Two Methods for the Reinstrumentation of Timbre-based Music

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Abstract: This article proposes two preliminary practical models when reinstrumenting timbre-based music for a different acoustic instrumental setup for use by composers. I apply these methods to an excerpt of my music which relies on timbral structuring. This shows how reinstrumentations of timbre-based music need to differ from reinstrumentations of pitch-based music which may transfer sounds by octaves and otherwise retain pitch structure yet have not systematically transferred timbre.

Timbre-based reinstrumentation requires diligent study of what the timbres are in a piece in which determinate pitch material might be absent or structurally irrelevant. Much timbre-based music has abandoned the structuring power of pitch organisation in favour of smoothly structuring the gradations of timbre itself. The continuum between pitch and noise, which can be quantified with various spectrotemporal descriptors, is of particular value in understanding timbre-based structuring in music.

Both methods suggest an ethos of reinstrumentation that detaches from mimicking the notation of the original and seeks instead the *highest fidelity* reproduction of a listener's dramaturgical experience of a timbre-based piece. Fidelity includes preserving the original compositional intention, an accurate replication of what sounds will sound in a standard performance, what an average listener's audition will process from it as the piece's dramaturgy, and what that experience can evoke in the listener. The first method introduced here to describe the listener's experienced dramaturgy is based on the degree of noisiness. The second method recognises the likeliest intended chronology of the listener's expectations, attention, and rewards, as well as the timbral limits of the goal instrumental setup.

Keywords: reinstrumentation, timbre--based music, noise, spectromorphology, music analysis, listening expectation, dynamic form

1. Introduction

Reinstrumentation is closely linked to *composition, instrumentation*, *and analysis,* and most reinstrumentations are made by composers, professional arrangers, music theorists, musicologists, and conductors. Requests for rapid reinstrumentation may arise from concert organisers for practical reasons of programming or changes to the performing body where a reliable method can prove helpful. When discussed under the topic of transcription, instrumentation is a necessary part of any compositional process and is widely included in academic music curricula, more so than reinstrumentation. Conventionally, instrumentation means the application of an abstract (often notated) musical construction to instruments, while reinstrumentation concerns a swap of the performing instruments, most typically in a piece of music in which the phenomenon of pitch provides the foundation of motivic-thematic material and in which networks of pitches structure the piece overall. The basis of reinstrumentation, however, changes drastically when the organising substance of a piece is not pitches but noise or other strong manifestations of timbre.

The discourse of *pitch-based* versus *timbre-based* music was proposed by Leigh Landy[1] and reflects on the experientially most structuring, non-reducible features in a given piece of music. He defines *timbre* as the audible and often instrumentally controllable features of sound that are outside the notions of pitch level, amplitude, location, acoustic features of the space, or timing. In pitch-based music, (exact) pitches prevail while timbre-based music either lacks determinate pitch or minimises its structural role. In between lies music that develops timbre yet still has pitches as the main medium of structuring. Timbre-based music needs more analytical means and is my interest with the present method.

Essentially, all music that is not pitch-based is timbre-based and follows some (not always consciously applied) logic of timbre. The conventional model for reinstrumentation proceeds from replicating pitch to transferring the original pitches to the goal instruments. While the reinstrumentation of timbre-based music poses different questions than conventional pitch-based music, the *fidelity* can be similar to conventional "note-for-note fidelity".[2] Timbral changes work for pitch-based repertoire without negatively impacting "note-for-note" fidelity since pitch class is typically not affected by this reinstrumentation, yet the results of a "timbre-for-timbre fidelity" may be challenging. The function of a timbre would have to be matched as closely as possible, in dimensions of timbre that are deemed crucial in that particular case. In timbre-based repertoire, the occurrences of pitch are restricted in time, disallowing a continuous structuring or listening based

1 Leigh Landy, *Understanding the Art of Sound Organization* (Cambridge, Mass.: The MIT Press, 2007).

2 "Fidelity" is a term used by Jonathan Kregor; see Kregor, *Liszt as Transcriber* (Cambridge: Cambridge University Press, 2010), 20.

on pitch, or there are too few different pitches to warrant a network of pitch relations which then could receive structural differentiation.

This notion leads to the two methods of reinstrumentation proposed below. I offer two new tools that do not require access to any specialised analytical software or recordings of extremely rare timbres that software would need to evaluate complex timbres in the piece. Even if samples are available on an editing platform, software seldom offers a ready-to-use instrumentation solution.

Often, the act of reinstrumentation is motivated by practical need: an original piece exists, and the particular chronology of the effects that it can evoke in the listener should be preserved. This chronology is transferred to a new instrumentation with fidelity towards the intended effects. In classical orchestral transcriptions made from tonal pieces written for piano, an essentially single-timbre instrument, reinstrumentation aims at an enrichment by the addition of timbre-based effects, since timbral organisation was lacking in the piano version. In the case of my music analysed below, however, timbral organisation is not only already present in the original but essential to its effects.

Reinstrumentation of timbre-based music potentially endangers the high-fidelity preservation of effects that occur from timbral organisation, while effects from rhythm, pitch, and dynamics are mostly unaltered. Since the original compositional intent with timbres can differ from the eventual effects of timbral organisation on the listener, I take the effects as the starting point of reinstrumentation. I recognise two methods for dealing with these effects. My focus is *two new tools of spectrotemporal analysis* providing new perspectives on the activity of reinstrumentation.

For the researcher and instrumentator (in this case, the re-orchestrator), there exist up-to-date computer software methods, such as Orchids or CataRT, for the analysis of timbre that generally fulfil the needs of instrumental substitution for pitch-based repertoire.[3] Conceptually closest to this in the past, some conventional orchestration manuals included instrument substitution charts.[4] I present here a more tailored method that focuses on timbre and furthers the inclusion of noisy timbres into analysis and instrumentation. Similar research is still rare.[5] This way, the reinstrumentation process can include noisy sounds and be practical, faster, and more accessible to any composer, without the need for timbral analysis software.

3 The substitution of timbres is here called audio mosaicing. See IRCAM and Diemo Schwarz, "IRCAM Tutorials / SKataRT, CataRT & MuBu", 13 December 2021, https://www.youtube.com/watch?v=kNcS7NSn7aI.

4 One such chart that influenced me was included in Alfred Blatter, *Instrumentation and Orchestration*, second edition (New York: Schirmer Books, 1997).

5 Among the current research on the topic, see particularly Arash Majd, "Post-Pitch World: Timbre as the Primary Element of Form" (PhD dissertation, University of California, 2020).

I propose specific *timbral descriptors* developed to evaluate different perceivable features of a sound, including considerably inharmonic timbres as well. Some readers may be familiar with the Timbre Toolbox or the articles on this subject by Megan Lavengood,[6] which deal with empirical measurements of timbre. The most complex calculation in my subjective method will be applied in section 3. Combining the descriptors allows the achievement of accurate, discriminating, and balanced representation of the sound.[7] Both the commonly used software and my method conduct similar detailed work with timbral audio descriptors. Generally utilised software often rather speaks of audio descriptors, since their theoretical background is in speech-modelling projects. We seek an application that more directly springs from and applies to contemporary timbre-based music. Particularly, my descriptors are geared towards identifying relevant *spectromorphology* and *noisiness*. In the repertoire explored here, the most meaningful immediate and structurally robust dimension in listening is no longer pitch height, but because of the missing harmony, we are left with listening within the continuum between pitch and noise.[8] I understand noisiness as the combined effect of features of sound that diminish its intelligibility as one singular and stable pitch. The widely circulated term "spectromorphology"[9] describes the minute differentiations between sounds as their contour in frequencies and dynamics is observed over time. Spectromorphological aspects can be visualised in FFT[10] spectrograms of the sound and can constitute a strategy of listening. Such an analytical focus derives from the notion that morphological differentiation in timbre-based music relies on more than differences between pitches but rather takes into account the entire sound phenomenon.

One drawback of such FFT-based software has been the *need to define the time segments* for each timbre from a sounding sample, while with notated instrumental music the individual sounds are considered as heard in their full temporal and morphological extent in a way that affects the perception of timbre. However, the process of human hearing unwinds in several steps and operates at varying magnitudes of delay relative to

6 Megan L. Lavengood, "The cultural significance of timbre analysis: A case study in 1980s pop music, texture, and narrative", *Music Theory Online* 26, no. 3 (2020); and Geoffroy Peeters, Bruno L. Giordano, Patrick Susini, Nicolas Misdariis, and Stephen McAdams, "The Timbre Toolbox: Extracting audio descriptors from musical signals". *The Journal of the Acoustical Society of America* 130, no. 5 (2011): 2902–2916.

7 On the subjective features, see Juhani T. Vesikkala, "The Noise–Pitch Continuum in Timbral Music" (PhD dissertation, HAMU, Prague, 2022), 17–20, and comparison of descriptors, 62–68.

8 A realisation proposed by Kaija Saariaho, among others – see Kaija Saariaho, "Timbre and Harmony: Interpolations of Timbral Structures", *Contemporary Music Review* 2, no. 1 (1987): 93–133.

9 From Denis Smalley, "Spectromorphology: Explaining sound-shapes", *Organised Sound* 2, no. 2 (1997): 107–126.

10 Fast Fourier Transform, a standard method for numerically and visually demonstrating the audible content of a sound, which can help the analyst determine what is likely attended to in listening.

the sounds heard; the fleeting moments that audition can observe “are not in any sense the content of auditory perception”.[11]

The terminological difference between sounds and timbres is blurred once the temporal and morphological progress of an instrumental sound is taken into account. One might, for example, describe the freely released sound of a bamboo tree, blocks of wood seemingly chaotically hitting each other, by the Smalleyan term “swarming”. If a segment from the decay of the sound were to be spectrally analysed, this would hardly do justice to the listening experience of the sound. When focusing on timbre, sound descriptors tend to reduce exact fundamental pitch and include registral region information instead. Some descriptors may even survey the physicality of playing efforts on the original instrument, even if reinstrumentations cannot carry this over to the new instrumentation (such as noisiness from the registral extremes being carried over from a pitched instrument to certain percussion instruments).

In my analysis below, 15 descriptors will be a sufficient number of numeric determinants to describe how a timbre may be perceived by an average listener who employs a timbral focus in listening. In comparison, noisiness in the existing software might be simply addressed by one descriptor: periodicity.

Some weighable descriptors are self-explanatory and uncontroversial: brightness, loudness, pitch, and periodicity. Methods of reinstrumentation include a step in which a timbre is identified in the original piece and mapped to another timbre in the resulting reinstrumentation. This mapping solution may be mechanical or contextual. In *mechanical mappings*, any occurrence of a certain timbre will be rewritten as a certain other timbre and creates a fixed pairing of timbres in the original vs. the result, whereas *contextual mapping* has no such fixed pairs, but rather the same timbre in each of its occurrences may result in a different timbre each time.

Timbre-browsing interfaces (scrubbing) may, however, develop into an undesired source of confusion if a great corpus of sounds is offered and no direct unidirectional mapping solution is shown. Here, the proposed method shows the existence of such interfaces by positioning timbres visually into a two-dimensional space for easy access. It is undertaken entirely without sound recordings or computer software.

2. The original piece before reinstrumentation

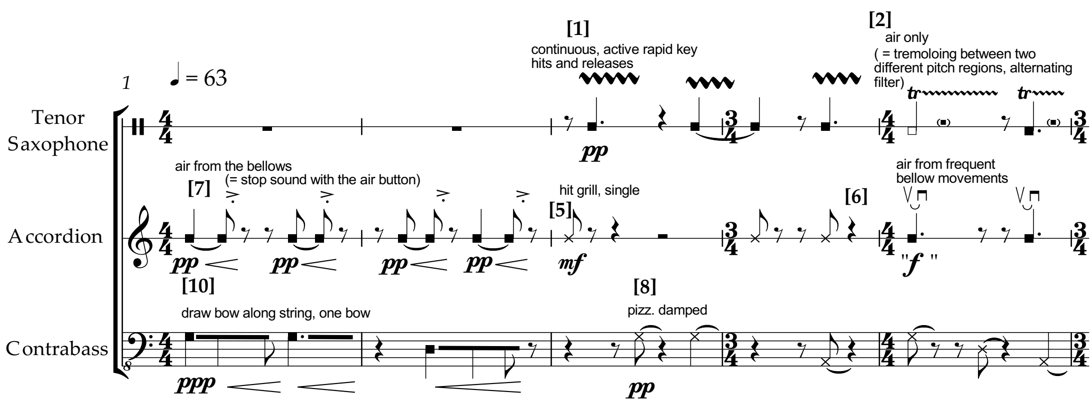
The practice of composing for rare instrumentations was historically supported by the prospect that the piece could be later reinstrumented to reach a broader public as reductions for the piano, and that this process for tonal music was relatively simple. Yet simultaneous with timbre-based interests developing in the early 1900s, compositions

11 Roman Ingarden, *The Work of Music and the Problem of its Identity*, trans. Adam Czerniawski (Berkeley: University of California Press, 1986 [1966]), 32.

tended more towards instrumentation-dependence and utilised the ethos of what Tomi Mäkelä[12] calls the “special ensemble”. The practice of reinstrumentation has since become a possibly intimidating task, and examples of successful reinstrumentations of timbre-based music are hard to find.

A composer who encounters requests from concert organisers for reinstrumentation might calculate the task as being too great and too risky, since the composer-reinstrumentator first needs to guarantee a preferably systematic and smooth means of reinstrumentation before embarking on the task. This makes it preferable to rather compose a brand-new piece for the requested goal instrumentation. Reinstrumentation to the goal setup is an appealing alternative and the basis for this article. My reinstrumentation methods will apply when the composer is determined that a particular timbre-based piece of music can function regardless of its specific timbres and that the same *timbral functionality* on which the piece relies can be realised with a different set of instruments.

The topic of *timbral functionality* in timbre-based repertoire is loosely analogous to tonal functionality, as a feature that should remain unaffected in the piece after reinstrumentation. The example piece here (Fig. 1) is a trio sketch composed for this occasion for tenor saxophone, accordion, and double bass, which I as the author aim to reinstrument for string quartet.



12 Tomi Mäkelä, *Klang und Linie von* Pierrot Lunaire *zu* Ionisation*: Studien zur funktionalen Wechselwirkung von Spezialensemble, Formfindung und Klangfarbenpolyphonie* (Frankfurt am Main: Peter Lang, 2004).

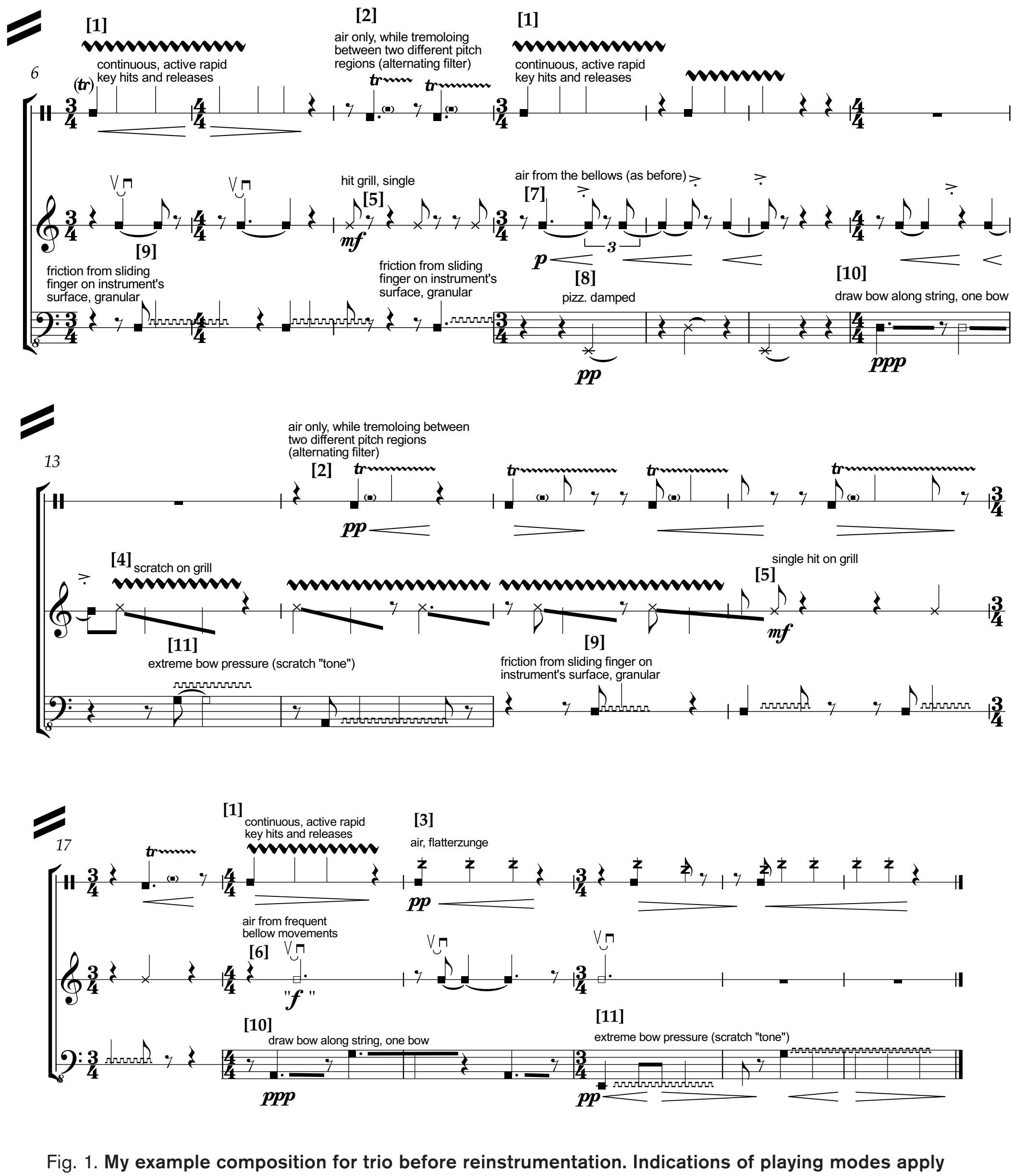


Fig. 1. **My example composition for trio before reinstrumentation. Indications of playing modes apply until the next marking.**

On closer inspection, it is possible to distinguish 11 distinct timbres, each connected to a morphology and dynamic. The excerpt features the following timbres (see Table 1), listed by instrument:

Tenor saxophone (three timbres)	Timbre 1) continuous, active rapid key hits and releases; Timbre 2) air only, tremolo between two different pitch regions (alternating filter); Timbre 3) air, flatterzunge.
Accordion (four timbres)	Timbre 4) scratch on grill; Timbre 5) hit grill, single, *mf*; Timbre 6) air from frequent bellow movements; Timbre 7) air from the bellows, crescendo, almost immediately stopped with the air button.
Double bass (four timbres)	Timbre 8) pizz. damped; Timbre 9) friction from sliding finger on instrument's surface, granular; Timbre 10) draw bow along string, one bow, ppp; Timbre 11) extreme bow pressure, con pressione ultimo (scratch "tone").

Table 1. **The 11 instrumental timbres in the original composition**

In the following text, I will present two reinstrumentation methods and show how the necessary analytical steps can be done with different degrees of preserving the timbral organisation, even when the number of instruments changes. Notably, when transferring from three to four instruments, it is not possible to follow the strictest mechanical reinstrumentation, yet the fact that the goal setup is timbrally more uniform and includes two violins will facilitate the process.

The methods range within the continuum from mechanical to context-aware instrumentation, featuring the following aspects:

- All occurrences of timbres in the original are reflected by occurrences of same or similar-sounding timbres in the resulting piece, at the same pitches (where pitch is present).
- Mechanical vs. contextual mapping; one sound in the original either always becomes a certain sound in the result or the resulting sound can vary slightly based on the timbral structure of the piece.
- Preservation of instrumental lines: the number of original instruments matches the result.
- "Covering" each pitch, accounting for it in its original register; continuous instrumental lines are altered only when it is necessary due to instrumental balance or limited dynamic or pitch range.

– The sequence of a listener's expectations that come from listening to the most salient sounds and the most structural features is carried over from the original to the resulting piece. The sequence occurs again as such even if not all timbral occurrences, timbral similarities, blending situations, registers, dynamics, or timings are retained.

Both methods entail a thorough timbral analysis and a taxonomy in a two-dimensional timbral space. In both cases, we will analyse the use of timbres in the excerpt of Fig. 1. The analysis of sounds that relies on verbalisation is subjective and must be made by the human analysing the piece before the analysed sounds become part of a taxonomy of sounds. The taxonomy will be used in both mechanical mappings and contextual mappings.

Two types of *chronology* are discussed separately: what I call *reward chronology*[13] in the essentially subjective listening brain and the more objective *timbral chronology*, which is often clearly readable in notation. Reward chronology often differs slightly from the intentions of the composer. I take its source to be what Ingarden[14] calls the "concretion of the heard performance".

Dramaturgy (as borrowed from a different field in the arts) describes the likely intentions for rewards by the composer before the instrumental interpretation of the piece. Dramaturgy is seen in how sounds proceed in notation and can be analysed to form audible, attendable patterns that can result in rewards.[15] Any form-bearing features in a piece are part of its dramaturgy. The timbral chronology intended by the composer plays a large role in the dramaturgy of timbre-based pieces.

In the following sections, the description of the two methods demonstrates how the piece can transform into a reinstrumentation in my goal setup.

3. Method 1

The first method is a *mechanical, exact mapping* of one timbre from the originating instrumentation to another timbre in the goal instrumentation. The mechanical nature of this method also makes this type of mapping feasible to automatise. This method includes a spectromorphological taxonomy of all relevant timbres in the piece. All timbres present in the original piece and all possible timbres playable by the goal instrumentation can be shown in the same two-dimensional timbral space.

I suggest a system of 15 spectrotemporal descriptors, which allow one to roughly distinguish between timbres and to position them appropriately relative to each other.

13 Vesikkala, "The Noise–Pitch Continuum in Timbral Music", 181.

14 Ingarden, *The Work of Music*, 19.

15 The methods cannot account for the rewards from visually observing and "theatrically" listening to the same sound sources.

The descriptors are related to spectrotemporal and morphological aspects of sound and will place the timbres of the original piece within a broader taxonomy of acoustic timbres. The main dimension common to all descriptors is the degree of noisiness. Noisiness is taken to consist of any audible features that make a pitch-based listening even slightly less feasible. The development of such features into the 15 descriptors can be found in detail in my dissertation.[16] They are:

- Brightness or Spectral Centroid (spectrally bright sounds are more tense than less bright sounds[17]);
- Amount and dispersal of simultaneous frequency components (the opposite of Spectral Flatness);
- Inconsistency of the amount and general positioning of frequency components;
- Width of frequency bands;
- Inconsistency of frequencies, especially fluctuating (fundament) pitch level and dynamic presence;
- Independence of frequency contours;
- Dynamic instability of frequency bands when held;
- Internal and textural independence of dynamic contours;
- Lack of clarity between attack (noise) and body of sound (pitch), and amount of attacks;
- Prevalence and role of attacks;
- Energy distribution in time (loud sounds are more difficult to describe);
- The maximum length at which this sound can be achieved (sounds of a short or irregular duration are more difficult to describe);
- Non-harmonicity of relationships between frequency components, also called inharmonicity;
- Non-hierarchical relation of components' strengths, both in FFT snapshot and in decay. This includes changes to the noisiness degree by amplitude vibratos,[18] by noisiness resulting from deviations from the harmonic series, or by volume differences between the harmonics;[19]
- Sense of noisiness brought about by (extreme) register.

16 Vesikkala, "The Noise–Pitch Continuum in Timbral Music", chapter 3.1.1.

17 Fred Lerdahl, "Timbral hierarchies", *Contemporary Music Review* 2, no. 1 (1987): 141.

18 Philippe Manoury, « Les limites de la notion de 'timbre' », in *Le timbre: Métaphore pour la composition*, ed. Jean-Baptiste Barrière (Paris: Éditions Christian Bourgois/IRCAM, 1991), 299.

19 Pasi Lyytikäinen, "Hälyn funktioita musiikissani" [Some functions of noise in my music], *Säteitä 2009* (Helsinki: Sibelius Academy, 2009), 90.

Only the basic definitions of the descriptors are given above. Evaluating each of the 15 descriptors means answering questions, for which the closest matching answer out of five options returns a numeric integer value of −2, −1, 0, +1, or +2, respectively. These options or criteria verbalisations follow five steps, from the most pitched option, through the Froise option (a perceptual balance between pitch and noise components, a portmanteau word for frequency centroids and noise) in the middle, to the most noisy option.[20]

By knowing the 15 descriptor criteria, anyone familiar with timbral listening can classify any new timbre and produce their own values. Users can also customise the process by making their own differing taxonomy or introducing weighting factors to some descriptors. The noisiness value results as a simple sum of the descriptors' values. The full taxonomy, as given in my dissertation, serves as a practical reference for some of the common instruments and composers for the purposes of timbre-based instrumentation.

A useful value that results from these values is *timbral internal variance* (TIV), which is formed by calculating the mathematical variance between sufficiently many descriptor values (in our case 15), to form a balanced selection.[21] Counting the variance applies the formula for population variance, as follows:

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

Put simply, TIV aims to reflect the obstacles that a sound's classification poses to human audition. In the range from 0 to around 4, larger values would mean that the timbre evokes stronger reactions due to its complexity and is internally incongruent, having both pitched and noisy features.

The numeric values of noisiness, TIV, and the 15 descriptors for the timbres of the excerpt are as follows (Table 2):

[20] Froise as the middle region of both noisiness and of the noise–pitch continuum allows a state of multi-stability which can be treated or studied separately, as apparently two writers before me have done; see Tolonen 1969 and Lyytikäinen 2009.

[21] Vesikkala, "The Noise–Pitch Continuum in Timbral Music", 81.

instrument	Tenor saxophone			Accordion				Double bass			
Timbre number and name	1. continuous, active rapid key hits and releases	2. air only, while tremoloing between two different pitch regions (alternating filter)	3. air, flatterzunge	4. scratch on grill	5. hit grill, single, *mf*	6. air from frequent bellows movements	7. air from the bellows, crescendo, almost immediately stopped with the air button	8. pizz. damped	9. friction from sliding finger on instrument's surface, granular	10. draw bow along string, one bow, *ppp*	11. con pressione ultimo (scratch "tone")
Noisiness sum	3	4	0	9	6	5	11	0	2	11	13
TIV	0.560	1.262	1.467	0.773	0.640	1.289	0.462	0.800	0.649	0.996	1.316
A	0	2	0	1	0	2	1	0	0	2	2
B	–1	0	1	0	–1	1	1	–1	0	1	2
C	0	0	0	0	0	0	1	–1	–1	1	1
D	0	0	1	1	1	1	1	–1	0	1	2
E	1	1	–1	1	0	0	0	0	0	1	1
F	0	–1	1	0	0	0	1	0	1	–1	1
G	0	2	–1	0	0	–1	0	0	0	2	0
H	0	–1	–1	0	0	–2	0	0	1	–1	–1
I	0	1	2	2	0	1	0	1	1	2	1
J	2	2	2	2	1	2	1	1	0	2	–2
K	0	–1	–2	0	0	0	0	0	–1	0	2
L	0	–1	–1	–1	2	–1	2	2	–1	0	0
M	1	1	1	1	2	2	2	–1	2	1	1
N	1	0	–1	2	1	0	1	1	0	0	2
O	–1	–1	–1	0	0	0	0	–1	0	0	1

Table 2. **The timbres in the original piece, categorised with the 15 spectromorphological descriptors A to O. Apart from the TIV value, positive values are noise, negative are pitch, and the 0 value corresponds to the intermediate region called Froise. Often, a minimal amount of spectromorphological activity and complexity leads to classification as pitch, a medium amount to Froise, and a large amount to noise.**

The pair of TIV and noisiness forms a two-dimensional graph onto which timbres can be positioned, and the result is called a *timbral canvas*. To show timbral relative positions at this accuracy, two dimensions will suffice, and the basic timbral canvas type is based on TIV versus noisiness. In this example, closeness of timbres will be determined based on the relative position of the two timbres on the TIV–noisiness canvas alone. Later, we will also work with the descriptors grouped by their amplitude, frequency, and temporality.

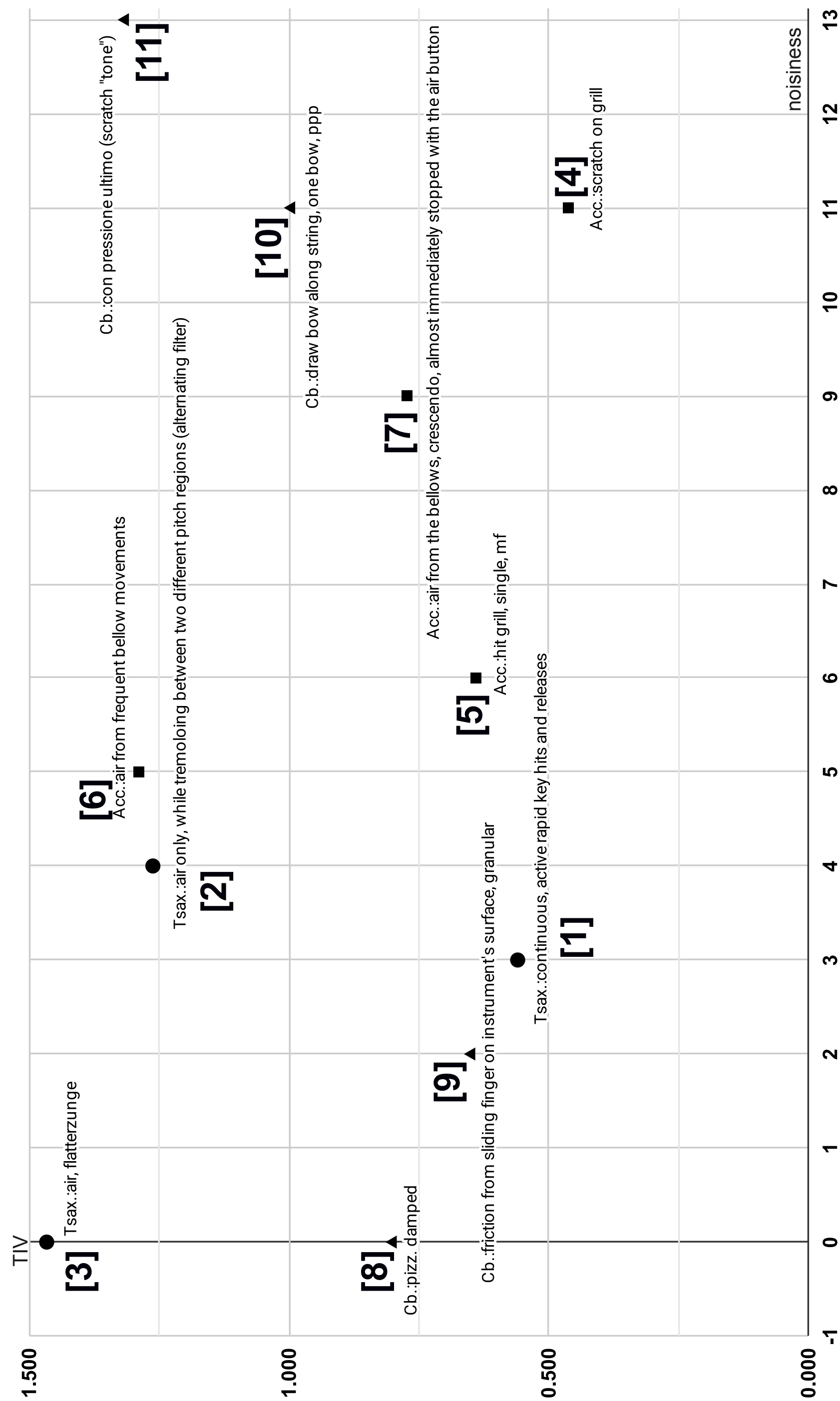
The TIV and noisiness canvas is the most accurate for such comparisons, since both noisiness and TIV values have a wider, more detailed range of values. An exact matching noisiness value should be preferred, and secondarily an exact matching TIV value (which reflects the way the TIV is calculated).

Beyond the closest matching timbre, consideration can be given also to timbres that have a noisiness value ±1 from that timbre and TIV values as similar as possible (compared by simple subtractions from the original value). A demonstration of this particular transfer: the same playing mode is often similar-sounding on the goal ensemble cello and the original double bass, and the sounds of the bass could be closely transferred to the cello as the easiest solution. However, the following solution will look for another nearby sound. Notably, leaving a timbre unchanged is not as commendable a reinstrumentation as one could hope, since the timbre would have different implications for the piece in its new timbral environment. Moreover, a transfer from three to four instruments is an expansive reinstrumentation, and the considerations in an opposite direction will differ slightly. The 11 timbres of the example piece can be visualised as follows (Fig. 2).

When descriptors are grouped[22] according to one of the observable spectrotemporal features frequency (Freq), amplitude (Amp), or temporality (Temp), we can form three new timbral canvases that zoom in on one spectrotemporal feature at a time. For instance, one new canvas is developed of the two axes Temp and NTemp (the letter N standing for *non*). The values of Temp for any given timbre are the sum of those nine descriptors that have a temporal, durative aspect, while the sum of the remaining six non-durative descriptors leads to the NTemp value. Any one of the other three canvas versions could also be used when its representation of timbral movements shows promise structurally.

Fig. 2. **The TIV–noisiness canvas with the 11 original timbres. The vertical axis (TIV) reflects the range of internal complexity values that these timbres have, while the horizontal axis proceeds from the Froise region to the noisy sounds on the right. Instruments are differentiated by the shapes at the timbral canvas coordinate, by circles (tenor saxophone timbres), squares (accordion), and triangles (double bass). Often, this chart would continue to the left to include negative noisiness values (the pitch region), yet this set of timbres does not have pitched sounds. The shape of the timbral constellation shows a central empty area which can contribute to distinguishing between the timbres.**

22 More detail in Vesikkala, "The Noise–Pitch Continuum in Timbral Music", chapter 3.1.3.


TIV
noisiness
[1] Tsax.:continuous, active rapid key hits and releases
[2] Tsax.:air only, while tremoloing between two different pitch regions (alternating filter)
[3] Tsax.:air, flatterzunge
[4] Acc.:scratch on grill
[5] Acc.:hit grill, single, mf
[6] Acc.:air from frequent bellow movements
[7] Acc.:air from the bellows, crescendo, almost immediately stopped with the air button
[8] Cb.:pizz. damped
[9] Cb.:friction from sliding finger on instrument's surface, granular
[10] Cb.:draw bow along string, one bow, ppp
[11] Cb.:con pressione ultimo (scratch "tone")
1.500
1.000
0.500
0.000
-1
0
1
2
3
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It follows that each timbre in the original can be matched to its nearest possible timbre in the inventory of timbres that is available in the goal instrumentation. Many pieces use only a few timbres per instrument and thus many available timbres in the goal instrumentation will find no use at all. If the goal instrumentation has fewer timbres available than the number of timbres in the original, and no instruments remain the same, ambiguity results and some timbres in the result will have come from two or more timbres of the original – that is, several timbres in the original piece map onto one single timbre in the resulting piece.

My method's observations are simplified in that the analysis only considers individual timbres, and simultaneous combinations of timbres are not considered as one unit even when they blend in perception. After all, the blend phenomenon can mostly be explained as resulting from spectrotemporal similarity (and, in pitch-based music, from pitch similarity), which fundamentally results from close distances in timbral space.

With an unambiguous mapping, reverse mapping of the timbres remains possible. The instrumental source is abstracted out and the abstractions can be utilised further in different contexts. Once a timbre has a numeric classification, the reinstrumentator here and in many other typologies can construct a corresponding timbre, which Reibel and Ferreyra[23] call to "deliberately manufacture objects which correspond to our typological patterns". This happens by forming textures using the timbres, applying dynamics, inserting silences, and making registral changes.

By this method, the closest timbres on violin, viola, and cello are taken as substitutes for the original timbres. A similar list could be made for any pair of instrumentations and for any other timbral canvas version, if it proves to more systematically demonstrate the timbral structuring of the piece.[24] The timbres from the original (as numbered above) thus become the following 11 string timbres (plus some alternative options). See Table 3:

[23] Guy Reibel et al. *Solfège de l'objet sonore de Pierre Schaeffer et Guy Reibel* (Paris: INA GRM, Nouvelle edition, 1998–2005, Compact disc and booklet), 74.

[24] Many string timbres include potentially six or more variables in playing and their timbres are close enough to be generalisable throughout all four orchestral string instruments. Thus, a six-digit shorthand marking for these timbres is used in the taxonomy and written out in full here. See Vesikkala, "The Noise–Pitch Continuum in Timbral Music", 83–87.

Number of the original string timbre, and its substitute timbre in the result (refer to the numbered timbres in Table 1)	**Noisiness value**	**TIV value**	**Noisiness and TIV values of the original timbre; any changes from the original**
Timbre 1) **vl. or vla.** pizz. behind the bridge, p...mf	3	0.560	[3, 0.560]
Timbre 2) timbre f01i10, that is flageolet with pausing or perforation, accentuation irregular repetition OR timbre 011i01, that is contour or free figure, pausing or perforation, irregular repetition, high pitch	4	1.262	[4, 1.262]
Timbre 3) 010r01, that is contour or free figure, regular and rhythmic repetition, high pitch	0	1.333	[0, 1.467]; TIV differs by the least available amount
Timbre 4) **cello:** batt./tapping on damped strings	9	0.773	[9, 0.773]
Timbre 5) **violin:** Bartok pizz.	6	0.640	[6, 0.640]; as needed, viola will be also employed
Timbre 6) **cello:** low double stop, trem., gliss. on one of the pitches, mf	5	1.289	[5, 1.289]
Timbre 7) **cello:** two strings, pont., gliss. upwards, trem., mf OR timbre F00001TLLf, that is bow pressure on flageolet, high pitch, sul tasto, legno, flageolet pressure. OR timbre F00001TVLLpnf, that is bow pressure on flageolet, high pitch, sul tasto, lentissimo, legno, at the bow tip, flageolet pressure.	11	0.729	[11, 0.462]; each of the three timbres has the same values. TIV differs by the least available amount
Timbre 8) two options: timbre 000r02PP, that is steady repetition of two pitches, pp, pont. [1, 0.729] **cello**: poco pressione, mf [-1, 0.862]			[0, 0.800]; the closest matching timbre is the same timbre (damped pizz., tasto) 0, 0.800 on the cello, yet it will not be used.

Number of the original string timbre, and its substitute timbre in the result (refer to the numbered timbres in Table 1)	**Noisiness value**	**TIV value**	**Noisiness and TIV values of the original timbre; any changes from the original**
Timbre 9) four options: **cello:** seagull gliss. ord. / **violin:** high pizz. (secco) / **cello:** pizz. behind bridge, mf / **cello:** pizz. behind the bridge, p...mf	2	0.649	[2, 0.649]
Timbre 10) timbre F00002PV, that is bow pressure on flageolets, two pitches (any interval including unison), pont., lentissimo (slow bow) OR **violin:** extreme bow pressure (+5BD) near bridge, draw bow along string in region between fingerboard and bridge, ppp	11	0.862	[11, 0.996] TIV differs by the least available amount
Timbre 11) four options: timbre 101i01, that is bow pressure, pausing or perforation, irregular tremolo/repetition, high [14, 1.262] timbre 100r01, that is bow pressure, regular and rhythmic fast repetition, high [13, 1.182] timbre 101r01, that is bow pressure, pausing or perforation, regular and rhythmic fast repetition, high [13, 1.182] con poco pressione (scratch “tone”), double stop, trem. rather fast gliss., mf, middle register [12, 1.493]	14	1.262	[13, 1.316]; the closest matching timbre is the same timbre (scratch “tone”) [13, 1.316] on the cello, yet it will not be used, to make a fully new timbral environment and to demonstrate the method.

Table 3. **The timbral substitution chart, showing the timbral mappings from the original to resulting timbres when using the TIV–noisiness canvas version as a reference**

The reinstrumentation after this mechanical substitution chart is straightforward. Since the timbral coordinates are very similar, a TIV–noisiness canvas with the listed string instrument timbres is not shown here. Artistic licence occurs in judging balance, the overlaps of lines, use of alternative or equally distant timbres, and situations in which the same instrument cannot play two timbres simultaneously. The resulting piece for string quartet is as follows (Fig. 3):

Violin I
Violin II
Viola
Cello
(Bartok pizz.)
[5]
[1]
repeated rapid pizz. behind the bridge
[8]
pont.
bow pressure on flageolets, pont., slow bow
[10]
bow pressure, sul tasto, legno, flageolet pressure
[7]
[6]
pizz. (secco)
seagull gliss. (sul G)
[9]
seagull gliss. (sul D)
pizz. behind the bridge
bow pressure, sul tasto, legno, flageolet pressure

Fig. 3. **Notation of the result from method 1. The bracketed numbers indicate the original timbres as listed in Table 1.**

In this case, the instrumentation grew by one instrument, so most mappings are one-to-one, and a timbre need not be doubled on two instruments; doubling is, however, chosen for variety and for densifying texture when a dense texture creates a better resemblance to a granular timbre in the original (such as in the violin II and viola in m. 3). After this technical demonstration of the first method, I will discuss the reinstrumentation rationale that is informed by my general view of the phenomenon of music.

A core part of the identity of a piece of music are the *emotional and other cognitive rewards* that the listener can derive from the auditory tracking of patterns in sounding music and from making predictions that can be studied as brain activity.[25] Musical rewards have been covered by Menon and Levitin,[26] as a "predictive process" in auditory perception by Belfi and Loui,[27] and further by Cardona et al.[28] and Mas-Herrero et al.,[29] among others, yet the perspective of timbre-based music is yet to be introduced. Reinstrumentations are transfers that optimally preserve the rewarding features of the piece that make up much of its identity. Research on the topic of auditory rewards is relatively recent and, to my knowledge, findings have concentrated on tonal repertoire, not timbre-based music. A reinstrumentation of a standard ornamented Baroque harpsichord toccata to the string quartet would require a particularly rough transfer since it cannot retain well the original spectral, spectromorphological, or refined dynamic information, even though the pitch morphology (contour) could be exactly replicated. Such a reinstrumentation is accurate only to the extent that the rewards from the harpsichord version indeed came from the pitch realm and not from the remaining features that were rendered with less fidelity. Some rewards related to these features might survive yet may be reduced in number or in impact. This is where my methods 1 and 2 differ: reinstrumentation in the first method seeks to preserve the exact mapping of sounds (by one-to-one mappings onto similar timbral substitutes), while the second aims to preserve the rewards.

25 V. N. Salimpoor et al., "Anatomically distinct dopamine release during anticipation and experience of peak emotion to music", *Nature Neuroscience* 14, no. 2 (2011): 257–262; V. N. Salimpoor et al., "Interactions between the nucleus accumbens and auditory cortices predict music reward value", *Science* 340.6129 (2013): 216–219.; V. N. Salimpoor et al., "Predictions and the brain: How musical sounds become rewarding", *Trends in Cognitive Sciences* 19, no. 2 (2015): 86–91; Y.-P. Lin et al., "Electroencephalographic dynamics of musical emotion perception revealed by independent spectral components", *Neuroreport* 21, no. 6, (2010): 410–415.

26 V. Menon and D. J. Levitin, "The rewards of music: Response and physiological connectivity of the mesolimbic system", *Neuroimage* 28, no. 1 (2005): 175–184.

27 Amy M. Belfi and Psyche Loui, "Musical anhedonia and rewards of music listening: Current advances and a proposed model", *Annals of the New York Academy of Sciences* 1464/1 (2020): 99–114.

28 Gemma Cardona et al., "The forgotten role of absorption in music reward", *Annals of the New York Academy of Sciences* 1514/1 (2022): 142–154.

29 E. Mas-Herrero et al., "Unraveling the temporal dynamics of reward signals in music-induced pleasure with TMS", *Journal of Neuroscience* 41, no. 17 (2021): 3889–3899; E. Mas-Herrero et al., "Individual differences in music reward experiences", *Music Perception* 31, no. 2 (2013): 118–138.

4. Method 2

The second method refines the first. Method 2 includes the same phase of creating a taxonomy both for the original collection of timbres and for all the available timbres of the goal instrumentation, and it also maps the timbres onto each other. Any of the four timbral canvas versions can again be chosen to mirror the musical context, positioning the timbres in a two-dimensional timbral space based on the two timbral features chosen as most relevant as the X and Y axes.

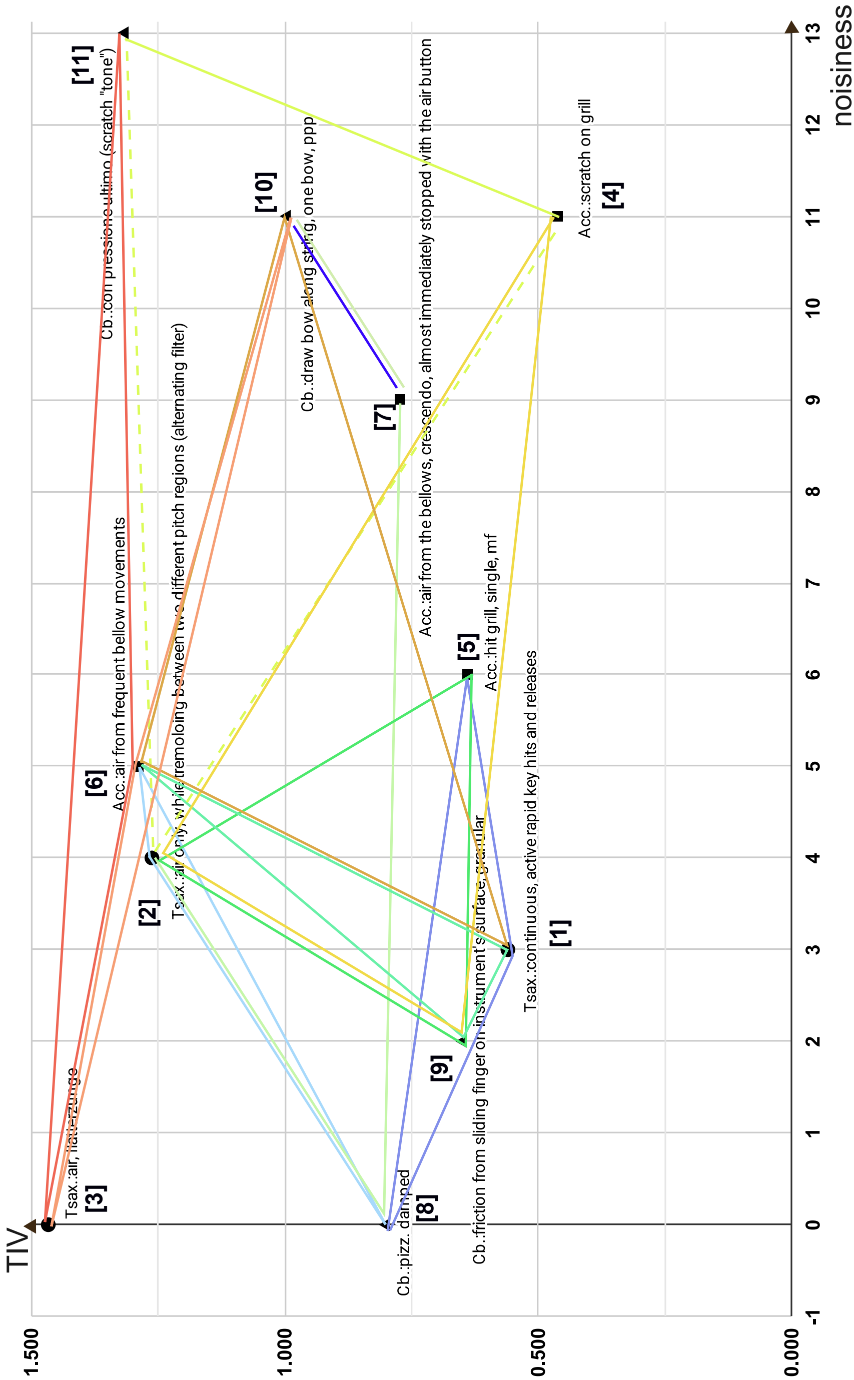
Method 2 additionally considers contextually how the timbres are positioned relative to each other, what constellations in timbral space are formed, what kind of progressions between timbres are common, and generally *what may regulate the chronology of timbral movement.* In this method, the timbral canvas can show the relative positions, gradations, and routes between timbres from any instruments. Any timbral space and its mentioned quantifiable features should be taken as non-authoritative and as the closest approximation of the elusive phenomenon of timbre.

Since method 2 focuses on the progressions between timbres, lines will show approximately simultaneous occurrences of timbres. (Arrows rather than colours can be used to show individual timbral progressions.) In each case, it is most feasible to view the timbres as simultaneous yet non-blending sounds, in groups of two or three instruments. The chronology of these 12 groups is shown in colours from blue through green and orange to red. The dashed line denotes a brief shift between a combination of either two or three timbres, while the standard lines show how timbral combinations establish through dense alternations.[30] Note that vertical vs. horizontal timbral distances are not scaled to the same visual proportion, for reasons of legibility.

The timbral groupings are shown below (figures 4 to 7), including the previously introduced TIV–noisiness canvas.

Fig. 4. **The TIV–noisiness canvas, now with the groupings of the timbres of the original piece shown. The dashed line shows a parenthetical new set of recurring movements between timbres. A reminder of the meaning of the numbered original timbres taken from Table 3: for tenor saxophone: [1] = continuous, active rapid key hits and releases; [2] = air only, tremolo between two different pitch regions (alternating filter); [3] = air, flatterzunge. For accordion: [4] = scratch on grill; [5] = hit grill, single, mf; [6] = air from frequent bellows movements; [7] = air from the bellows, crescendo, almost immediately stopped with the air button. For double bass: [8] = pizz. damped; [9] = friction from sliding finger on instrument's surface, granular; [10] = draw bow along string, one bow, ppp; [11] = extreme bow pressure, con pressione ultimo (scratch "tone").**

[30] If the musical material were based on overlapping attacks without repetitions of timbres, using arrows to show the progressions would be more useful than colouring timbre combinations.


TIV
noisiness
1.500
1.000
0.500
0.000
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
[11]
Cb.:con pressione ultimo (scratch "tone")
[10]
Cb.:draw bow along string, one bow, ppp
[4]
Acc.:scratch on grill
[7]
Acc.:air from the bellows, crescendo, almost immediately stopped with the air button
[6]
Acc.:air from frequent bellow movements
[2]
Tsax.:air only, while tremoloing between two different pitch regions (alternating filter)
[5]
Acc.:hit grill, single, mf
[1]
Tsax.:continuous, active rapid key hits and releases
[9]
Cb.:friction from sliding finger on instrument's surface, granular
[3]
Tsax.:air, flatterzunge
[8]
Cb.:pizz. damped

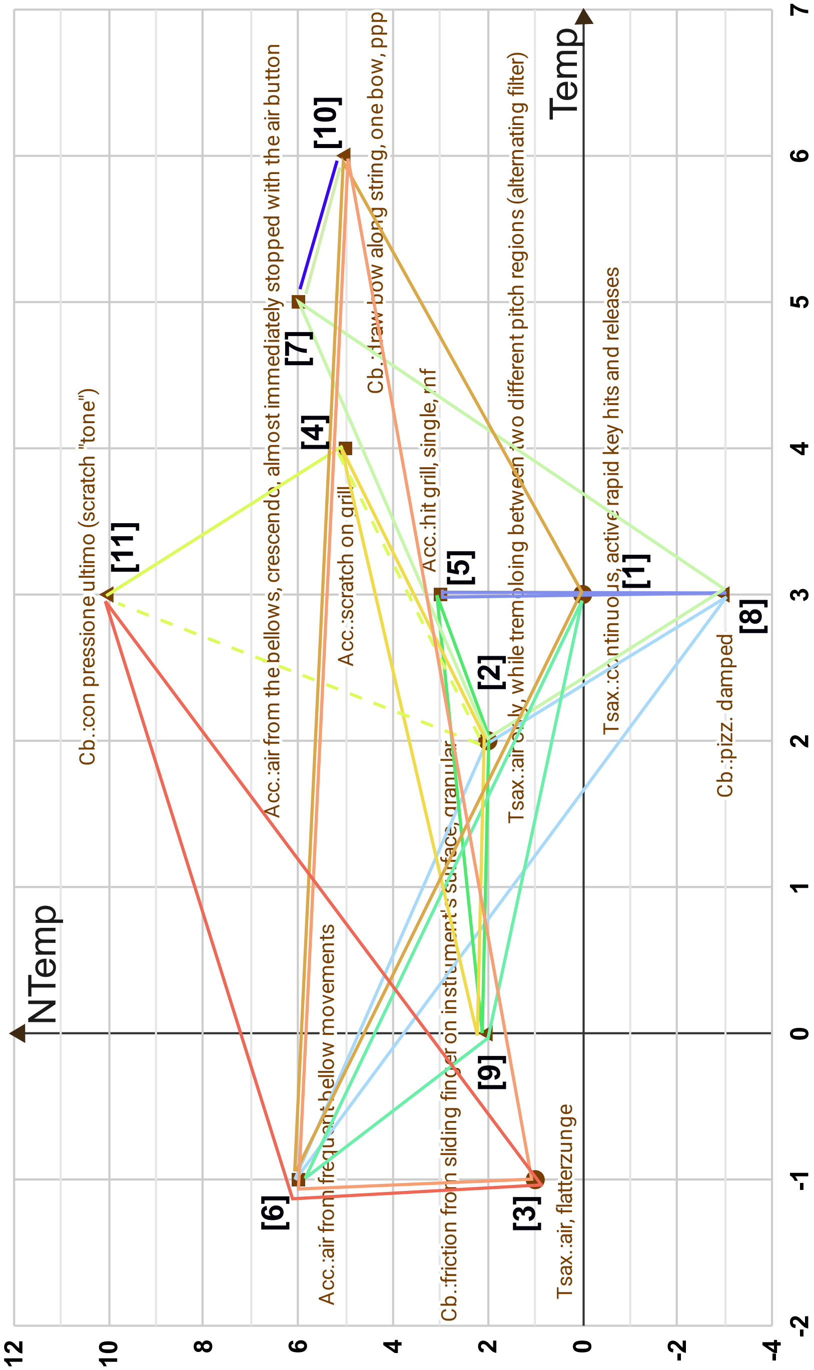
The following three canvas types show timbral distances in a continuum, yet now TIV is not directly included and noisiness lies in the combination of the coordinates. Here, timbral distances show more detailed deviations of timbre, especially those due to morphology. Each of the three focuses on spectromorphologies that create noisiness in one aspect of sound: temporal, frequency, and amplitude. In the following canvases, treading along an axis towards the edge means that the role of noise in the chosen aspect of sound becomes increasingly disparate; for example, the reached timbre has much noisiness from amplitude-related morphology yet very little noisiness from any morphology that is not amplitude-related. Such an extreme timbre can also evoke stronger reactions due to its organization, in a different way than the TIV value.

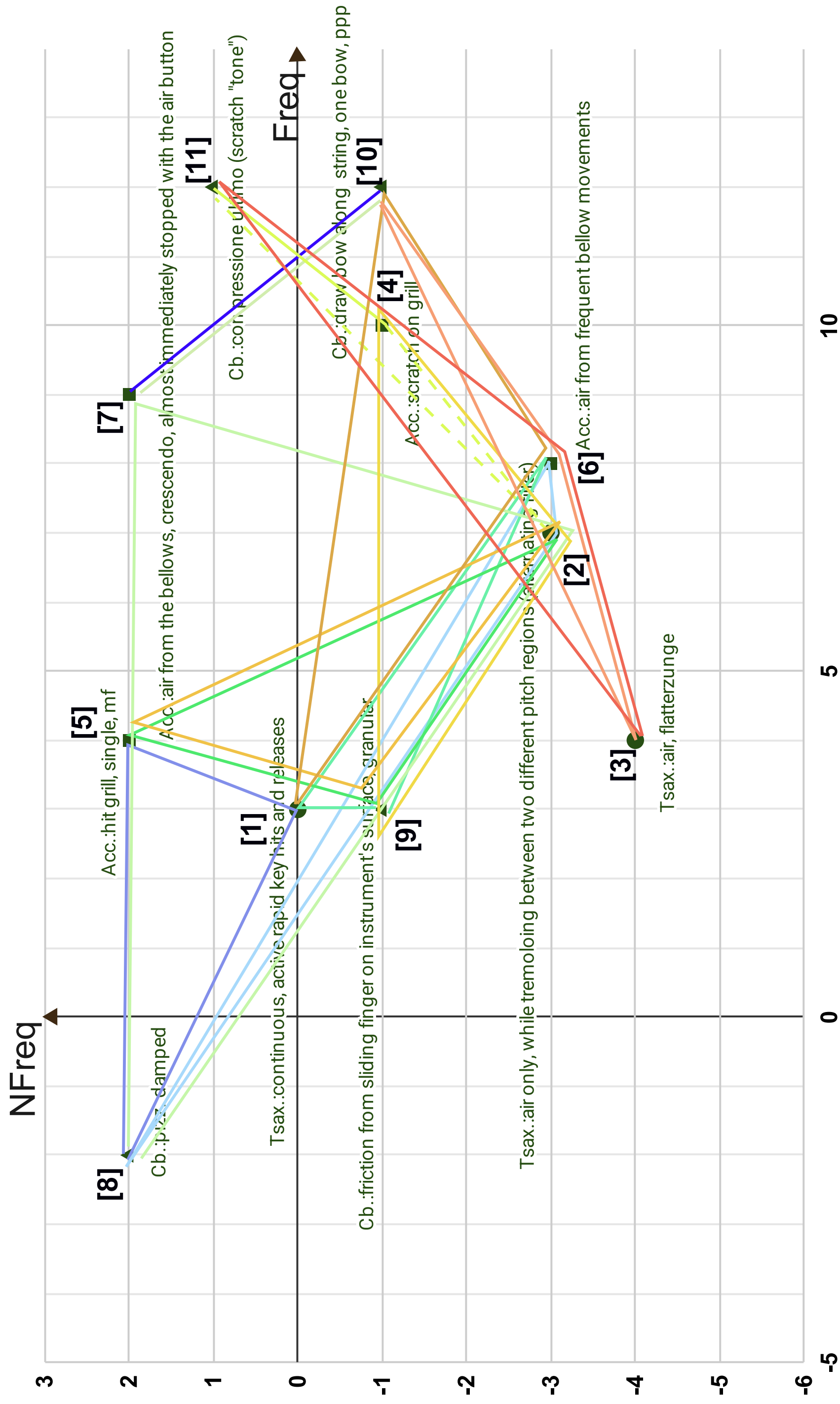
The other three canvas versions look as follows:

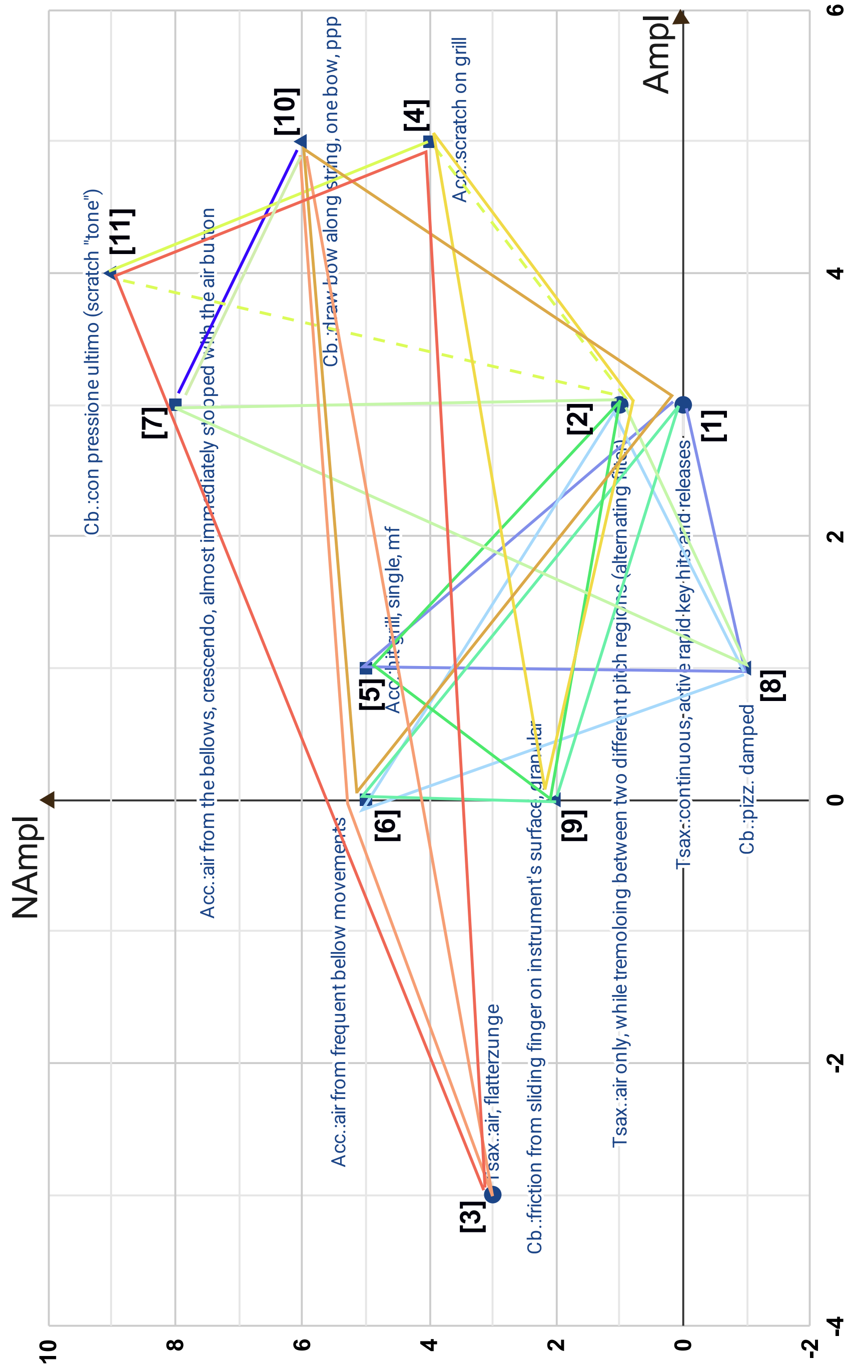
Fig. 5. **The Temp–NTemp canvas version with the groupings of the original timbres. The values on the horizontal axis result from those descriptors that are time-related, while the value on the vertical axis reflects those that are not.**

Fig. 6. **The Freq–NFreq canvas version with the groupings of the original timbres. The values on the horizontal axis result from those descriptors that are frequency-related, while the value on the vertical axis reflects those that are not.**

Fig. 7. **The Ampl–NAmpl canvas version with the original timbres. The values on the horizontal axis result from those descriptors that are loudness-related, while the value on the vertical axis reflects those that are not.**


NTemp
Temp
Cb.:con pressione ultimo (scratch "tone")
[11]
Acc.:air from the bellows, crescendo, almost immediately stopped with the air button
[10]
Cb.:draw bow along string, one bow, ppp
[7]
[4]
Acc.:scratch on grill
Acc.:hit grill, single, mf
[5]
Tsax.:air only, while trembling between two different pitch regions (alternating filter)
[2]
Tsax.:continuous, active rapid key hits and releases
[1]
[8]
Cb.:pizz. damped
Acc.:air from frequent bellow movements
[6]
Cb.:friction from sliding finger on instrument's surface, granular
[9]
[3]
Tsax.:air, flatterzunge


Freq
NFreq
[1] Tsax.:continuous, active rapid key hits and releases
[2] Tsax.:air only, while tremoloing between two different pitch regions
[3] Tsax.:air, flatterzunge
[4] Acc.:scratch on grill
[5] Acc.:hit grill, single, mf
[6] Acc.:air from frequent bellow movements
[7] Acc.:air from the bellows, crescendo, almost immediately stopped with the air button
[8] damped
[9] Cb.:friction from sliding finger on instrument's surface, granular
[10] Cb.:draw bow along string, one bow, ppp
[11] (scratch "tone")
-5
0
5
10
3
2
1
0
-1
-2
-3
-4
-5
-6


NAmpl
Ampl
[1]
[2]
[3]
[4]
[5]
[6]
[7]
[8]
[9]
[10]
[11]
Cb.:con pressione ultimo (scratch "tone")
Acc.:air from the bellows, crescendo, almost immediately stopped with the air button
Cb.:draw bow along string, one bow, ppp
Acc.:scratch on grill
Acc.:hit grill, single, mf
Acc.:air from frequent bellow movements
Tsax.:air, flatterzunge
Cb.:friction from sliding finger on instrument's surface, granular
Tsax.:air only, while tremoloing between two different pitch regions (alternating fast)
Tsax.:continuous, active rapid key hits and releases
Cb.:pizz. damped
10
8
6
4
2
0
-2
-4
-2
0
2
4
6

The three canvases each have their strengths,[31] even though they divide the noisiness information into two axes and dismiss the TIV information. The temporality canvas is generally robust when there are few timbres and many iterations of them, whereas when the use of timbres seems to derive from differences in frequency, the frequency-based canvas is useful, or when from loudness, the amplitude–based canvas, respectively. The value range of one descriptor is ±2. Thus, based on the number of descriptors that are used for each grouping of descriptors, the maximum values on these canvases are ±12 for NTemp, ±18 for Temp, ±6 for NFreq, ±24 for Freq, ±16 for NAmp, and ±14 for Amp.

For a comparison of the last three canvases, we can observe the first trio situation (measures 3 to 4) that has the timbres 1, 5, and 8. Being similar percussive sounds without much resonance, the timbres have similar noisiness, which the canvases are able to further distinguish each in their own dimension of sound. The timbre 1 is positioned centrally when using the Temp–NTemp (temporality) canvas, while timbres 5 and 8 feature varyingly as outliers in the other canvas versions. Of the canvases, this group is portrayed as the most detached in timbral space by the Freq–NFreq (frequency) canvas. The Ampl–NAmpl canvas shows progress from timbrally unified to less unified groups of timbres, in which the group of 1, 5, 8 can be seen to unfold from the centre and give way to more disparate timbres, for which amplitude morphology plays an increasingly central role.

Now we have timbres of the original composition with descriptor values and ways of positioning them relative to each other in timbral space using one canvas at a time. The next steps are to identify what constellations the timbres make and what can be said about the most common movements (trajectories) in that timbral space. In method 2, we will then reinforce the clearest timbral tendencies and patterns identified to bring about rewards in the piece, by means of optimising the coordinates of the timbres. The modifications often lead to a slightly different choice of timbres compared to an exact replacement.

There are at least eight simplified trajectory types:[32]

- Exact parsimony: movement to the closest available neighbour timbre.
- Parenthetical: different routes are taken, starting and ending with one and the same timbre. However, this timbre is not used so 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 of a sense of closure.

31 Vesikkala, "The Noise–Pitch Continuum in Timbral Music", chapter 5.1.3.

32 Vesikkala, "The Noise–Pitch Continuum in Timbral Music", 101.

- Quasi-parsimony: close enough neighbours yet not closest; contextually further than the closest possible timbre yet within the closest 40% of the timbres (in this case four timbres).
- Vectorial: movement proceeds in one direction or along a line in either direction.
- Radial: movement proceeds in several ways to nearby timbres; often movement creates a circle clockwise or counterclockwise; other logics are also possible. The route need not return to the original timbre.
- Grouping-based: movement to timbres in the group or outside the group specifically.
- Non-parsimony: movement to timbres that are not among the three parsimoniously closest options; any movement not explained by another trajectory type.

The trajectory types can be applied to individual instruments starting to play the next timbre, progressions of timbre from one instrument to the next, or the analytical approach in this piece – trajectories that occur within a steady non-blending timbral situation made of several instruments.

This canvas has very little exact parsimony (only present in the nearby timbral pairs 6 and 9 and 1 and 8); parenthetical trajectories are omnipresent because of the dense alternation of timbres, and the centric trajectory type is found concentrated in the middle of the piece in which the saxophone air tremolo timbres number 1 or 2 feature regularly in different contexts. Quasi-parsimony is common, since most combinations of three timbres are pairs within the four closest options. A movement at a small angle from pitched to noisy while the NAmp value increases, and vice versa, is common (vectors from lower left to upper right). This is evidence of vectorial trajectories. Since the onsets between the three timbres at a time do not follow a particular order, radial trajectories are not relevant in any of the canvases. Grouping-based trajectories occur only when a combination of timbres changes to another.

I will take the canvas Ampl–NAmpl as the basis of the following reinstrumentation since it shows a consistent pattern in which the timbral area covered by the instruments widens, and the middle part of the piece features almost equidistant combinations of timbres in the region defined by the start and end situations.

On returning to the original piece, we find that the same trajectories found in the Ampl–NAmpl canvas were common, with the exception that almost all combinations of three timbres now include the vector that points from lower left to upper right.

Depending on the canvas, different trajectory types arise at different quantities and are differently connected to the entirety of timbres. It is most feasible to view the timbres in this piece in groups of two or three instruments, as simultaneous yet non-blending sounds. In my analyses, I have recognised five common occurrences that I have labelled as *timbral trajectory strategies* (TTS), the logic of succession identified by the listener.[33] The five basic types are: Linear, Nuclear with outliers, Grouped, Merged, and Solar system with groups. Their identification is based on the kind of progressions between timbres that are used most by the music, and which types of movement occur less often – for instance, vectorial and parsimonious movements characterise the Linear TTS. Some TTS have rough requirements for the constellation of timbres in the space of the canvas as well. When determining the TTS, the trajectory types have been a necessary middle step that can now be bypassed.

Not every trajectory is explained by one TTS alone. Based on which trajectories are present the most, the canvases speak for the TTSs "Merged" or "Solar system with groups", in which the saxophone timbre forms the "sun" in the constellation. Additionally, the original piece, in all the canvas versions, would also categorise under these two TTS, since their criteria regarding the most common trajectories are again met. The TTS "Grouped" corresponds closely; however, exact parsimony is absent here since the timbres in these groups lie widely apart in timbral space. The "Linear" and "Nuclear with outliers" strategies can be excluded since vectorial movements and exact parsimony were rare. As for the other trajectories, the canvas versions differ. Due to the alternation of timbres within a group, the timbral movement here is very parenthetical.

Timbral trajectory strategies are about the concrete movements taken from one timbre to the next. How the timbres are situated relative to each other in timbral space, with their angles, distances, and local densities, determines the timbral constellation, yet not TTS. However, some constellations are more suited to realising certain TTS than others. For example, the Solar system strategy requires a timbral constellation in which there are enough timbres at a roughly similar distance from one central timbre that also is structurally determinant for the music and often accessed within the course of the piece.

Using the previously described mechanical method 1, in which human audition was applied to create the timbral taxonomy, timbral trajectories and timbral trajectory strategies were often sacrificed. However, human audition finds application also in judging how the movements between timbres should be classified. As this part of a listener's cognition is intrinsically informed by personal listening strategies, I deem this topic too far-reaching for the present scope. In this and similar cases in which TTS are clear yet pronounced differently in each version, the choice of timbral canvas version is a matter of analytical taste. With the presented excerpt (multilayered, nuanced segmentation, small timbral changes, similar noisiness degree surpassed by differences in morphology, and repeated and not particularly numerous timbres), the TIV–noisiness canvas version is a worse choice than the canvas versions that do not divide one spectrotemporal feature in half.[34]

33 For more on the trajectories that characterise each TTS, see Vesikkala, "The Noise–Pitch Continuum in Timbral Music", 141–144.

34 The realisation followed from a larger analytical corpus, see Vesikkala, "The Noise–Pitch Continuum in Timbral Music", chapter 5.1.3.

Whereas method 1 does not require knowledge of trajectories, the second method is intricately based on interpreting what greater timbral strategy and timbral *dialectic* the trajectories are part of. Out of a multitude of trajectories that occur in a piece, we can determine the *timbral dialectics* of that piece. "Dialectics" is a shorthand term for a structurally high-level phenomenon with which I wish to address the *abstract, difficult to verbalise or notate features of music that entail alternation or folding–unfolding between at least two states at the large temporal scale and encompass the whole duration of the piece and which its musical content is serving and grouped under.* Dialectical features in tonal repertoire are typically the unfolding of a tonal key by the use of (temporary) modulations and tonicising regions of functional chords. Dialectics exist even in music that is devoid of pitches or lacking pitch organisation.[35] The timbral trajectory strategies and timbral dialectics might not have been consciously intended by the composer yet are the main means by which the *chronology of a timbre-based piece* is organised.[36] This timbre-based sense-making compares analogously to that which in tonal music perception takes up several distinct disciplines of study. A timbral dialectic may arise from the mechanics of timbral movement according to the previously listed types of trajectories or may be altogether outside any timbral trajectory strategies.

The phase of analysing timbral organisation can deliver various results, from the mere indication of timbral distances (the type of analytical finding needed for both methods 1 and 2), to timbral trajectories, to a TTS (the preferable finding for method 2), or even to a clear timbral dialectic. The presence of the latter two strongly indicates the form-bearing role of timbre in a piece.

The realisation of the trios of timbres is itself grouping-based, and this trajectory type is also found in the use of the timbral regions, characteristically in each canvas version. As to the dialectics displayed by the canvases, some were more clear (refer to figures 4–7), and most canvases were able to show a dialectical tension–release pattern. In Fig. 4, we see TIV values first being rather similar and rather small, then detaching towards the extremes (particularly with the combination of timbres 2, 4, 11), to return to similar large values. The same progression is most clearly seen with noisiness in the frequency and amplitude canvases. Other dialectics present in the original piece and its transcriptions are those between crowded versus relatively empty regions on a canvas, the progress from narrow to wide to again narrow regions covered by the timbre groups

35 For more about nine dialectics that can be identified on the timbral canvases, see Vesikkala, "The Noise–Pitch Continuum in Timbral Music", chapter 5.1.2.

36 With the term "chronology", I discourage the use of some familiar terms such as a compositional plan (since even analysis of improvisations is made possible), order, or sequence (implying one-dimensionality whereas the effects of timbre can include simultaneity, blending, or other overlapping of timbres). The term "form" could be used with the distinction that standard small-scale forms or different levels of structural depth in an analysis are not meant by it. The term "timbral chronology" also realises a conceptual alignment with the hierarchically higher-level term "reward chronology".

(best perceived in the amplitude and noisiness–TIV canvases), and the order of leaving and accessing clear-cut timbral regions (particularly in the amplitude canvas).[37]

The first method does not require knowledge of the trajectories or dialectics in which the timbres participate. In contextual instrumentation, the goal of the second method, we closely match both of them as dramaturgical means. The second method is closer to a reduced listening approach than the first.

Trajectories can be recognised on any type of canvas, yet the instrumentator has to determine which canvas best reflects a concrete TTS. If indeed a different canvas shows trajectories better, at this phase that canvas may have to be preferred.[38] To achieve the same dramaturgical means, we will also need to identify the degree to which dynamics, timing, and register contribute to the dramaturgy, and whether one of these may even surpass timbre as the medium of dramaturgy. Especially when several timbres occur linearly after each other, the overall trajectory of the timbres may no longer fulfil the same dramaturgy as the original timbres did.[39]

[37] For more on the dialectics, see Vesikkala, "The Noise–Pitch Continuum in Timbral Music", chapter 5.1.2.

[38] Generally, the noisiness–TIV canvas is aimed at differentiating between timbres better than the other three canvas types which are suited for focusing on the effects of texture and morphology in one certain aspect of sound (and can be called morphological canvases). For more about which canvas works best for which type of timbre-based structure, see Vesikkala, "The Noise–Pitch Continuum in Timbral Music", 171.

[39] I will elaborate with my recent discovery that reinstrumentation method 2 retains the structure and chronology of musical rewards, which come from expectations and attention. The topic of expectations has initiated a vast discourse, with some suggestions for further study in the line of the proposed methods: D. Huron, *Sweet Anticipation: Music and the Psychology of Expectation* (Cambridge, Mass.: The MIT Press, 2008); Sabine Grimm and Erich Schröger, "Pre-attentive and attentive processing of temporal and frequency characteristics within long sounds", *Cognitive Brain Research* 25, no. 3 (2005): 711–721; H. Feldman and K. J. Friston, "Attention, uncertainty, and free-energy ", *Frontiers in Human Neuroscience* 4 (2010): 215; C. J. Peck et al., "Reward modulates attention independently of action value in posterior parietal cortex", *Journal of Neuroscience* 29, no. 36 (2009): 11182–11191; J. H. Maunsell, "Neuronal representations of cognitive state: Reward or attention?" *Trends in Cognitive Sciences* 8, no. 6 (2004): 261–265, doi: 10.1016/j.tics.2004.04.003; Ferreri et al., "Dopamine modulations of reward-driven music memory consolidation", *Annals of the New York Academy of Sciences* 1502, no. 1 (2021): 85–98. My terms "reward chronology" and its opposite, "punishment chronology", result from both correct and erroneous predictions. The attention that the sound is given also affects the fidelity by which the very timbre is decoded: "a sound may very well jump from one box [in the typology] to another according to the degree of attention which is paid to it, and the degree of complexity conferred upon it by its context"; see Reibel et al., *Solfège de l'objet sonore*, 75. Not all timbres are perceived with high fidelity or rewarded in real time, especially timbres of the most complex classifications. Relevant to perceiving timbres is the *EAR principle*: expectation–attention–reward. The full perceptual route includes a performer's mentalisation of the piece's timbral structuring and interpreting it as inevitably nonoptimal; for F. Busoni, a composer's steps from "inspiration through notation to performance" already entailed transcription (Kregor, *Liszt as Transcriber*, 11). The mentalisation continues to the resulting audible concretion of a heard performance of the piece, expanding from Ingarden (1986, 19) to the music as a chronology of heard stimuli, modulated by listener attention and (spectrotemporal) focus, creating an *event chronology* subjectively, as does the EAR principle, by which attentions and rewards modulate the further categorisation of timbres. We could speak of separate chronologies of reward, expectation, and attention (which is made of the novelty, type, ease of attending to, size and density, personal preference, and likelihood of the expected reward).

Working with the timbral substitution chart from method 1, and now with the Ampl–NAmp canvas version, it is possible to again mechanically map the timbres to the string quartet. The coordinates of some timbres clearly deviate from the original in ways that endanger the trajectories and TTS, which are the preferable ones in method 2. One modified mapping could be as follows (Table 4):

Number of original timbre (see Table 1); its Ampl and NAmpl values	**Useful exact substitutes at the same coordinate or nearby substitute timbres**	**Substitute timbre chosen; coordinate if not exact substitute**
Timbre 1) [3, 0]	no exact substitute, nearby option for violin at [2, 0] and three options for cello at [3, 1]	**violin:** high pizz. (secco) [2, 0]
Timbre 2) [3, 1]	three exact options for cello; three nearby options.	**violin:** punta d'arco, pont. [3, 2]
Timbre 3) [–3, 3]	the exact option 010r01 (free contour or figure, regular repetition, high) for any of the instruments; seven nearby options.	**cello:** using a similar pattern. To set it apart from the other pitched substituting material, it can also be made to gradually rise.
Timbre 4) [5, 4]	three exact options for cello	**cello:** bow hair, rotating circular bow, ppp
Timbre 5) [1, 5]	no exact substitute, one nearby option for viola at [1, 4]	**viola:** scratch tone (pressione), p [1, 4]
Timbre 6) [0, 5]	no exact substitute, three nearby options	**viola:** two strings alternating figure, irregular repetition, accentuation, high (020i11) [0, 4]
Timbre 7) [3, 8]	no exact substitute, one nearby option for cello at [3, 7]	**cello:** seagull gliss. pont. fast tremolo [3, 7]
Timbre 8) [1, –1]	exact option for cello, three nearby options	any string instrument (used for viola and cello): f00r11 = flageolet, regular and rhythmic repetition, accented, high [1, -2]
Timbre 9) [0, 2]	five exact options, nine nearby options	**violin and cello:** 001i11 = pausing or perforation, irregular repetition, accentuation, high
Timbre 10) [5, 6]	one exact option for violin, nine nearby options	**violin:** extreme bow pressure near bridge, draw bow along string in region between fingerboard and bridge, ppp
Timbre 11) [4, 9]	no exact substitute since the same timbre on the cello will be excluded, two nearby options for any of the instruments	any string instrument (used for violin and viola): pressure, pausing or perforation, regular and rhythmic repetition, high [5, 9]

Table 4. **The timbral substitution chart, showing possible timbral mappings from the original to resulting timbres when using the Ampl–NAmpl canvas version as a reference**

The primary focus is those timbres that do not map exactly and have at least two timbre options with different coordinates. These and even some of the timbres that were exactly substituted at the original coordinate could be changed to make the dialectics more pronounced.

The timbres in the lower middle part of the canvas could be brought even closer together and the remaining timbres towards the edges, creating a clarifying distance. To this goal, only using the value [0, 4] for timbre 6 comes into question. The other options [1, 5] and [0, 6] would bring it closer to the outlier timbres. For timbre 1 (originally saxophone at [3, 0] which lacks an exact mapping), one intriguing case means choosing the timbre at [3, 1] for cello and has three different timbres available. That would bring it to the same coordinate as the other saxophone timbre 2 that had a similar function in the piece. The other mapping is at [2, 0] for violin. The two adjustments have kept the dialectics even clearer, so that the exactly mapped timbres need not be reconsidered.

Notably, in method 2, the context of where a timbre occurs in the piece plays a small yet non-zero role, since the relative timing of a timbre determines timbral grouping, trajectories, and even dialectics, in a way that may lead to that timbral coordinate being adjusted in the reinstrumented result.

One possible notated result looks as follows (Fig. 8).

The canvas version Ampl–NAmpl is similar to the previous, yet the middle region timbres are stacked more closely together, as follows (Fig. 9).

Besides the numeric values, it is advisable to determine by listening which instruments' timbres are most faithful to the original timbres, especially in cases where options at the same timbral coordinate nevertheless sound very different. This can be used to direct decisions if the set of goal instruments is flexible, since instruments' timbral and technical capabilities can already be a limiter. In rare cases, certain facets of music are instrument-dependent,[40] and identifying this first determines whether to proceed with the reinstrumentation.

5. Interpretation and comparison of the methods

The result from the second method has more *ordinario* sounds than the result from the first method. This is because the reinstrumentations operate on similarity of noisiness and on its temporality, amplitude, frequency, or TIV (depending on the canvas chosen) and do not take into account the instrument and how it can be technically played. For many of the sounds, it does not make sense to notate pitches (beyond, for instance, the information of which string to play) since they would not make a great difference, yet in the technical realisation on the new timbre and possibly new instrument, sometimes pitches have to be chosen. Both results nevertheless maintain the timbral focus such that

[40] Lauri Supponen, written email and spoken interviews in May 2023.


1
Violin I
Violin II
Viola
Cello
pizz. (secco)
[1]
extreme bow pressure near bridge, draw bow along string in region between fingerboard and bridge
[10]
ppp
punta d'arco, pont.
[2]
two strings alternating figure, irregular repetition, accentuation, high
[6]
15ma
scratch tone (pressione)
[5]
p
seagull gliss. (sul D) pont.
[7]
pp
flageolet
[8]
6
[9]
9
pressure (scratch "tone")
[11]
[4] bow hair, rotating circular bow

Fig. 8. **Notated reinstrumentation result from method 2**

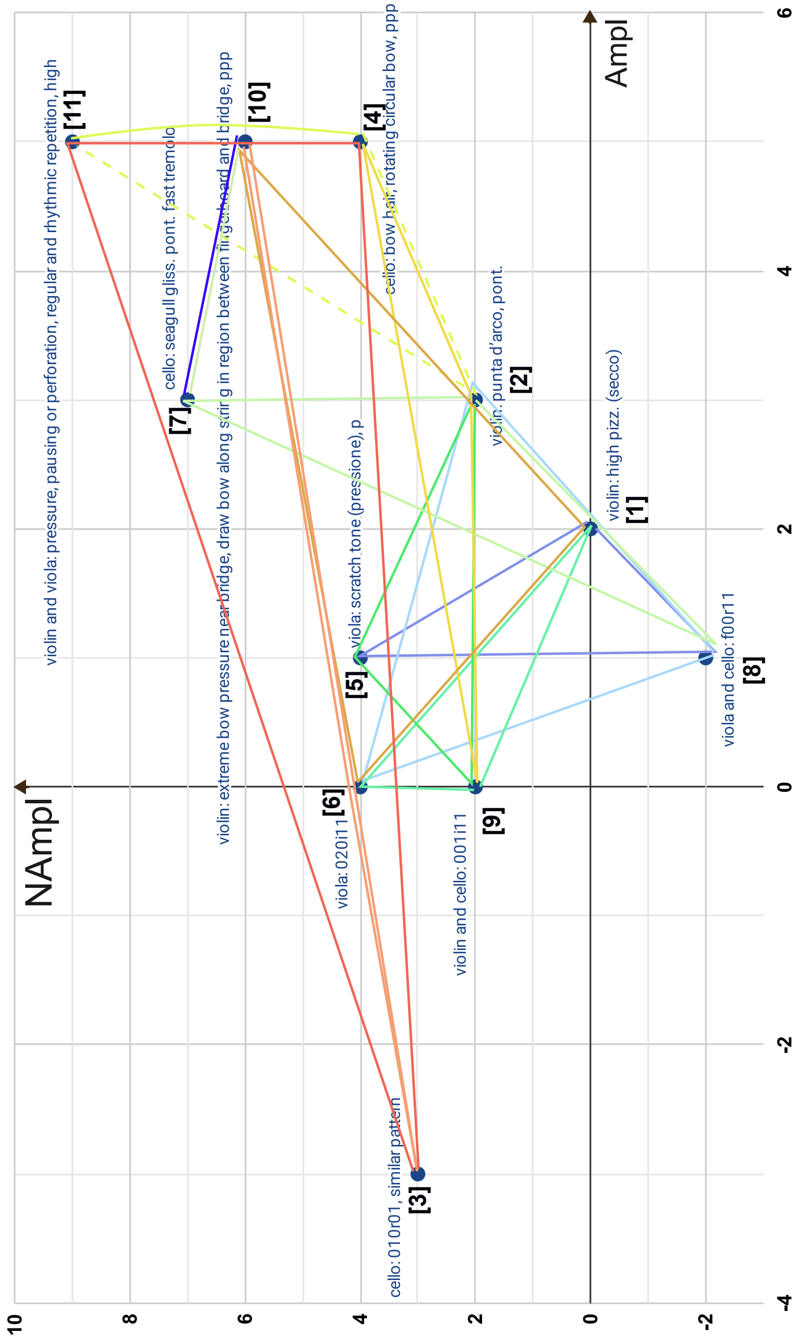


Fig. 9. **The Ampl–NAmpl canvas as the basis of the reinstrumented result from method 2. Compare this to Fig. 7.**

the pitches that occasionally have to be added to the instrumental parts of the original (that we are reinstrumentating) remain a subsidiary layer to the timbral progress, which in both cases is slightly different due to the choice of either the TIV–noisiness or the Ampl–NAmpl canvas.

What sets reinstrumentations apart from brand-new compositions is their close resemblance to the original composition, i.e. the *fidelity* of the transfer. In the first method, this means fidelity to individual timbres in as much as timbres can be concretised, whereas the second method provides greater fidelity to the timbral patterns. I consider timbral patterns in timbre-based pieces to be a component of their reward chronology, with the caveat that little can be said objectively about rewards in the present state of research. For both methods, the level of fidelity corresponds to its accuracy. In the two methods, timbral and spectromorphological rendering fidelity is strong; fidelity to preserving layers and sound sources is weak (yet can follow a consistent mapping); and structure replication fidelity ranges from medium in method 1 to strong in method 2. Conventional tonal transcription favours both the preservation of layers and structure replication at the expense of the first, and almost never compromises pitch-rendering fidelity (not shown in the following figures). What is described by structure is only somewhat made of timbre in tonal transcriptions and is made of mostly timbre in the timbre-based repertoire. The methods are compared with conventional tonal transcription in Fig. 10:

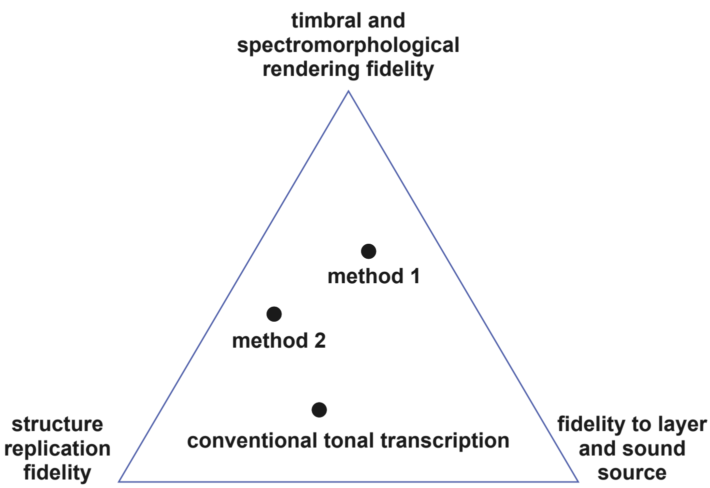


Fig. 10. **The two methods and conventional tonal transcription compared in their preserving capacities for fidelity to layer and sound source, structure replication fidelity, and timbral and spectrotemporal rendering**

Method 2 takes reward chronology into account to the extent that it can, while the mechanical method 1 does not but is the most unambiguous in its mapping of instruments. Timbral form-building is best replicated by method 2. With these priorities, the methods compare as follows (Fig. 11):

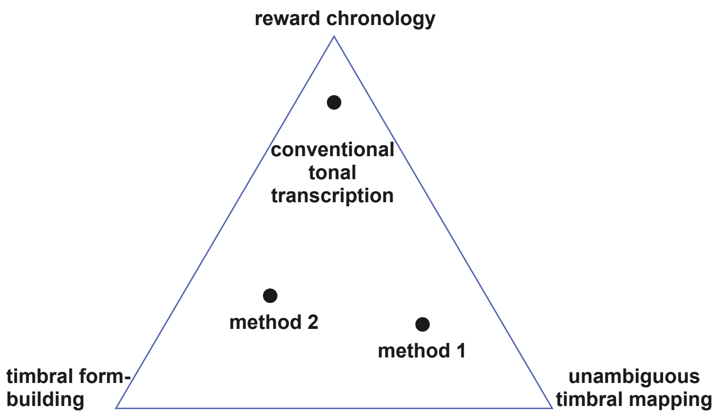


Fig. 11. **The two methods and conventional tonal transcription compared in their capacities for preserving reward chronology, unambiguous timbral mapping, and timbral form-building**

6. Conclusions

This article has proposed two methods, one general and the other more detailed, for the reinstrumentation of timbre-based pieces. The methods rely on a categorisation and analysis of timbres before the resulting sounds are assigned.

The first, simpler method of timbral reinstrumentation achieves the transfer of timbres to a new instrumental setup in a way that preserves maximum resemblance of the timbres. However, this highly local method bypasses any timbral patterns that may have informed the compositional choice, combination, and timing of timbres in the original piece. It is likely that such patterns would have contributed to rewards for the listener, which would be dissolved in the reinstrumented result.

The more detailed second method of timbral reinstrumentation considers individual timbres as material in the sonic medium that realise a reward chronology. Some timbres may need to be greatly altered to maintain fidelity to the overall reward chronology. Timbral identicality comes second to TTS and dialectics which affect reward chronology more closely. One analogy in tonal music is retuning a pitch that was out of tune after transposing a live performed chord in an ensemble; fidelity to the uniformity of the chord leads to the intended reward more than keeping an out-of-tune chord. The appearances of timbres constitute the timbral trajectories and patterns that structure the piece, and thus the original rhythmic pacing of new sounds has to be maintained. The instrumentator not only has to know what energetic impact a timbre and its timing has but also what structural role it plays in the overall progression of timbres for the entire piece. The two methods are most suited to repertoire in which timbre can be expected to be the main form-bearing feature in listening and that uses a wide range of timbres, some of them including noise.

The research presented here raises many ideas for further development and opens new perspectives for compositional thinking and reinstrumentation. Among the most interesting is the notion of reinstrumentation with a focus on preserving the timbral dialectics. If we consider various combinations of the original and the reinstrumented piece, it does matter whether both the original and the resulting piece are timbre-based or whether the timbral organisation is to be created from scratch to support otherwise pitch-based music. The latter case includes recent reinstrumentations of early music made by composers such as Sciarrino and Mundry. Such works have compelling results in terms of timbre-based form complementing the original pitch-based structuring.

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The doctoral research of composer, Grammy Award-winning choral baritone, and teacher **Juhani Topias Vesikkala** (*1990, Helsinki) at the Academy of Performing Arts in Prague focused on timbre, noise, and microtonality. Vesikkala's ongoing fascination is how all the steps of music make sense, from compositional pre-concepts via performance to listening strategies.