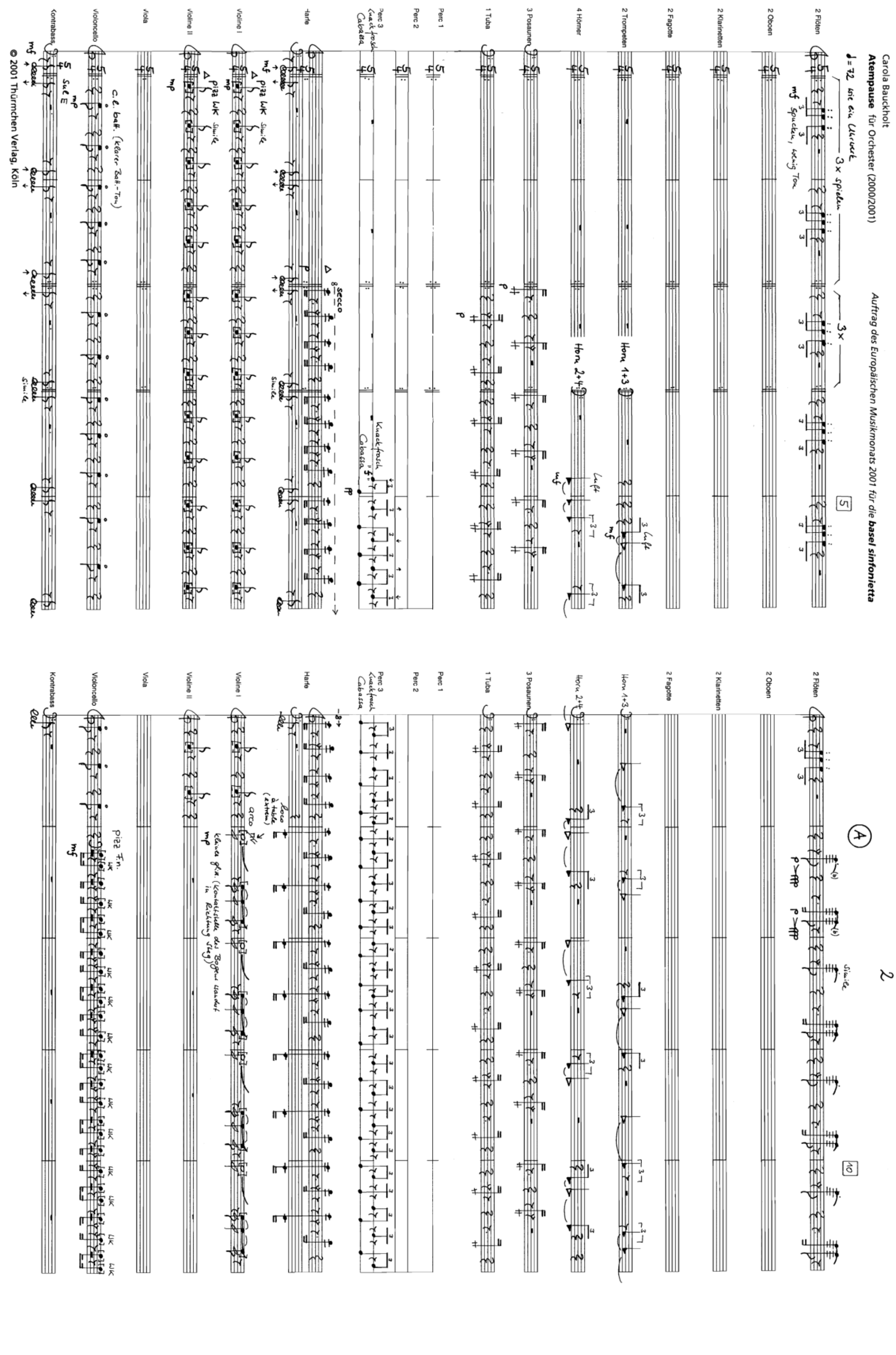


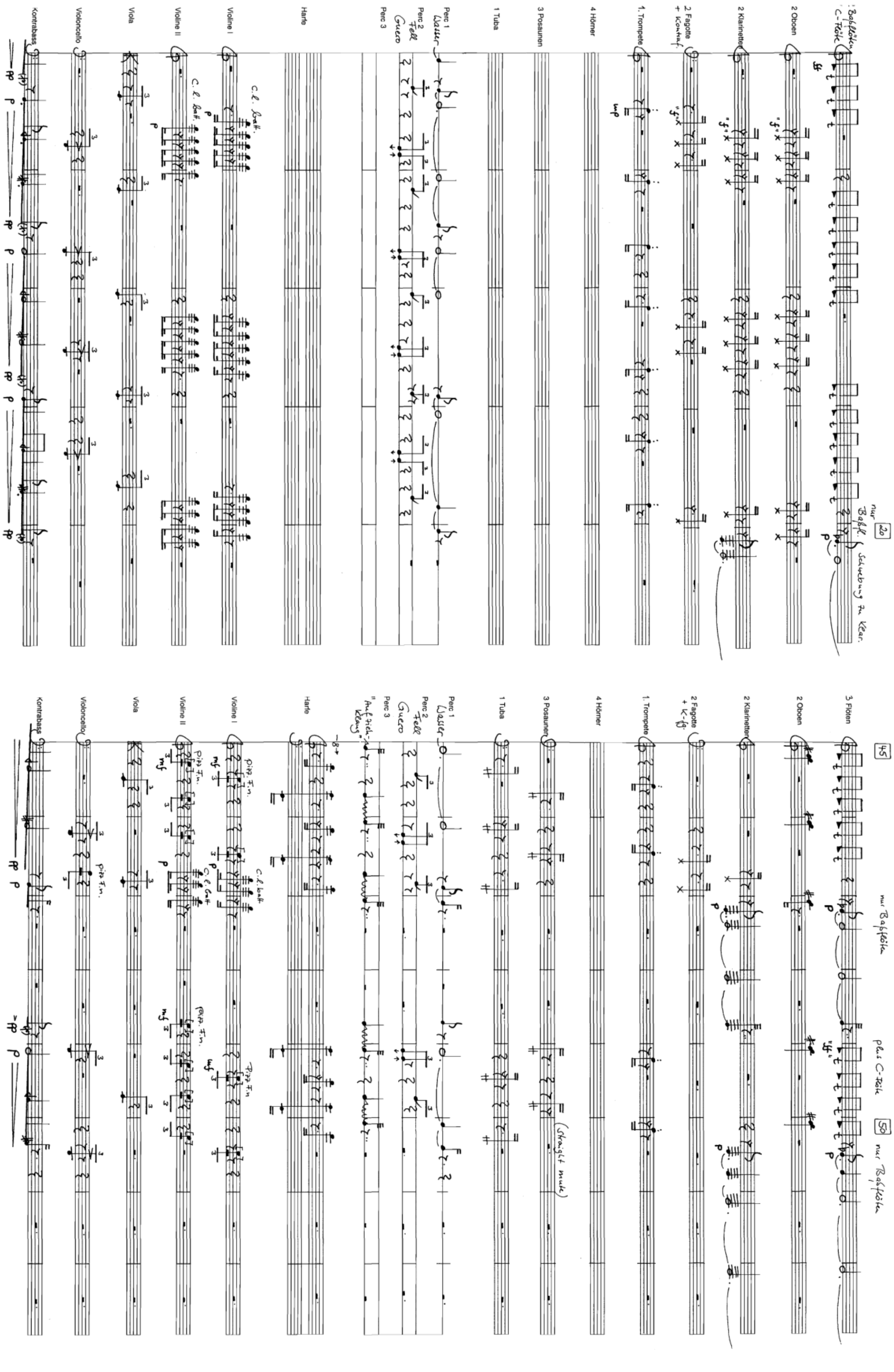
g) **Andre**, end of segment 1, start of 2 at m. 343, start of segment 3 at m. 369.



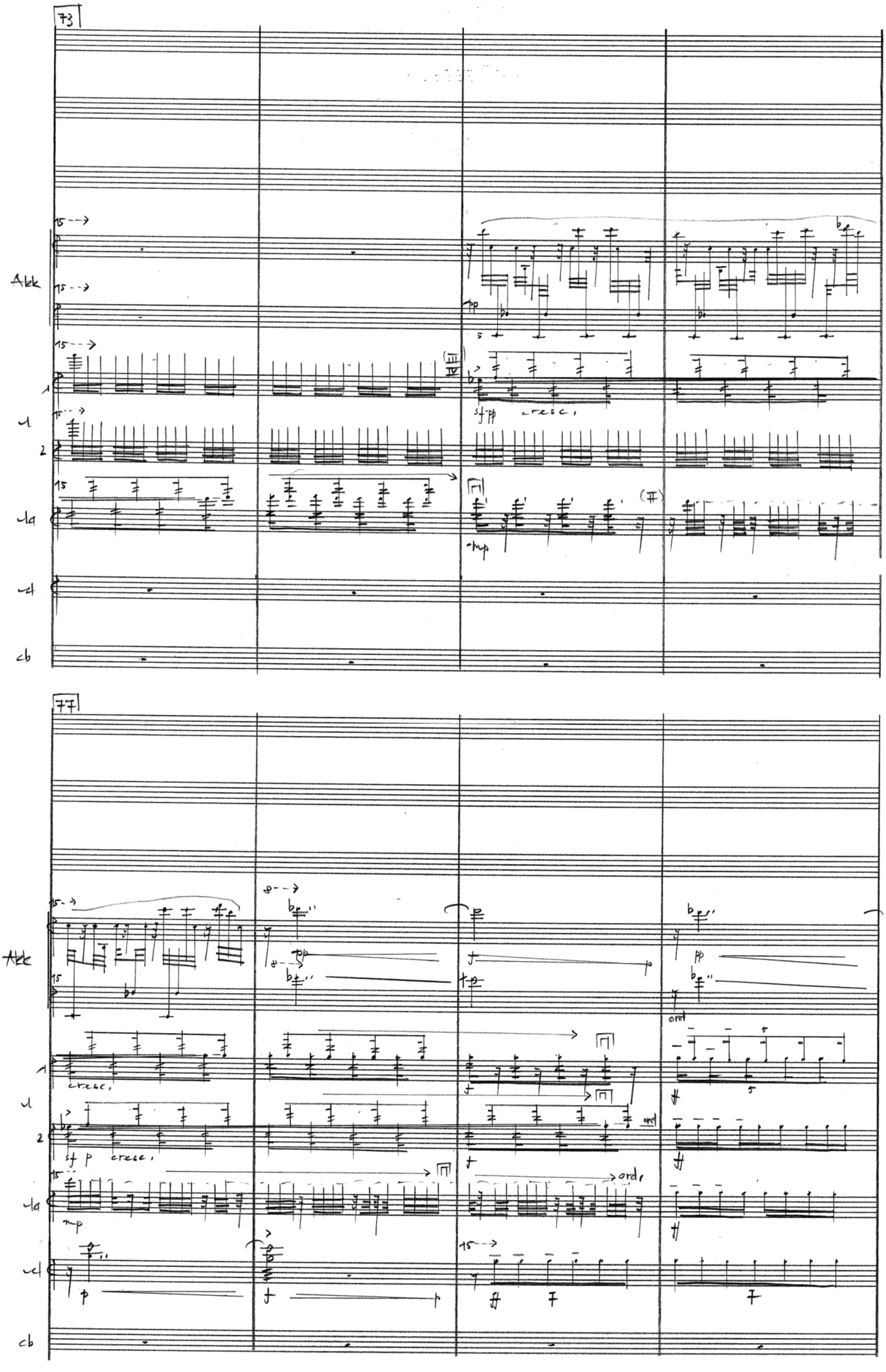

371
382
390
= 88
Fl. 1-2
Fl. 3-4
Ob. 1-2
Ob. 3
E.H.
Klar. 1-2 in B
Klar. 3 in B
Basskl. in B
Fag. 1-2
Fag. 3
Kfag.
Hrn. 1-2 in F
Hrn. 3-4 in F
Hrn. 5-6 in F
Tpt. 1-2
Tpt. 3-4
Pos. 1-2
Pos. 3-4
Tuba in F (in C notiert)
Schlagz. 1
Schlagz. 2
Schlagz. 3
Schlagz. 4
Hf. 1
Hf. 2
Klav. 1
Klav. 2
Vl. I
Vl. II
Vla.
Vc.
Kb.

h) **Bauckholt**, excerpts of several stations.

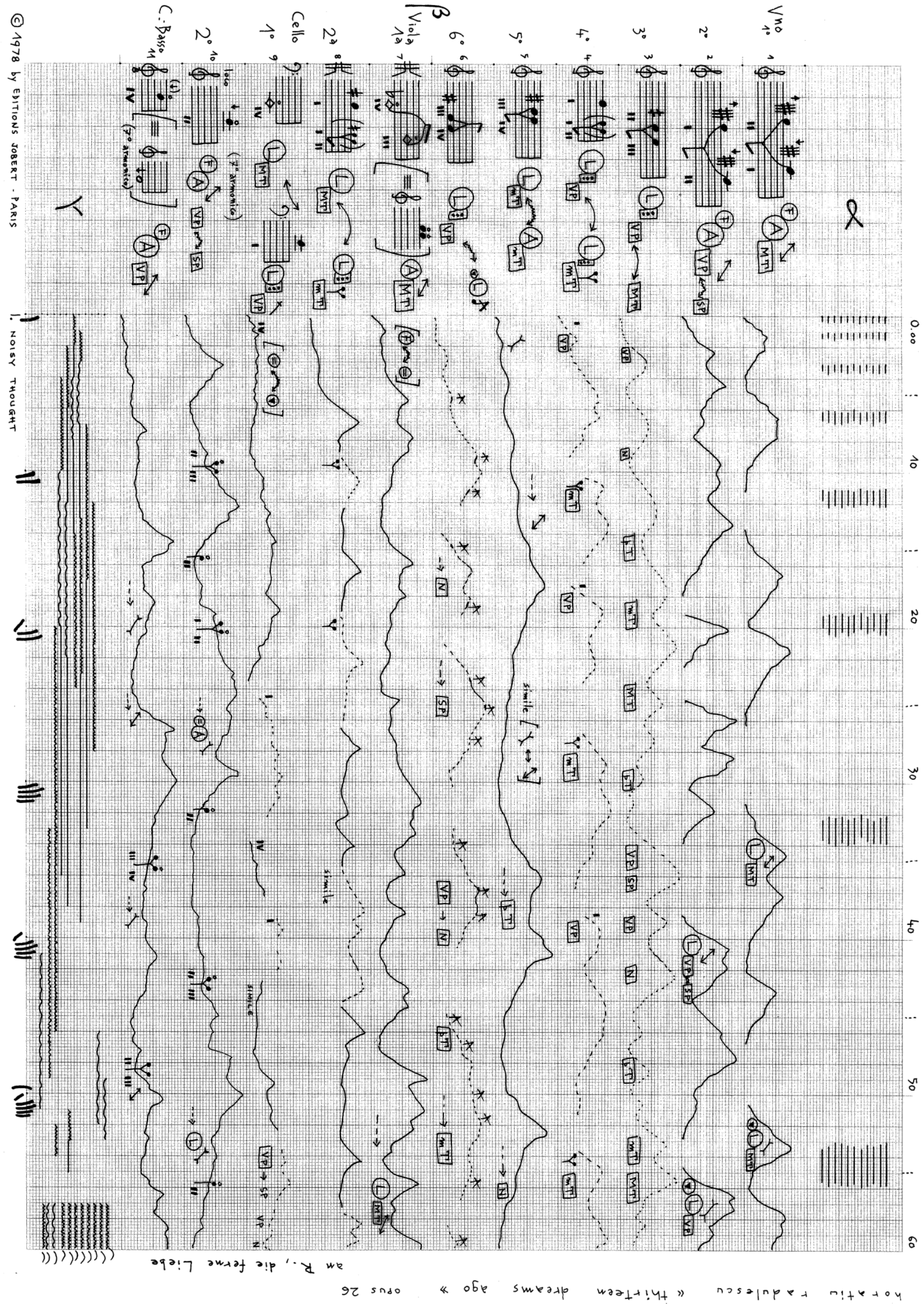



4
Kontrabass
Violoncello
Viola
Violine II
Violine I
Harfe
Perc 3
Perc 2
Perc 1
1 Tuba
3 Posaunen
4 Hörner
1. Trompete
2 Fagotte
2 Klarinetten
2 Oboen
20
8
Kontrabass
Violoncello
Viola
Violine II
Violine I
Harfe
Perc 3
Perc 2
Perc 1
1 Tuba
3 Posaunen
4 Hörner
1. Trompete
2 Fagotte
2 Klarinetten
2 Oboen
3 Flöten
45
50
nur Baßflöten

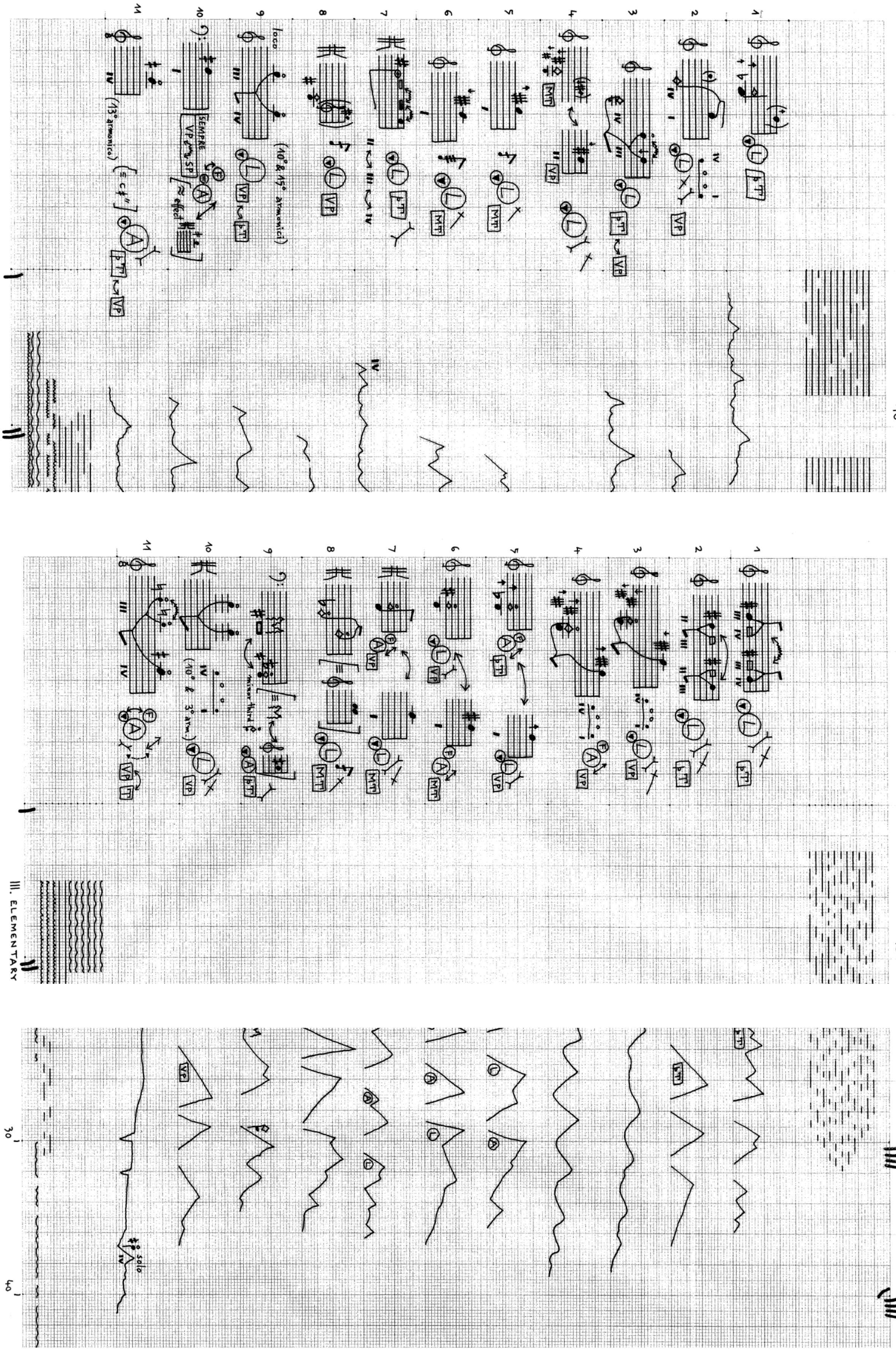
i) **Furrer**, excerpt from the beginning of the sixth cycle.


73
Akk
vl
vla
vcl
cb
cresc.
77
ord.

j) **Rădulescu,** , excerpt from the start and development of aggregate 1. This page of notation lasts 60 seconds.



k to m) Above to below: start of aggregate 2, start of aggregate 3, end of aggregate 3.



n) **Lachenmann**, excerpt from m. 142–152, the middle of the analysed passage.

x) Trompeten: Die eingeklammerten Töne zeigen die Ventilstellung an (die anderen Notenköpfe entsprechen dem Helligkeitsgrad)

148
Fl.
4 Ob.
3 Klar.
4 Hn.
3 Trp.
3 Pos.
2 Tuben
Jet whistle
Gr. Trommeln
Fell mit zuvor aufgelegter Bürste gestrichen
Pk.
Fell mit zuvor aufgelegter Bürste gestrichen
Schlagz.
Tamtam
(weich)
Pfte.
1. 2.
(ph. A.) „H“ [a]
a 4 (con sord.)
Vl.
c. s. I
c. s. II
c. s. III
c. s. Br.
c. s. C.
c. s. Kb.
pont.

Appendix 5. Method in outline

Fig. App. 5.-1. The procedure with our analytical modules illustrated.