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Gesture transformation through electronics in the music of Kaija Saariaho

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Abstract

This paper will examine two key works by Finnish composer Kaija Saariaho, *Verblendungen* and *Lichtbogen*. It will analyze the pieces from a teleological perspective, focussing on gesture development and interaction between acoustic and electroacoustic elements. It will propose a new methodology appropriate to spectrally-focussed mixed music which will provide the means to map parametric change over time. The methodology will also provide basic models of interaction between the disparate electronic and instrumental parts which comprise mixed music.

1. Introduction

Kaija Saariaho has developed a unique musical language, fitting neatly between instrumental and electroacoustic methodologies. Regardless of which idioms a given piece of hers explores, however, her focus on spectral transformation reveals the richness of influence electroacoustic traditions have had on her writing. Replacing the tonal language of consonance and dissonance, she has selected the broader spectrum of tone and noise (Saariaho 1987). This concern forms the primary teleology [1] implicit in the form of her music, as well as in her individual gestures. An examination of two of her 'mixed' pieces[2], *Verblendungen* (1984) and *Lichtbogen* (1986) will illustrate how these concerns are manifest, as well as how the electronics in each work influence the morphology and capacities of gesture. The two works were chosen for their lucidity in this area, and because they represent two different strategies in combining large ensembles of instruments with electronics. *Verblendungen* employs a fixed tape part to which the instruments must synchronize and *Lichtbogen* features live electronics which are entirely created through processing of amplified instruments. Because of these very distinct configurations, different strategies toward the interaction between acoustic and electroacoustic elements can be observed. Similarly, the different configurations appeared to influence the types of morphologies used in each piece.

Beyond an analysis of these two pieces centred on acoustic-electroacoustic interaction, this paper will present and employ a new gesture-focussed methodology from a teleological perspective. Past gesture-based analyses have been largely the domain of acousmatic music, and while this has influenced some analyses of acoustic music, the same effort has not been expended toward

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[1] In this context, teleology is used to describe orientation toward a goal, the sense in which gestures are organised toward specific points of change.

[2] Pieces which combine acoustic and electroacoustic elements

analysis of mixed music. Because of the unique capacities of mixed music, a unique analysis methodology is required. This is firstly to understand the relationships between separate forces with their own traditions, and secondly, to take advantage of the detailed information provided by the score, which has carried over from acoustic music into mixed music.

2. Definitions

If we are to invoke a 'gesture-based' methodology, first it will be necessary to make clear what is meant by 'gesture'. Most broadly we will be referring to gesture as any perceptual unit or 'sound-shape' which develops over time. By focusing on 'perceptual units' we are rooting our work in perceptual analysis, but we hope also to illustrate how these units can be definable by very specific empirically observable elements. The term 'sound-shape' will serve as a useful metaphor. The notion of shape can be related very directly to observable variables. Shapes, in this context, can be thought of as envelopes for the modulation of different musical parameters.

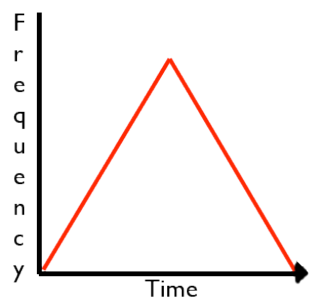

Fig.1: example of 'shape' as envelope for parameters

For example, if we perceive a 'triangle shape' it will likely correspond to some parameter, such as frequency, being modulated by that shape over time. Similarly, the modulation of other musical parameters–for example, dynamics and timbre–can be heard as 'shapes' in the same fashion.

As we are applying this gesture-based analysis to 'mixed music', it will be prudent to be precise about the nature of this music before the analysis is applied. Most simply it is music which incorporates both acoustic and electroacoustic elements. This definition carries no aesthetic implication, but we are focussing on a subset of music which does. Specifically, we are looking at pieces for larger ensembles of instruments in conjunction with electronics (where in some way they could be said to be 'equal' halves, each of which carry related musical material).

Characteristically, these pieces combine the 'languages' of instrumental and acousmatic music[3], rather than allowing either to dominate. There are many examples of pieces where this combination does not take place. Many pieces by Steve Reich, for instance, employ electronics, but they are used to extend the instrumental-based language his music occupies. Similarly, there are many pieces from the acousmatic tradition (most commonly seen in the soloist and tape arrangement) where the instrumental portion serves to bring an element of presence or interaction within an abstract acousmatic discourse.

3. Background

Music which does seem to achieve a balance between the traditions of instrumental and electroacoustic music is that which has emerged from the 'post-spectralist' school of composers. This style emerged in the 1980's and was lead by composers, many of whom studied at IRCAM and were subsequently influenced by the earlier school of French spectralist composers (Pousset, 2000). Appropriately, the majority of these composers have some significant work involving large ensembles with electronics, and some, like Saariaho, have established their careers with pieces in this configuration. Other composers who represent this style well are Philippe Hurel, Marc-André Dalbavie, and Claude Vivier. Among these, Saariaho is significant in that for much of her career she wrote almost exclusively mixed pieces. This period of her work, which extends for most of the 1980's and into the mid 1990's, established her musical language as concerned with the tone-to-noise continuum. The two pieces we will examine closely in this paper represent this interest explicitly.

4.1 Analysis - Introduction

In each piece, one main gesture typology or 'shape' forms the central unit. In *Verblendungen*, it is a diminuendo-shape, and in *Lichtbogen*, an arc. These are the micro-level morphological units of their respective pieces, though they gradually can develop and change over time, often as a result of their interaction with the electronic components. The gestures have a teleology to them; they develop toward specific points of change. This is manifest both at the level of individual gesture – each gesture has a trajectory from one state to another – and also at the macro-level of form, in the way that the gestures develop as they reiterate.

Gestural evolution forms a main focus of the development in these works, but this focus is shared with the development of interaction between the electroacoustic and instrumental components of the work. However, these two foci are intimately related; most often it is the

[3] These terms are used broadly as well. By 'instrumental language' I mean those suggested by the physical makeup of the instruments in the Western musical tradition. While a great variety of possibilities are available to these instruments, they were devised for an harmonic music, and so the sorts of limitations by which they are characterized influence the 'language' associated with them. Similarly, acousmatic music refers here simply to electroacoustically devised music, where the sound sources are not causally present at the time or place of listening.

relationship between the instrumental and electroacoustic parts which directs change in gestural evolution. Within these works, we have observed three basic models of interaction. The first is when they operate in *unison*, which could easily be the goal-point or beginning-point for a given piece. A second is *mutation*, where strongly differentiated elements of one part can be seen to 'influence' the direction of another. And finally, *emergence*, where one part can be seen to extend the parameters of the other, or else materializes as a result of those parameters. Ascription of these models depends on causal inferences which, within post-hoc analysis, cannot be confirmed with certainty. However, particular correlations do suggest causal structures in the same way that disparate sonic elements can form individuated gestalt gestures in perception. This means that while no means definitive, a perception-based causal analysis can yield fruit and provide a coherent picture of a piece of music. Similar to the manner in which gestures can be described by observable elements after the perceptual assumption is made, so too can interactions be observed and defined more concretely after the initial assumption of causation. It is our aim, then, to provide an analysis which is cogent and useful based on assumptions of causal structures. There are other elements at play in Saariaho's music, but the central aspects of gesture development and acoustic-electroacoustic interaction will form the focus of our research.

4.2 Analysis - Methodology

The analysis was carried out through a parameter-based framework for tracking gestural change. Each gesture iteration was seen as an envelope for parametric change, though not all possible musical parameters were logged. We directed particular attention to elements deemed especially morphologically relevant to the aesthetic language of the pieces. The first parameter we focussed on was *dynamics*, as in score-derived amplitude instructions. Next, we looked at '*activity*', or how 'textured' the sound was; as in reiterations of attack, fluctuations of pitch, etc. While this is a very broad category which contains traditional ideas of rhythmic patterns and melody, Saariaho seems less interested in those sub-elements in these pieces, and more focussed on a holistic sense of development between less active and more active. Additionally, we looked at *spectral breadth* and *motion,* and most importantly, the *continuum from tone to noise*. Harmony and timbre are also important, but in her music these operate predominantly as sub-structures of the tone-noise continuum.

Many of these parameters are familiar concerns of electroacoustic music, but are not as native to instrumental music, and so it is important to devise a methodology for relating these concerns to the vocabulary of instruments. While we do have more precise descriptions in notated instrumental music for parameters like dynamics, a parameter like tone/noise is less immediately evident. There are, however, a number of ways instruments can affect the noisiness of spectra. Instrumentation, playing technique, and register are variables involved. In the strings, harmonics and playing *senza vibrato* are techniques which bring the sound closer to pure tone, while bowing closer to the bridge or applying pressure to produce a scratching sound will increase the noisiness of spectra. Some instruments dramatically affect spectra based on their register, as in the flute family, where the high register produces a 'purer' sound, and the breathy lower register becomes more spectrally complex. Similarly, certain instruments will be noisier or more pure in tone in and of themselves. Within the diverse world of unpitched percussion instruments, for instance, there is a dramatic range of spectral qualities. For the purposes of analysis, each of these variables were assigned a number value based loosely on how they affect spectra. Negative values indicate a purification of tone, whereas positive values indicate estimates toward their affect on spectral noise.

We have provided a chart (See Table 1*)* which includes the techniques Saariaho uses; many will be familiar and some are more idiosyncratic. Different 'families' are separated into columns, and are vertically organised according to their approximate affect on spectra. Techniques or instrumentation higher in each column are those which will create purer spectrum. These values are coloured green. Conversely, techniques or instrumentation which cause the spectrum to thicken, producing noisier sounds, are lower on the list and are coloured red.

	Flute Family		Other Winds		Brass Family		Percussion		Piano		String Family	
Tone	Flute Harmonics	-2	Harmonics	-2	Low Register	-1	Bowed	-2	Timp. Mallet tone field	-1	Harmonics	-2
Λ	High Register	-1	Low Register	-1	Mutes	-1	Soft Mallets	-1	Pedal	-1	Sul Tasto	-1
|	Senza Vib	-1	Senza Vib	-1	Senza Vib	-1	Marimba	0	Una Corda	-1	Flautando	-1
|	Norm	0	Norm	0	Norm	0	Vibraphone	0	High Register	-1	Mutes	-1
|	Molto Vib	1	Molto Vib	1	Molto Vib	1	Glockenspiel	0	Norm	0	At the tip	-1
|	Trills	1	Trills	1	Trills	1	Crotales	0	Trills	1	Upbow	-1
|	Ostinati	1	Ostinati	1	Ostinati	1	Xylophone	0	Ostinati	1	Senza Vib	-1
|	Flutter tonguing	3	High Register	1	High Register	1	Hard Mallets	1	Low Register	1	Norm	0
|	Low Register	3	Multiphonics	2	Multiphonics	2	Tubular Bells	2	Pizz. on strings	2	Molto Vib	1
|	Instrumentaion: Alto Flute	4	Flutter Tonguing	3	Flutter Tonguing	3	Gongs	2	Strum Strings	4	Trills	1
|	Bass Flute	5					Toms	4			Ostinati	1
|	Breathing Phonemes 'voice'	6					Bass Drum	4			Change bows quickly	1
|	vowel phonemes	0					Field Drums	4			Tremolos	2
|	'm' 'n' phonemes	0					Snare -snares off	4			Tremolo as dense as possible	3
|	'r' 'l' 'b' 'r' phonemes	1					Snare -snares on	5			Metal Practice Mute	2
|	'h' 's' 'sh' 'ch' 'f' 'v' 'z' phonemes	2					Cymbals	6			Pizzicato	1
|	t' 'k' phonemes	2					Guiro	6			Snap Pizz	5
|							Ratchet	6			Col legno battuto	5
|							Maracas	6			Sul Ponticello	3
|							Sandpaper Blocks	7			est. Sul Pont.	5
|											Downbow	1
|											At the frog	1
|											Bow pressure - scratch	6
V											Col legno tratto	6
Noise											mute string - produce noise	6

Table 1; Tone-noise values for instruments and playing

The values are not precisely linearly organised, as the layout was also sensitive to grouping similar techniques together. The values ascribed are very rough estimates; the value can never be precise as it is dependent upon performers interpreting instructions. For instance, *sul ponticello* will not always make a bow-stroke 50% noisier; it is sensitive to the performer's interpretation. All that is required, however, is a very rough sense of the spectral effect, so that large-scale trends may be determined. This aspect of data-culling provides a brief window into the methodology behind the analysis, but it will become more clear as we describe our findings in each of the pieces.

4.3. Analysis - *Verblendungen*, methodology, cont.

Verblendungen is Saariaho's first major work for orchestra, and includes a fixed, computer-generated tape part to which the orchestra must synchronize. The main gestural unit in this piece

Fig. 2: *Verblendungen* Shape (Saariaho, 1987)

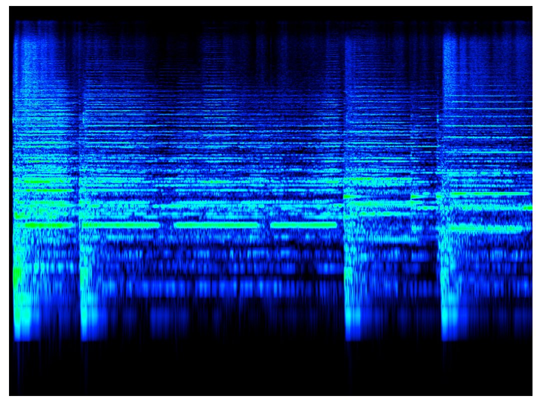

Fig. 3: Spectrograph image of first 30~ seconds of the piece, revealing how closely the visual correlate is retained upon translation into the audio realm.

is a diminuendo shape, which was inspired by a brush-stroke made by Saariaho. The visual sign of a brush-stroke can easily be associated as analogous to a bow-stroke from a stringed instrument, which fittingly provides the original unprocessed source material for the tape portion of the piece. (Saariaho, 1984) Beyond the direct analogue of visual and aural 'strokes', more generalized associations can be made when this shape is applied to musical parameters. Intuitively, it is easy to imagine various parallels: thickness of stroke to loudness and noisiness, for instance, or the striated artifacts of the brush lifting off the canvas as a movement from homogenous sound to more polyphonic, textured material. The general brushstroke or diminuendo shape provides the global form for the piece, which is in turn comprised of many smaller similarly-shaped gestures. At the gesture level, there are several easily-identifiable signposts which indicate new iterations and show a consistency linking them throughout the piece. One is a percussive attack, which is almost always generated by a percussion instrument with its own steep decay (piano is included in this definition). As the gesture continues through other instruments, it reaches a variable decay portion, as energy is dissipated from the attack.

This is normally manifested in the loss of amplitude and/or noise, but the shape of the decay is

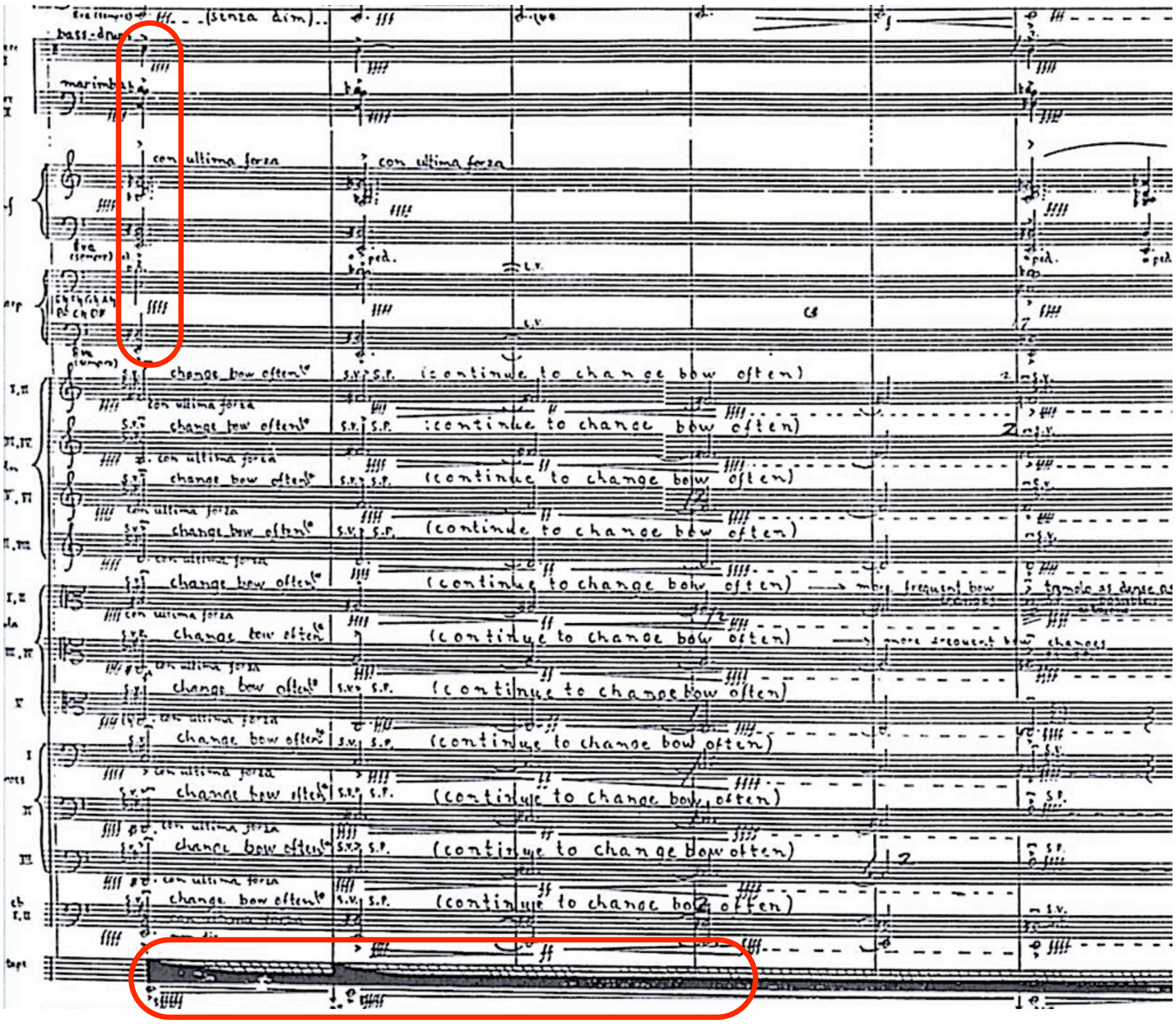

Fig. 4: A fragment of the first page of score from *Verblendungen.* Highlighted are the percussive steep-decay elements which indicate the beginnings of gesture iterations, and the graphical notation for the tape

one significant element which changes as the gesture develops.

Most of the analysis is derived from the score. The data of the noise values, dynamics, etc. from the instrumental part is accessible here, and it provides 'signposts' for where gestures iterate. Steep-decay percussion transients tend to indicate the beginning of a diminuendo-gesture, as corroborated by the more graphical notation for the tape part. The basic tape notation gives dynamic in comparison to the instrumental portion, as well as graphical symbols indicating more tone or noise based elements. The black decay shapes (see Fig. 4) illustrate the presence of pitched material, whereas the latticed vertical lines represent bands of noise. And so the score provides most of the raw data for the analysis – level of dynamic, noise, 'activity', where a gesture begins and ends, etc. – but this is supplemented by listening and spectrograph observation to ensure accuracy and to provide information where score information is unavailable or ambiguous. For instance, the graphic tape notation does give a broad sense of the presence of noise-based or pitched elements, but more precise figures as to where a sound lies on the continuum must be extrapolated based on these supplementary observational methods.

The data gathered from the score is then put into a spreadsheet.

	1b	1e	2b	2m	2e
Bar #	1	1	2	3	5
Dynamic	ffff	ffff	ffff	f	fff
Noise level	43	38	43	38	39
Noise level tape (out of 10)	10	10	10	10	10
Tape Dynamic	fffff	fffff	fffff	fffff	fffff
Frequency map	E1-F#4	E1-F#4	E1-F#4	E1-F#4	E1-F#4
Motion	/	/	/	/	/
Type of motion	/	/	/	/	/
Activity	1	1	1	1	1
Dynamic (orchestra)	9	9	9	6	8
Noise level (orchestra)	4.3	3.8	4.3	3.8	3.9
Dynamic (tape)	10	10	10	10	10
Noise level (tape)	10	10	10	10	10
Highest Pitch	4.5	4.5	4.5	4.5	4.5
Lowest Pitch	0.7	0.7	0.7	0.7	0.7

Table 2: The first two gesture iterations (or first five bars) of *Verblendungen*

Data is culled only at points deemed relevant to the morphology of the gestures. This includes, of course, the beginning and end portions, but also at any points of significant change during the gesture. These points are represented in the header cells; with a number value indicating the gesture iteration and characters 'b', 'm' and 'e' indicating beginning, middle and end points respectively. Numerical suffixes are applied for gestures with multiple middle points logged. So, '1b' is the beginning of the first gesture, where '14m3' would indicate the third 'sample' of the middle-point of the 14th gesture iteration. Since most data was derived from score, bar numbers were logged for reference (rather than absolute time values), though actual data may have been logged from a particular point within that bar. For example, the first gesture began and ended in the first bar, and so there were two points mapped within that bar.

The basic methodology for logging the 'noise level' of the instruments was mentioned previously - number values were assigned to specific techniques and instrumentations. This was added to the number of instruments playing at the sample point (with offsets based on the natural amplitude of those instruments - a trumpet might receive 2 points, whereas 4 violins might only receive 1). [4] This aggregation method does theoretically allow for some logical curiosities, especially in works for smaller forces. For instance, a solo violin playing a natural harmonic would result in a noise value of -1. However, the method was tailored toward larger-ensemble pieces, and while it was not meant to be infallible, it did provide approximate values which correlated to spectrograph information. The data for the noise level of the tape part was more perceptually-dependent, but was also cross-checked with spectrograph images. Additionally, Saariaho's graphical notation did provide some indication of the amount of noise-based material in the tape part at any given point.

Values for dynamics were a simpler matter, obtained by logging the appropriate markings from the score. However, to turn this into something useable for graphs, it had to be converted into a number value. Thus, mezzo-forte was given a value of '5' with other markings deviating from that point. The piece's highest dynamic indication was 'fffff' which works out to be '10' and had no indicators lower than 'ppp' (1), allowing *niente* to be '0' and all other indications to remain integers. The 'frequency map' was also a simple matter of logging lowest and highest pitches in the instrumental portion. This too was converted to a number value (each semitone had an integer value, starting with A-0 at '1'.[5]) and then divided by 10 in order to maintain the consistency of the 10-point scale.

Spectral breadth and motion were simply indicated based on whether the highest or lowest pitches changed over the course of the gesture, and the direction (up or down) was logged. There are some obvious limitations to this method, in that what was logged were (generally) the fundamental pitches, whereas the actual frequency output is much broader. Additionally, the frequency content of the tape portion was not possible to log independently, as we were unable to obtain a separate recording of the tape part. However, in each case the general 'curve' was well-represented by the simplified method of logging notated pitches, and so it served as a useful approximation. The 'type' of motion –whether it was stepwise or gradient (i.e. with glissandi)– was also logged out of interest, though this data was not used and did not appear to follow an obvious pattern.

'Activity' values were perhaps the most subjectively obtained, though they were constrained within the same 10-point scale and remained at integer values. The first gesture in the piece is relatively static; all instruments are instructed to play whole-notes *senza vibrato*. And so, the gesture was given a value of '1', indicating very little activity. Adjustments were made to subsequent gestures perceptively relative to this value. For instance, as vibrato was added, the value would go up, and as tremolos were added, it would increase further. More 'activity-dense'

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[4] Again, a subjective estimate, but one based on knowledge of orchestration.

[5] Quarter-tones could be easily accommodated with .5 values. Of course, more elaborate microtonal tunings make matters more complex, but can still be represented numerically in this scale. For ease of analysis, we were thankful that Saariaho's instrumental writing didn't venture into this realm.

gestures were ones which featured rapid fluctuations in pitch, quick re-iterations of attack (as indicated by repeated 32nd notes, for instance) and polyphonic or heterophonic textures. With a mind to keeping these values similar across pieces, the highest value in *Verblendungen* was '6', as it is, perhaps, a comparatively 'inactive' piece in this sense. In general, however, the values for 'activity' were the most subjective, relying heavily on listening. As with the noise values and values of spectral breadth, the purpose of this was to get an approximation in order to observe large-scale trajectories.

4.4 *Verblendungen* - Results

From this collected data, the overall shape of the piece becomes clear. Below are the global charts, separated into orchestra and tape components. As mentioned earlier, data was collected at 'sample points' relevant to gestural morphology, not according to linear time. And so the X-axis on these graphs reflects the gestural evolution, and not necessarily the linear-temporal evolution (though they should roughly correlate).

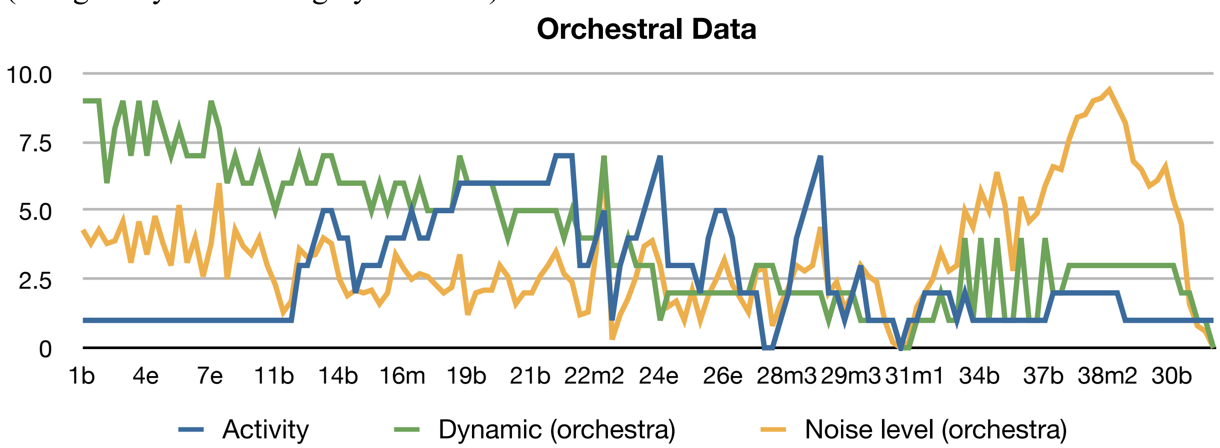

Fig. 5: Global data for the development of orchestral parameters in *Verblendungen*

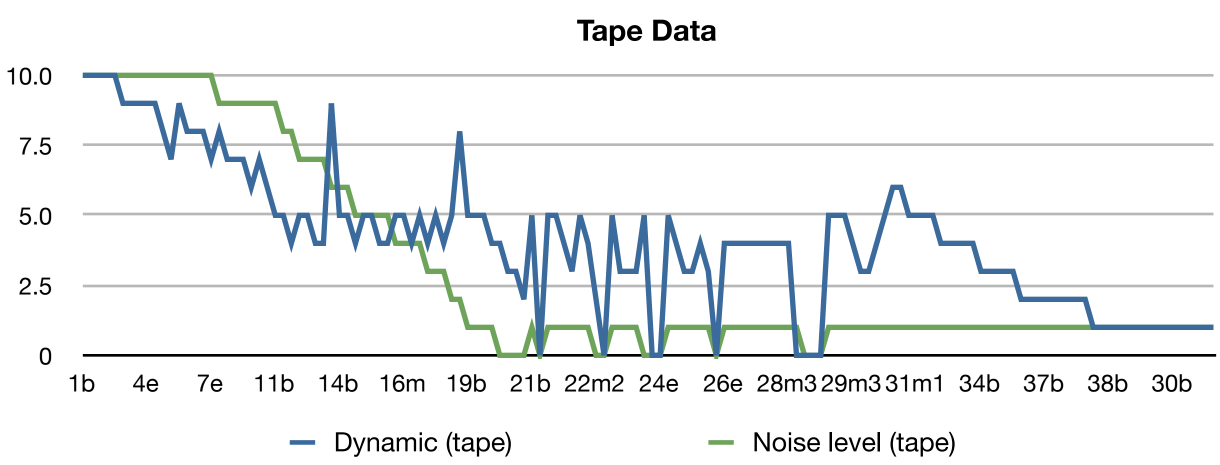

Fig. 6: Global data for the development of tape parameters in *Verblendungen*

A sense of trajectory appears evident within each parameter. There is a general downward impetus for dynamic and noise, both in the instrumental and electroacoustic parts. It is worth noting that the global shape of the tape portion extends to greater extremes than the instrumental portion, but they both maintain a similar downward trajectory. This directionality reflects the diminuendo shape as a guide for the formal plan of the piece, and the directionality of individual gesture iterations can be observed at this level as well. The iterative peaks and valleys generally visible within both of these parameters (noise and dynamic) is indicative of the individual gestures' basic shape. The graph also makes evident another important structural element in the global form of the piece. About two-thirds of the way through, the global diminuendo is 'restarted' in a shrunken form for a sort of 'coda section', after the parameters have reached their lowest point and the initial energy has been dissipated. This occurs after a unique moment in the piece, a minute-long tape solo, whose own shape is a bit more nebulous but tends to follow a similar diminuendo-type trajectory. For reference, this is represented as gesture iteration 30, and in the graph can be seen as a '0' point for all of the orchestral parameters, and as the largest peak in the second-half of the piece for the dynamic of the tape part. We will propose a potential causal explanation of the relationship between the tape solo and the restart of the parameters, with the earlier proposed interaction models in mind. Before this and other more interpretive aspects of our analysis, however, we will reveal the rest of our results.

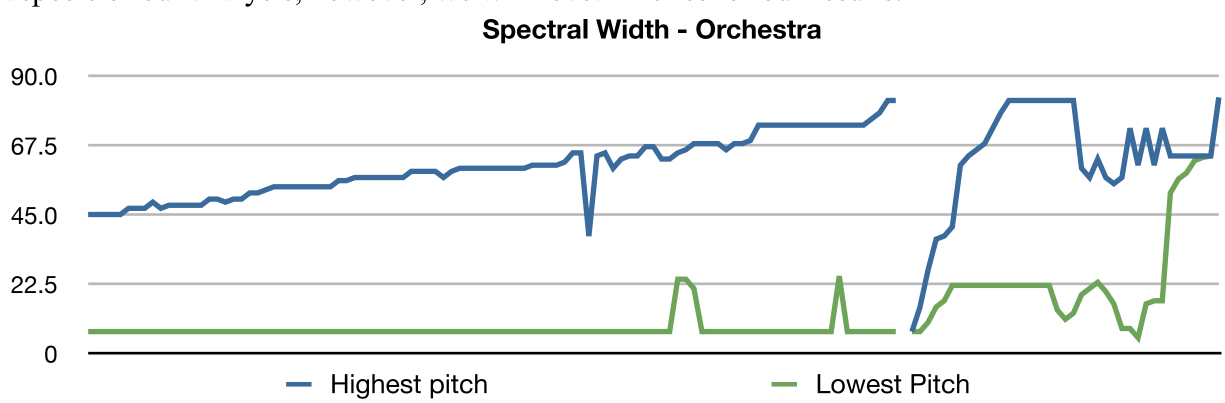

Fig. 7: Global data for the development of spectral width in *Verblendungen*

Above is the graph for the spectral width of the piece which also illustrates the piece's spectral motion. As is very clear here visually, there is a general upward impetus in terms of spectral widening. In general, this graph serves as a mirror image of the downward impetus of energy in the piece's dynamic and noise content. In the case of noise, the relationship between these opposite directions may be causally interpreted. As the pitches in the orchestra occupy a broader range of spectra, the space between them increases and the pitch relationships adopt more harmonic qualities. As with the other parameters, the coda section is clearly represented here. It has a distinct shape, but follows the same trajectory; it emerges from a single pitch at the very bottom of the spectrum into a single pitch at the very top.

These results, some of which are based on subjective perceptual analysis, can still be 'tested' in a way, due to the rigor of Saariaho's pre-compositional process for the piece. For some of the parameters we were interested in in our analysis, she created 'parameter curves' in order to guide the development of particular elements through the course of the piece.

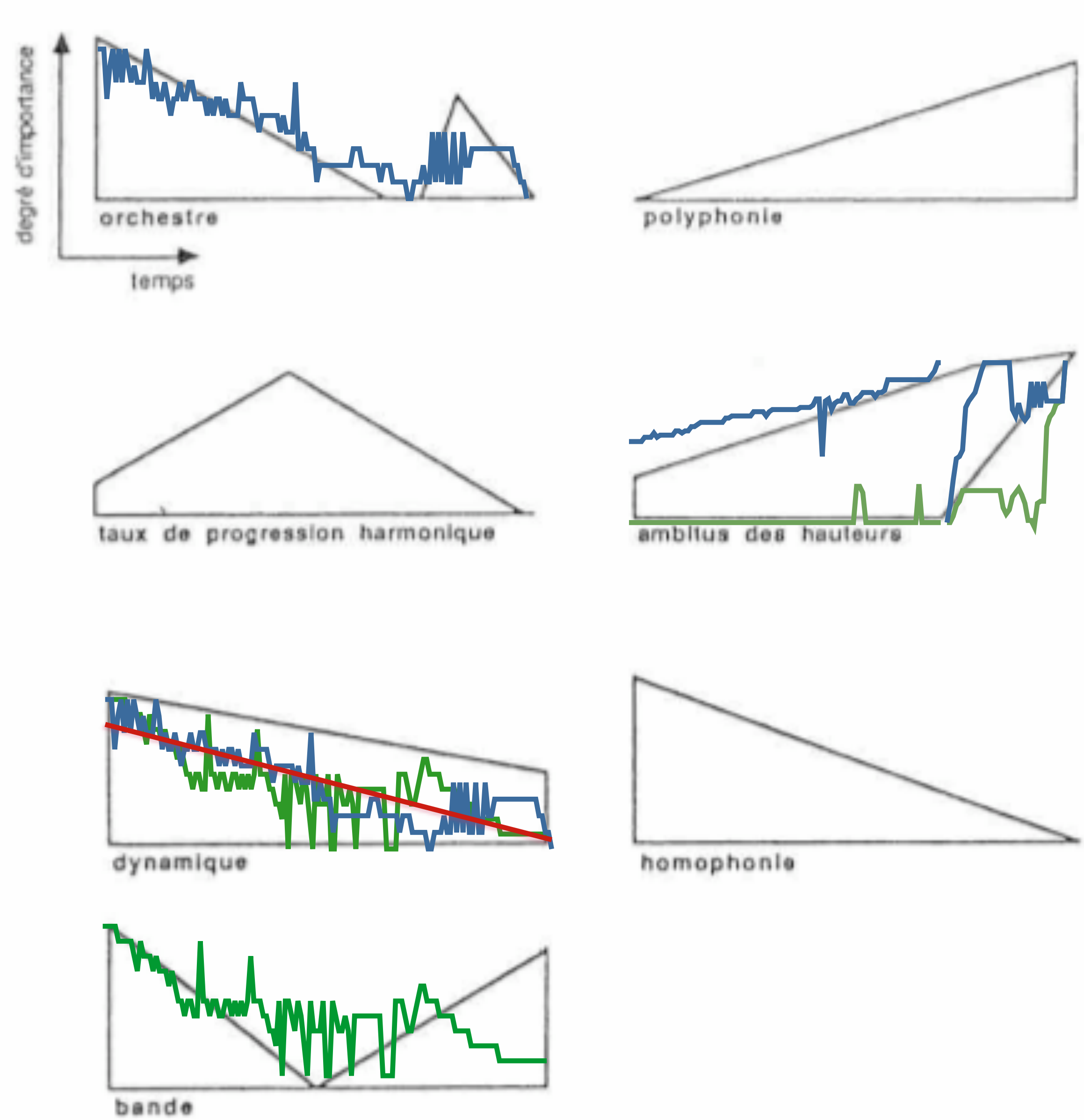

Fig. 8: Saariaho's pre-compositional parameter curves (Saariaho 1987)

We have overlaid the results of our analysis above the curves for the relevant parameters. We did not map homophony or polyphony directly, except as a factor in the 'activity' parameter, and so there are no relevant comparisons for those curves. Similarly, we did not look at harmonic progression, though what she plans here is the *rate* of progression, which is similarly-shaped to our activity results, perhaps illustrating a correlation between textural density and rate of harmonic change. The overlays for 'dynamic' are both the dynamic values of the tape and orchestral portions (in blue and green, respectively), which correlate well the the pre-compositional curve, with expected deviations. A red trendline is superimposed, taking average values to show the trajectory more clearly. The analysis overlays for the 'orchestra' and 'tape' curves are taken from the dynamic of each part, although this is an imperfect match, as what Saariaho has mapped is the more ambiguous 'degree of importance'. Despite this, they tend to correlate well, though the discrepancy may account for the inconsistency in the final section of the tape graph. While the dynamic in that section is at least *piano* throughout, arguably the pitched tape material takes on a greater degree of importance as it carries the transition from noise-based sounds into pure tone. Finally, the analysis graph for spectral width correlates very well to Saariaho's map for '*ambitus des hauters'* or 'pitch range'[6]. In general, it should be visible that much of Saariaho's pre-compositional thinking survived the process of composition and subsequent analysis, which should serve as a testament to the clarity of form in her music. Furthermore, the use of parameter curves such as these suggest that Saariaho was thinking within a teleological framework, indicating the appropriateness of the methodology of our analysis. What is perhaps perplexing is that she has not included a general curve for the tone-noise continuum in the piece, despite her interest in using this continuum in her music as a replacement for the dynamic qualities of tonal music. She has placed particular emphasis on *Verblendungen* as an example of a piece which attempted to manifest this (Saariaho 1987, McAdams and Saariaho 1985).

In absence of pre-compositional mapping for noise trajectories, then, we must rely on post hoc analysis data, which nonetheless appears to corroborate the general formal ideas behind the piece. Saariaho has written: "...the tape part begins with noisy, rhythmical material and ends with a quasi-orchestral luminosity made up of violin sounds. Conversely, the overall development of the orchestral part is the opposite of this: instrumental sounds take on a more and more noisy texture until they are completely lost in the quasi-orchestra of the magnetic tape" (Saariaho 1987). And so, while we are not provided with a visual parameter curve for the noise contours, her textual description provides one clearly. The general impetus for the tape part is to move from pure noise to pure tone, and the general impetus for the orchestra is the exact converse; to

[6] *Ambitus* is a term taken from medieval music, which in Gregorian chant refers specifically to the distance between the highest and lowest note. It can also refer to the specific range of a voice or instrument.

move from tone to noise. Comparing the noise values for the two parts makes this evident.

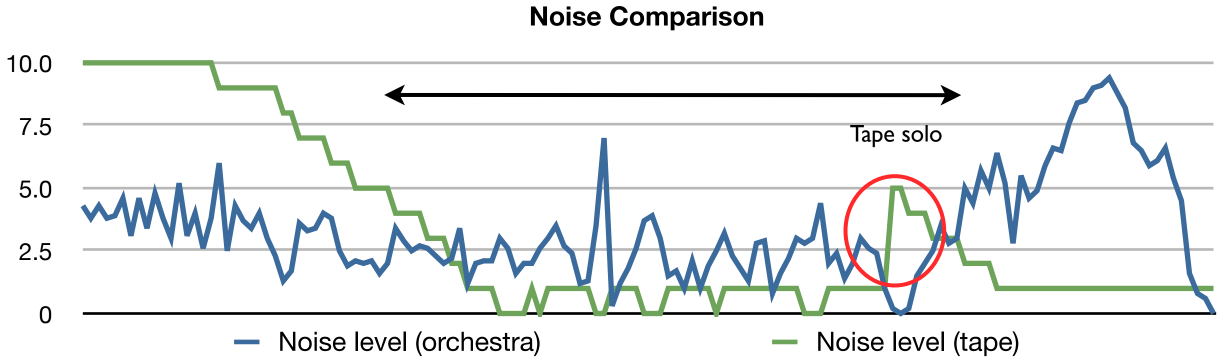

Fig. 9: Comparison of noise values between orchestra and tape parts in *Verblendungen*

The clear general trend here is that extreme levels of noise move from the tape to the instrumental part. Referring back to our models of interaction, this appears to represent the mutation model very well, where a trait carried by the tape part 'infects' the instrumental part and it gains those properties. The middle section indicates this apparent causal relationship well, where we see humps of tape noise which are immediately followed by spikes of noise in the orchestra as they decay. After a few iterations of these, the trait becomes dominant in the instrumental part. This occurs after a dramatic increase in tape presence during the tape solo, which is indicated in the graph by the last bump of noise in the tape. We suggest that this can be interpreted causally, such that the presence of the tape instills the instrumental part with the capacity to become noisier. Most of the instruments in the orchestra were designed for an harmonic language, and so their spectra is not particularly noisy when played with traditional techniques. Conversely, with electronics it is remarkably simple to synthesize complete white noise. As the tape part in *Verblendungen* begins with apparently synthesized noise, it is tempting to see the increase of noisy techniques in the instrumental part during the ending as causally related to this.

The sense of causation and trajectory evident in the global form of the piece is also visible at the gesture level. A sampling of gestures will reveal how the overall trajectory is manifested iteratively.

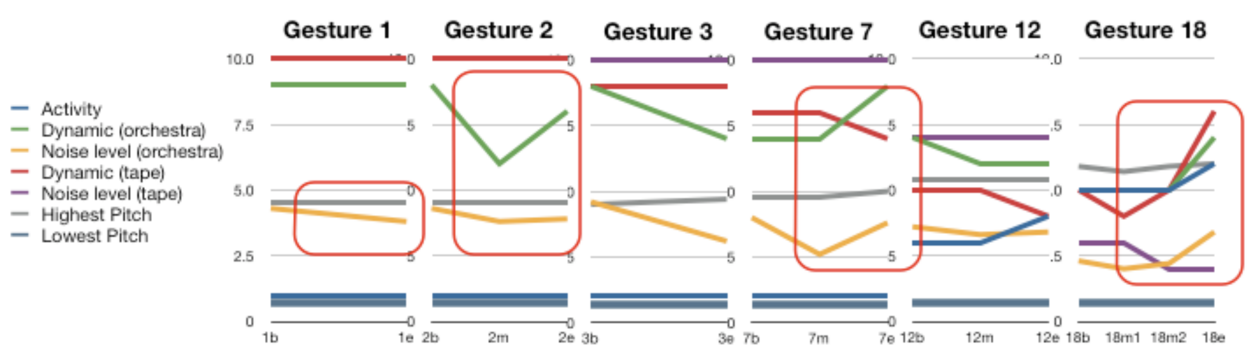

Fig. 10: Examples of gesture-iterations from the first section of *Verblendungen*

The first changes are seen as a gradual reduction in noise, represented by the yellow line descending in gesture 1. This adapts to include a loss in dynamic in subsequent iterations. One can see in the second gesture, however, a foreshadowing of the first big change: there is an increase in energy at the tail. An increase in noise and dynamic at the decay portion of the gestures is one of the longer-term trajectories in the piece, and that becomes clear if they are juxtaposed visually. The tape, however, moves more linearly from a state of maximum noise and dynamic toward tone and silence. This, coupled with the fact that the tape part is fixed and the instrumental part live, suggests to us that in a sense the instrumental part is reacting to it, and so causal interpretations in this case are read as the tape being the instigator of change.

The global developments in the gestures' properties include a gradual loss of dynamic and noise, as well as an increase in activity, gesture duration, and upward spectral motion. These elements develop more acutely through time, as is already visible above in gestures 7 and 18.

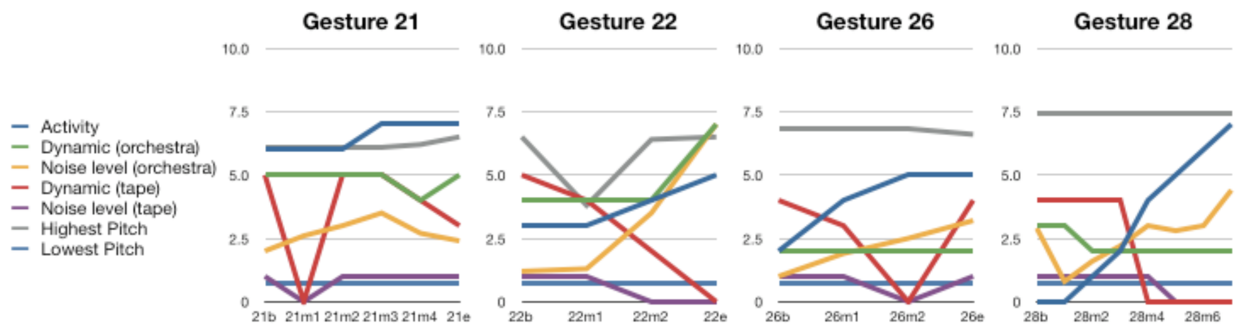

Fig. 11: Examples of gesture-iterations from the middle section of

The gestures in the middle section show a more direct exchange of parameters from tape to instruments on the micro-level. As is seen in these examples, the red and purple lines indicating tape dynamic and noise tend to slope off, which is exchanged for an increase in dynamic and noise in the instrumental part, as shown by the green and yellow lines.

There is a larger change in the coda section, as we see a peak again in dynamic and noise re-iterating the initial diminuendo shape.

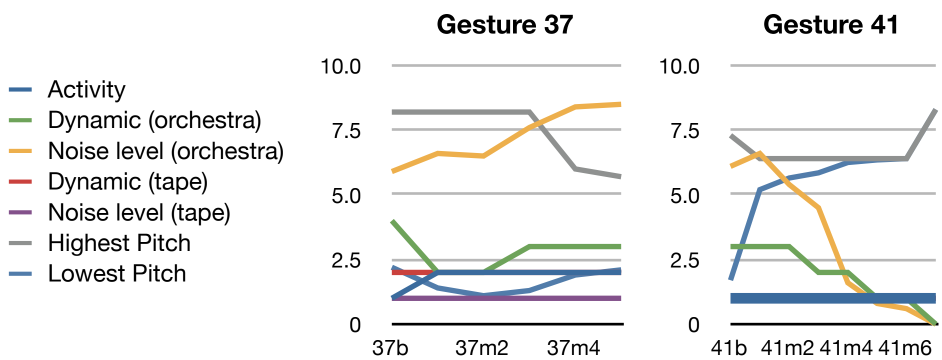

Fig. 12: Examples of gesture-iterations from the final section of *Verblendungen*

In the last gesture, one can see the highest and lowest pitches joining up , creating the last complete movement from noise to tone. The instruments are actually playing quite noisily at this point, with the winds blowing pitchless air and the strings playing extremely *sul ponticello*. So the transition from noise to tone, is one of essentially reducing the band of the spectrum until there is a focus on one pitch with a bit of noise around it. The tape part then fulfills the final transition into pure tone (which can be achieved more precisely with electronics).

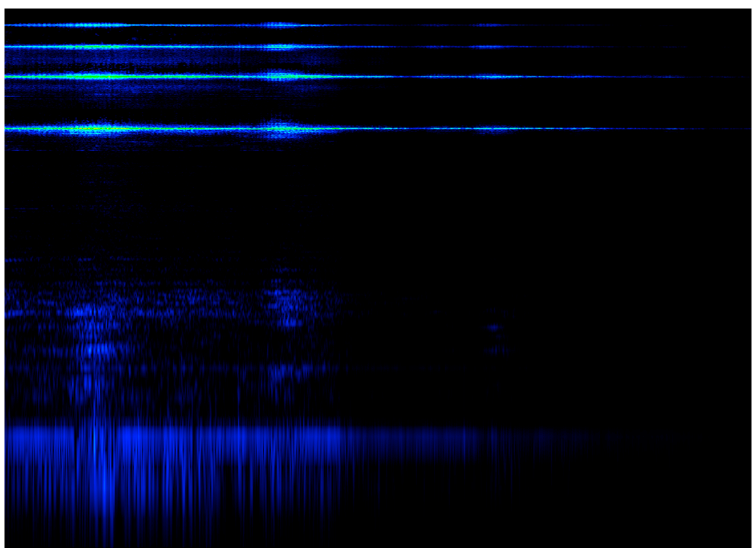

Fig. 13: Spectrograph image of the ending of the

As can be seen in the spectrograph image above, the noise content surrounding the isolated pitch is quite full. Because of the noise of bow pressure, there is even a fair bit of noise content in the lower frequency range, far divorced from the isolated pitch.[7] However, on the right side of the

[7] It is assumed that bow noise is the cause of this, however it is likely that other environmental factors during the recording are part of the explanation. Some of the low frequency hum does continue after the instruments have stopped playing, which is probably not present on the tape part itself.

image, we see the pitch after the instruments have stopped playing, represented quite purely by the tape part.

From these results, it is possible to make some general observations. There is a sense in which the electronic portion of the piece 'controls', or at least pioneers, the teleology of the parametric evolution. The initial activity and noise in the tape represent later goal-points for the instrumental part. Additionally, the tape part functions to represent extreme ends of the tone-noise continuum. The purest noise and the purest tone in the piece come from the tape part, as exemplified by the bands of white noise at the beginning, and the transition into a pure pitch at the ending. As mentioned earlier, the fixed nature of the electronics in this piece insinuated to us a causal relationship. As well as in the very literal sense that the orchestra must respond to the tape during performance, the formal plan for the piece implicates the tape part as a causal agent to which the instrumental part reacts. Thus, the mutation relationship proposed for the piece is suggested by the medium of electronics itself. Additionally, because the tape and orchestra parts are independent, they are able to start of with different properties and then affect each other or converge. At the very least, the limitations and possibilities afforded by this configuration narrow the subset of relationship categories.

4.5 *Lichtbogen* Analysis

The second piece we analyzed, *Lichtbogen* shares many aspects with *Verblendungen*, but is also strongly differentiated, largely as a result of the different configuration of the electronics. *Lichtbogen* is for a large chamber ensemble (nine instruments) and live electronics. Each of the instruments are amplified, and the live feed is made available to the electronics, which process the sounds in a number of ways. Additionally, the primary gesture or 'shape' chosen also affects the form of the piece and the individual teleology of its gestures. While *Verblendungen* focussed on a diminuendo shape, *Lichtbogen* is centred around an arc. This is suggested already in the title, which means 'light arcs'. Similarly to how shape of *Verblendungen* was inspired by a brushstroke, the shape of *Lichtbogen* comes from an analysis of a cello bow-stroke moving from one harmonic to another (Saariaho 1987). In between these points of pure tone is a noisy transition. And so, if the gestural shapes of the piece are to be interpreted as envelopes for

Fig. 14: Example of harmonic glissando (Saariaho, 1987)

parametric change, then the audible 'arc' is a tone-noise-tone envelope. The shape becomes very clear upon spectrograph analysis, as one can see movements between tone to dense noise and back very easily.

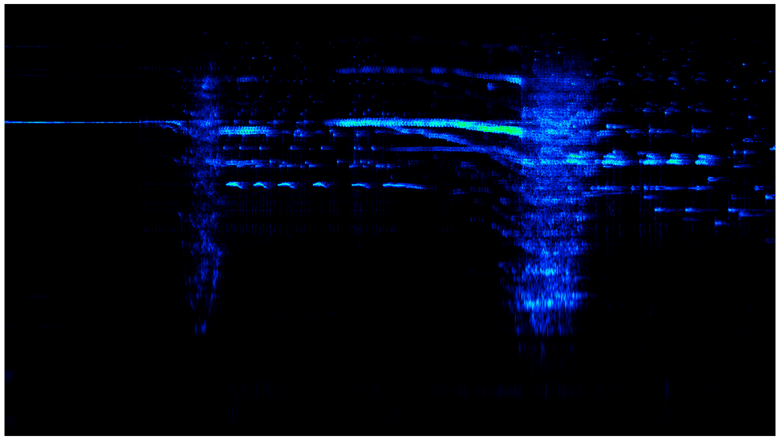

Fig. 15: Spectrograph illustration of two gesture

In the example in Figure 15, thin lines of string harmonics are transformed into noisy clusters by application of bow pressure and electronic processing. In this example, there is no significant expansion of orchestration, so the accumulation of density comes from playing technique and electronics processing alone.

The arc-envelope is used to control other parameters as well, such as pitch. This is manifested in the piece's many glissandi, as well as in 'melodic arcs'. This scalar melodic shape first appears in its complete form roughly half-way through the piece. So as a formal element, it ties the two 'halves' of the larger arc-shape of the piece together. Smaller fragments of the arc appear as solo melodic lines in the flute and violin throughout the first half of the piece. And so one way in which the shape develops is through transformation from arc 'fragments' into complete arcs. This is seen very directly in Figure 16, as half-arcs are reiterated leading up to the first complete melodic arc.

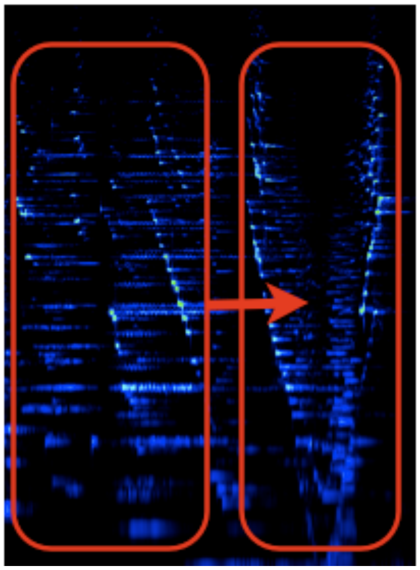

Fig. 16: Spectrograph of melodic

The overall shape of the piece seems to follow the general arc shape as well. Levels for activity, dynamic and noise are at their peak on either end of the piece, though it is also clear that there are sub-arcs within that structure.

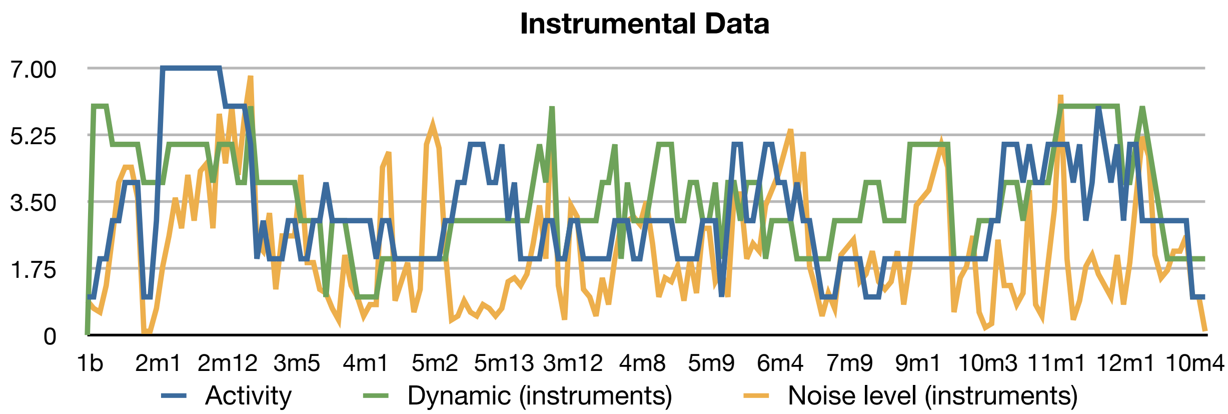

Fig. 17: Global data for the development of orchestral parameters in *Lichtbogen*

The parameters for the instrumental portion appear to be quite symmetrical, indicating a chain of at least 3 major arcs, with smaller arcs amid those at the gesture level. These same patterns are reflected in the data for the spectral width of the piece, which shows three major sections.

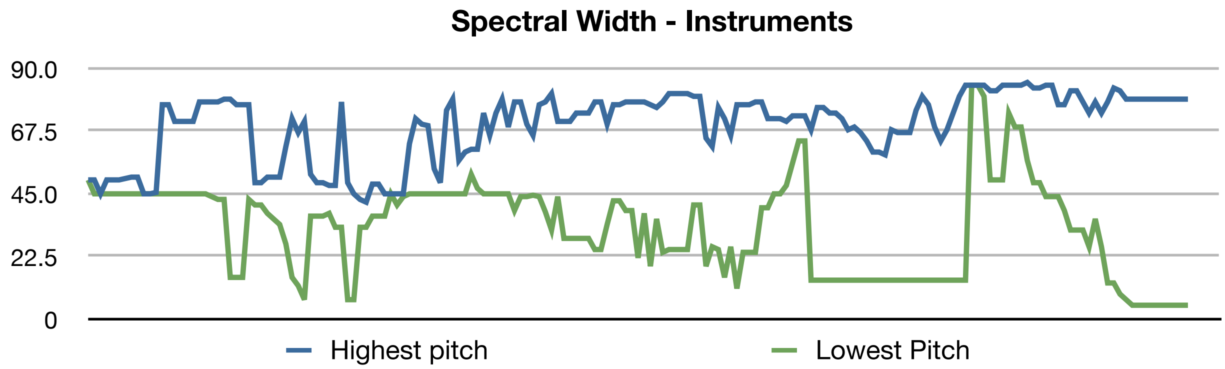

Fig. 18: Global data for the development of spectral width in *Lichtbogen*

These sections begin with contracted range, either on a single pitch or very close to it, and expand from there until they contract again, thus closing the arc. The last section could either be seen as comprising two distinct sub-arcs, or else as an inversion of the arc-shapes before it. It begins and ends in places of great spectral width, and peaks at a contraction. It would not be unthinkable that an ending section would invert the mapping of the previous sections. As was seen in *Verblendungen*, a major event two-thirds of the way through did cause a large-scale formal change, and so it is plausible that the same construction was used here.

As mentioned, the electronics in *Lichtbogen* differ significantly from those used in *Verblendungen*. The instruments are processed live through effects units on a mixing board.[8] The three processes are amplification, harmonization, and reverb. Because the electronics are processing existing instrumental sounds and because the control of that processing is manipulated by an index knob on a mixing board, the arc-shape which forms the structure of the piece is inherently implied: the technology required application of processing through systems which can apply it only gradually, and not discretely, and so the movement between 'dry' and 'wet' mixes lends itself well to the particular shape of the arc. Individual gestures in the piece as controlled by application of electronics are essentially limited to the arc-shape, but their global trajectory follows a different path.

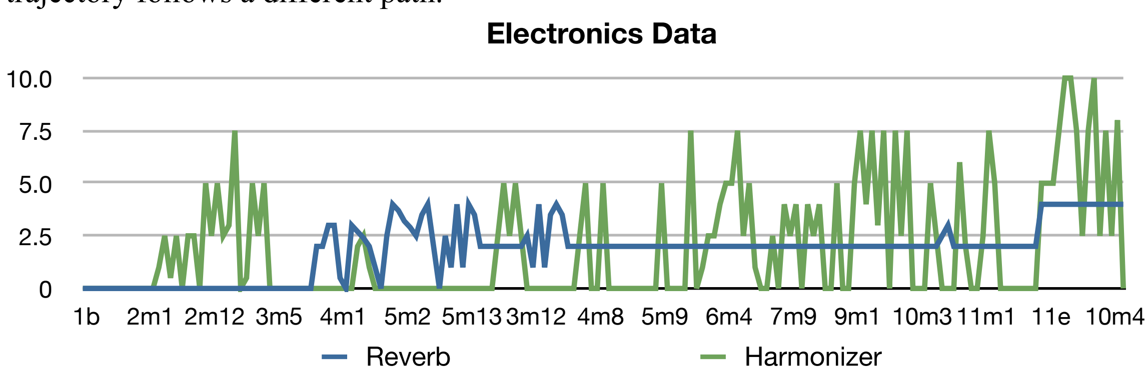

Fig. 19: Global data for the development of electronics parameters in *Lichtbogen*

[8] Contemporary performances of the piece are usually processed through Max/MSP patches which Saariaho has created to replace the original methods.

As Figure 19 illustrates; application of processing creates discrete arcs at the gesture level. At the macro-level of form, however, there appears to be a general impetus toward an increase in density. In this way the electronics can be seen as providing a foil to the more cyclical macro-level structure of the instrumental parameters.

More importantly, the type of processing selected insinuates that the electronics serve to expand the morphology of the individual arc-gesture shapes. They work especially in ways which expand the noise palette of the piece. For instance, amplification increases the repertoire of flute breath sounds, which is used to dramatic effect at the piece's ending. The harmonizer thickens the spectrum around a given instrumental gesture: it reproduces and transposes the pitch of the input signal to +40 cents above and again at -35 cents below. The effect of the harmonization is to dramatically broaden the stroke of the input sound; expanding it to a more noise-based timbre. The effect of reverb processing is less pronounced, but it does thicken the density of sound (also effectively thickening the spectrum) and allows for more seamless overlap between parameters.

The harmonizer, in particular, forms the basis of many of the arcs in the piece. It is notated in the score clearly below the staves indicating the index of processing (as a percentage) at any given point. This notation is encircled in red at the bottom of the score in Figure 20.

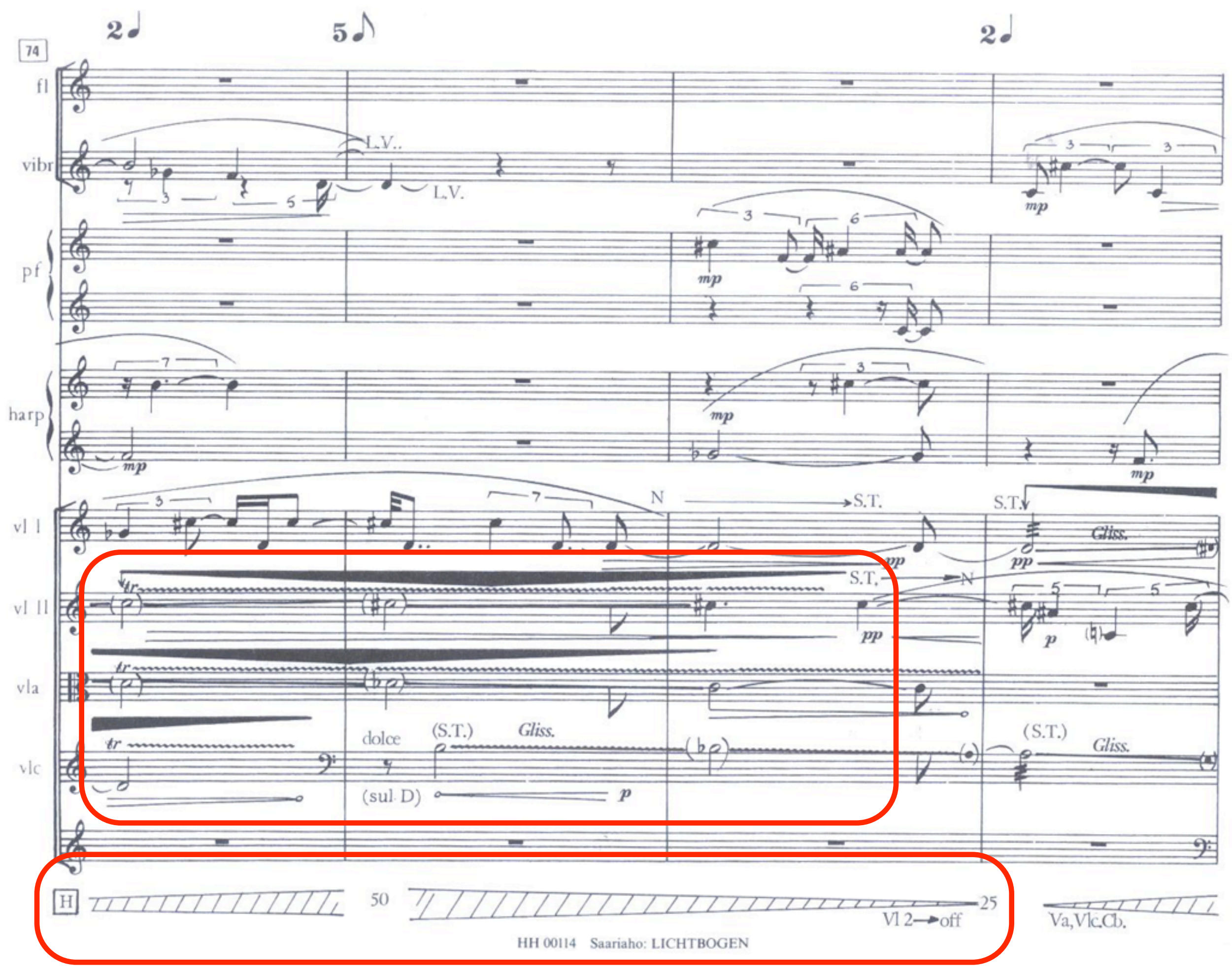

Fig. 20: Score excerpt from *Lichtbogen*. Indicated is the graphic notation 'scratch tone' in the strings and the notation for the live electronics. [H] indicates the effects unit used (harmonizer) and the index of processing as a percentage (50) is given. Other instructions such as which instruments are processed is indicated as well.

As seen in Figure 20, the application of this process only occurs as a response to the use of 'scratch tone' in the strings (which Saariaho notates graphically with thick black triangles). Of our proposed models of interaction, this suggests one of emergence, as the parameter of noise in the instrumental part is expanded upon by the electronics, which always emerges as a response to an existent parameter in the instrumental part, and serves to extend their capacity for spectral extremes. A graphical comparison of the noise values of the instruments and the level of harmonizer processing applied will reveal their close relationship.

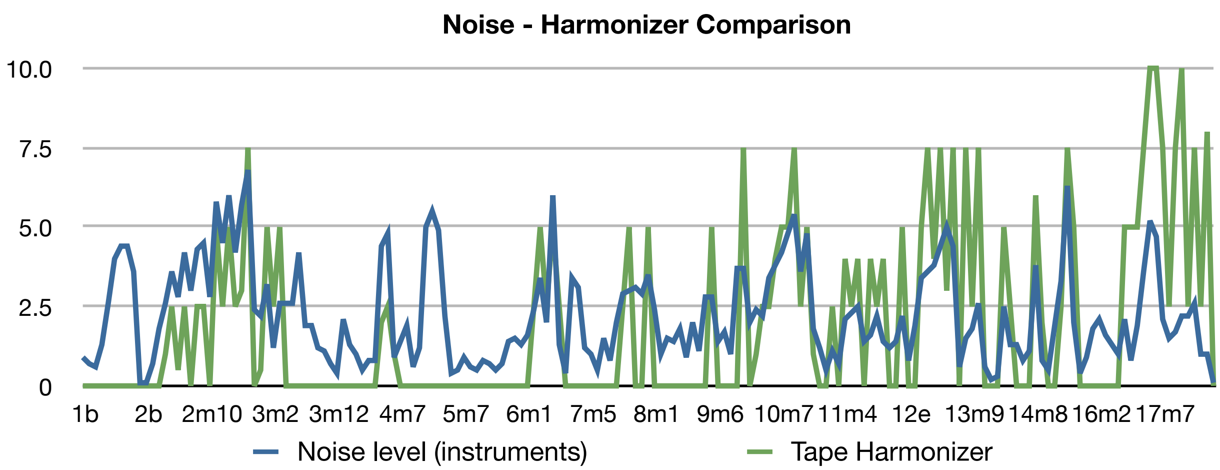

Fig. 21: Comparison of noise values in instruments to index of harmonizer processing

As shown, the harmonizer only emerges as part of a similar peak in noise in the instrumental part, though as the piece progresses, it expands beyond the noise properties from the instrumental part from which it emerged.

In this way, a kind of causality is very evident in *Lichtbogen*, as the application of processing occurs as a response to very particular stimuli from the instrumental portion. And so, the sense in which the gestures in this piece have an aspect of teleology is also very clear. They have a trajectory from tone to noise and back, which can only be extended so radically as it is through the use of electronics.

As the configuration of the electronics in *Verblendungen* lent itself to particular shapes and models of interactions, so too does a different configuration in *Lichtbogen*. Because the electronics process existing instrumental sounds, the instruments, almost as a necessity, control or direct the teleology of the gestural development. As mentioned, the arc shape is also clearly suggested by the manner in which the processing is applied.

5. Conclusions

A comparative analysis of the two pieces reveals some key findings. Electronics in both pieces serve to expand the capacity of instrumental gestures, extending their parameters into extremes. They also affect the morphology of those gestures as a result of the nature of their configuration. Fixed, independent parts suggest specific shapes, whereas live processing suggests different shapes. Differing configurations also lend themselves to different interactive relationships, often posing one of the two parts as an instigator of a causal scheme.

These elements likely extend into Saariaho's other pieces as well. *Io*, which was composed the year after *Lichtbogen*, combines the two approaches, featuring both a fixed tape part and live electronics. As such, it is a much more complex work with multiple gesture typologies and interaction models. It directly references some of her past work, including *Verblendungen* and *Lichtbogen*, borrowing some of the same gestural shapes and compositional ideas. Since the 1990’s, Saariaho’s music has become increasingly melodic, though this change is still embedded within a gestural framework. It may be fruitful to examine some of these later pieces to see if they can still be interpreted with the same methodology.

Other potential avenues for future applications of this research are numerous. If the methodology established in this paper is to be of much use, it will be necessary to see if it bears results when applied to the works of other composers. Other mixed pieces by composers also described as ‘post-spectralist’ might benefit similarly from these methods. Aspects of the analysis methodology would also be applicable to purely instrumental works which are situated in a spectrally-minded framework. Another avenue to explore is that these analysis methods could be applied in reverse as a compositional tool. And finally, a long-term goal is to use these and other analyses as the framework for meta-creation[9] projects.

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[9] Meta-creation: the development of computational systems that produce or simulate artistic creativity. For more information see Eigenfeldt 2009.