Analysis of Denis Smalley's Wind Chimes – A Summary

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The following is a summary of an analysis of Denis Smalley's *Wind Chimes* (Smalley, 2004), a detailed version of which formed the heart of my PhD thesis (Hirst, 2006). The thesis was re-written and published as a book (Hirst, 2008). Links to these publications can be found in the References section. Where chapters are mentioned, these refer to chapters in the thesis/book.

Framework for Analysis

Three research questions were posed at the outset of the investigation, pertaining to the development of a framework for the analysis of acousmatic music. These can be summarised as follows:

> Can a framework for the analysis of acousmatic music be derived from cognition theories, research on the auditory perception of everyday environmental sounds, and studies into the perception of Western tonal music? If so, what are the framework's attributes?

In Chapter 5, all the constituents of such a framework were brought together. The framework has the following main elements: Segregation, Integration, Assimilation and Meaning (SIAM). To assist with assimilation, meaning, and the discussion of discourse within the work, an approach to listener interpretation and attention was developed (see Figure 5.1).

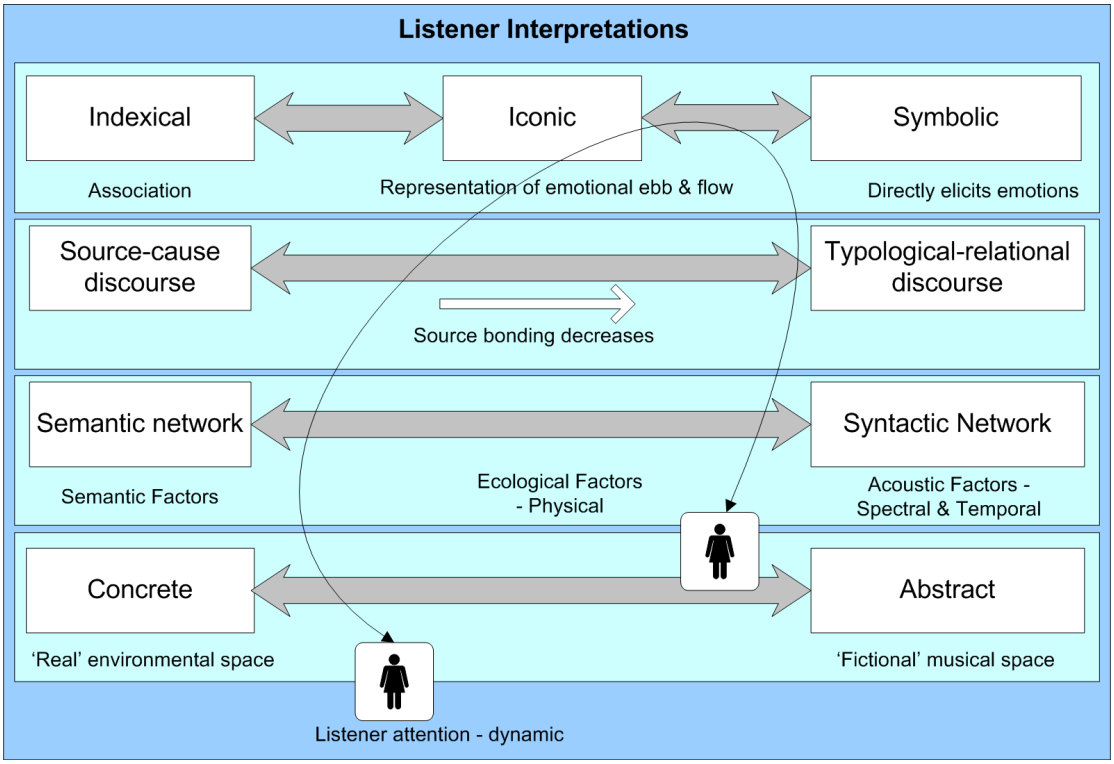


Figure 5.1: Listener interpretations of acousmatic music

The SIAM Framework

Here is a brief recap of the SIAM framework:

> Segregation: identification of sound events and the factors responsible for identification.
>
> Integration – Horizontal: identify sequential streams and patterns of sonic objects; determine causal linkages, relationships and possible syntaxes; consider organisation in time and the horizontal integration of pitch.
>
> Integration – Vertical: consider vertical integration and segregation as a cause of timbre and texture variance; consider psychoacoustic dissonance and musical dissonance; consider emergent properties relating to pitch (horizontal overlap).
>
> Assimilation and Meaning: consider discourse on the source-cause dominant (semantic) to typological-relational dominant (syntactic) continuum; consider global organisation in time and any hierarchical relationships; consider expectation-interruption, arousal and meaning.

The broad form of this procedure is derived from the work of Bregman (1999) on auditory scene analysis, in combination with Bigand's ideas on event structure processing (Bigand, 1993). The segregation and identification of sound objects also draws on the work of McAdams (1993). The establishment of factors responsible for sound segmentation and recognition has been influenced by the perceptual studies of everyday environmental sounds carried out by Gygi (2001), and by Howard and Ballas (1980). Identification of horizontal streams and the consideration of syntactical relationships between sound objects, and patterns of sound objects, has been informed by the experiments carried out by Ballas (1993). Considerations relating to vertical integration have been combined from Bregman (1999) and Smalley (1994). The notion of source-cause discourse derives from Smalley (1994), while the hierarchical "detection" methods of time-span reduction and prolongation reduction have been documented in Bigand (1993), and Lerdahl and Jackendoff (1983). Arousal and meaning is discussed in Dowling and Harwood (1986) and they refer to the symbolic interpretation ideas of Pierce (1931-35). A model of implication-realisation has been elaborated by Narmour (1989).

The listener interpretation-attention illustration (Figure 5.1) provides the context within which the musical work resides. It is an attempt to define a cultural space for acousmatic music that highlights the crucial role of the attitude of the listener. The study has arrived at a multi-layered depiction of possible listener interpretations, represented as a set of dichotomies. Each dichotomy has two poles separated by a continuum. One continuum explores the world of signs and symbols in that it borrows the terms defined by Pierce (1931-35) and elucidated by Dowling and Harwood (1986). The next continuum uses the kind of terminology developed within the tradition of *musique concrète*, inspired by Pierre Schaeffer and extended by the work of Smalley (1994). Whereas Schaeffer documented sound object "typology" extensively (static emphasis), Smalley has written a great deal on "morphology", or the way sounds change with time and the consequential implications of their transformation (dynamic emphasis). This second continuum is from source-cause discourse dominance to typological-relational dominance. Composers exploring expression along this continuum play with the "operation" of source bonding.

The next continuum, from “semantic network” to “syntactic network”, has been informed by the work of psychologists and it seeks to document the factors responsible for sound recognition. Starting from the left we recognise sounds from the world of our everyday experience, we can give a name to them and we can ascribe them a meaning. As we move along the continuum to the right, the ecological psychologists would argue that we may not recognise other sounds directly, but we can make inferences about the nature of the sounding material and the way the material has been excited. These are physical factors telling us something about the sounds and their environment. Further to the right, acoustic factors dominate and the spectral and temporal information can activate syntactic networks that establish temporal patterns between sounds in a sequence.

In the final continuum, there is an attempt to show that the concrete world of a real environmental space can operate in a very fluid-like relationship with the abstract realm of a purely fictional musical space.

Whether consciously or sub-consciously, a listener can move freely through all of these layers of interpretation while attending to an acousmatic work. Perhaps the interpretation continua could be identified as different listening modes. It should be noted that these modes are not exhaustive in that there exist a myriad of other listening modes that haven’t been highlighted here. What has been highlighted are the kinds of interpretation that may have a useful relationship with the “culture” of the acoumatic music genre, derived through the literature on acousmatic music and the psychology of the listening process.

To round off this section, the assertion can be made that:

> A framework for the analysis of acousmatic music can be derived from cognition theories, research on the auditory perception of everyday environmental sounds, and studies into the perception of Western tonal music.

The attributes of the framework, derived in previous chapters, have been re-iterated here, along with the sources for their origins. The questions pertaining to the application of the framework can now be addressed.

Application of the Framework

In the introduction chapter, a second set of research questions were concerned with the practical application of a cognitive framework to the analysis of acousmatic music:

- What methods and tools must be adopted to apply the cognitive framework to the practical analysis of repertoire acousmatic works?
- What notational forms must be derived to communicate any analytical findings in a written medium?
- What new insights result from the application of the constructed framework and methodology?
- Is the framework an effective approach to the analysis of acousmatic music?
- What are the implications for subsequent research?

Each one of these questions will now be addressed.

Methods and Tools

The first component of the defined methodology was to carefully consider the aims of the study, which were to apply the SIAM framework in an analysis of the work *Wind Chimes* in order to: Discover insights into the work itself, discover the syntactic forces that may operate between sound events within the work, and to test the appropriateness and usability of the SIAM framework

The analytical method was a combination of signal analysis and critical listening. A number of different types of signal analysis and representation methods were trialled before a sonogram representation was settled on. It was deemed to be the most useful in terms of sound event segmentation and frequency representation. The program Adobe Audition was used to play the sound file and to create various spectral displays of frequency versus time at different resolutions. To enhance the listening process, the graphical programming language PD (Puckette, 1996) was used to assist with "tuning in" to significant frequencies and pitches aurally.

The work was segmented into sections taking into account several factors including human long-term memory considerations, the "sliding window" notion of our short-term working memory, usable screen size displays, and factors associated with the musical work itself, such as segmentation at obvious sonic boundaries like moments of silence or passages with long sustained sounds. These boundaries defined a series of nine “sections” within the work, which were numbered for easy reference.

Analysis proceeded in a linear way from start to finish. For each section, a set of observations was recorded in text form, and a pictorial representation of separated sound events was drawn in pencil on paper along a timeline. Analytical data was also drawn on the pictorial representation. The data that was collected included an event's: start time; duration; perceived pitch or significant frequency components or both; graphical indications of amplitude envelope; graphic symbols depicting special features, e.g. pitch glissando. A "discussion" passage was also written for each section in order to interpret the observations that were made.

Once the observations, pencilled pictorial representation, and discussion passages had been completed, the question of how to record and communicate observations then arose, and so a Flash-based "interactive study score" was developed to provide a dynamic visual representation along with synchronized playback of the recorded work being analysed.

Having analysed the work from moment to moment in a serial fashion according to the SIAM framework, the whole work was reviewed in order to observe and describe global structures and recurrent syntactic forces operating within the work. That part of the framework says that the following factors need to be considered: the nature and type of discourse, global organization in time, hierarchical relationships, and implication-realization.

In order to discover hierarchical relationships, the time-scale was “reduced” by distilling the full study score into a “short score”. This step was designed to facilitate assessments concerning semantic factors, syntactic factors, acoustic factors, hierarchical formation, categorical generalisations, including how these various factors progress through time, and how they relate to each other.

In practical terms, a hard copy of each two-minute screen was printed, joined together, and annotations from the discussion passages were added for each section. Having segregated the sound events through representation in the study score, the discussion annotations were meant to highlight the functional relationships between the sound events, and thereby concentrate on the integration aspects. The result of this process was an annotated study score.

The next step was to reduce an eight-page annotated study score to a four-page analytical reduction or short score.

Reduction to short score involved:

- The recording of the major features from each section of the work.
- The grouping of those major features into categories.
- Examining the progression of major features from section to section.

As the reduction technique proceeded, the list of major features seemed to group into the following categories: texture; frequency related organisation; time related organisation; special features; semantic reference versus a syntactic reference.

A table was created to plot the way these categories changed from section to section, and the net result of the reduction process was a four page short score created from the eight screens of the interactive study score. Conclusions were then drawn regarding macro structures operating within the work.

Reflecting on the process of analysis, one can observe that the application of the framework is not a stepwise, serial sequence of actions, but rather a checklist that is accessed according to what may be appropriate for a particular segment of the work.

Most of the analytical process was carried out by hand, and was very time-consuming. Segmenting the sound events, recording times and durations, trying to determine salient frequencies in the midst of complex textures, and then transcribing the results, could take a full day's work just to analyse 30 seconds of the piece. This very labour-intensive approach could be facilitated by some sort of data reduction techniques,

such as auditory modelling, or a semi-automated approach, for example the use of some auto-correlation methods to facilitate salient pitch detection (see below).

Concentrated, critical listening was the primary means of analytical investigation, but the signal analysis techniques greatly enhanced both the detection of phenomena and the specification of hard data. One of the under-stated aims of the investigation was to provide enough of this hard data, in terms of exact timings and frequencies, so that another researcher could view the study score and create their own interpretation of the work.

Refinements to the means of representation could be made, but this will be taken up in the next section.

Notational Forms

The question addressed in this section is: What notational forms must be derived to communicate any analytical findings in a written medium?

In deriving notational forms, consideration has been given to the communication of analytical results, and to the use of notation to assist in the analysis itself.

A number of different signal analysis and representation methods were trialled. They included spectral analysis, fundamental frequency analysis (including auto-correlation), amplitude envelope trace, and noise analysis. Of all of these forms, the spectrogram (or sonogram) was found to be the most useful in terms of sound event segregation. High resolution spectrograms were created and a combination of visual inspection and aural tuning (using the oscillator bank patch) assisted in the identification of relevant frequency components.

To communicate the findings of this segregation-integration process, several types of representations were devised:

- An interactive study score.
- An annotated study score.
- A short score.

Interactive Study Score

The interactive study score divided the work up into two minute segments for representation on a visual display screen. With time displayed horizontally, the screen was divided vertically into a sonogram display area at the top, and an annotated graphic symbol area below (see Figure 6.1). The sonogram area was further divided into a full spectrum display above and a part-spectrum display underneath. The zoomed-in version of the spectrum, below 1500 Hertz, was useful for concentrating on pitch aspects.

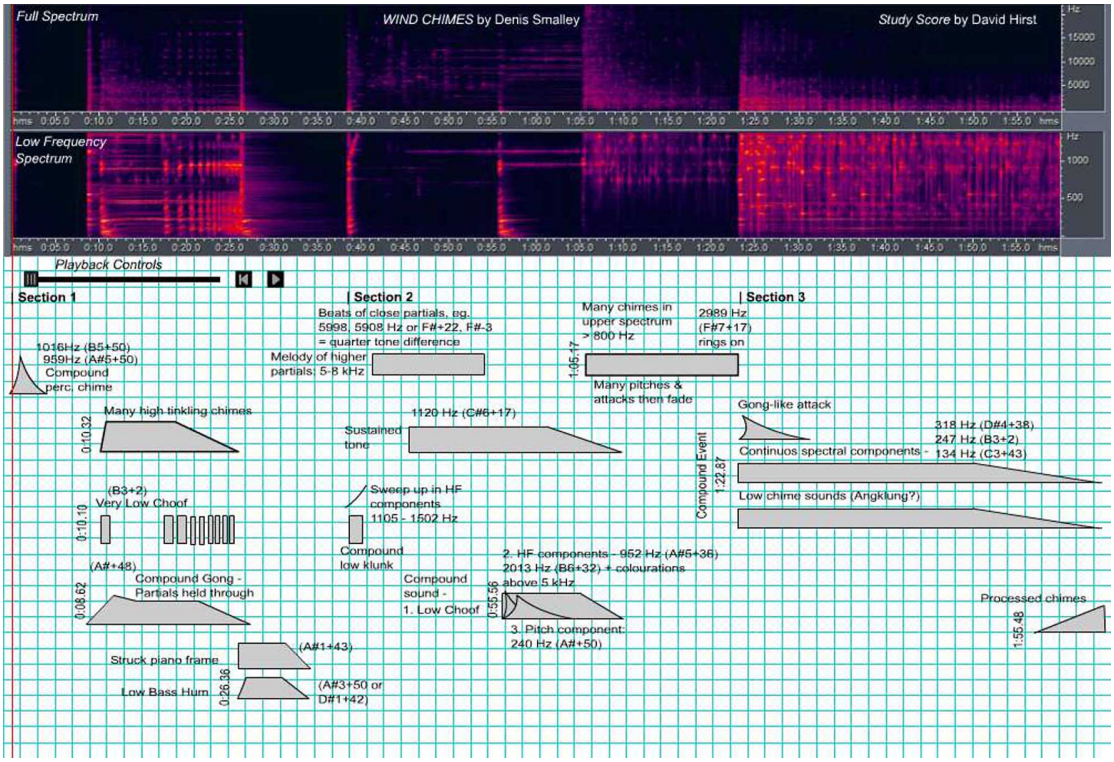


Figure 6.1: Screen shot of the Wind Chimes "interactive study score"

The area underneath the sonogram is meant to depict the segmentation of the work into separate sound events, and to provide some hard data on those sound events, such as important frequencies and pitches, as well as descriptive information (e.g. "gong-like"). A grid background was constructed to facilitate alignment with the time scale of the sonogram plots. Horizontal placement of graphic symbols represents fairly accurate representation of an event's start time and approximate duration.

The playback controls are used to initiate the playback of the sound track of the piece in synchrony with the visual representation. The ability to start and stop playback at

will facilitates the isolation of specific events at particular time points within the whole work. In a sense the study score is depicting the work "out of real-time" in order to enhance analytical investigation. It is mainly descriptive of events and doesn't necessarily show the relationships between events. This issue is taken up in the next section on the "annotated study score".

Annotated Study Score

A hard copy "annotated study score" was created from screen grabs of the interactive study score. The purpose of this step was to highlight the functional relationships between the sound events and thereby concentrate on the integration aspects. Sections were marked on the printed study score, and annotations from the observations and discussion passages were added for each section. Lines and other markings linking related events were also added. One thing that should be noted here is that annotation of relationships for representation on the submitted study score interactive was considered, but the amount of information was deemed to result in visual complexity to the point where it would cause visual confusion, rather than elegant illustration.

The annotated study score can be thought of as a working document that is a preparation for, and a transition to, the creation of a "short score" through the process of time-span reduction.

Short Score

The next step was to reduce an eight-page annotated study score to a four-page analytical reduction or "short score". Remember that the idea of this step was to distil the full score into a shorter score, so that we could produce another meta-level in the analysis in order to create a hierarchy in the interpretation (time-span reduction), and begin to look at the progress of the whole work.

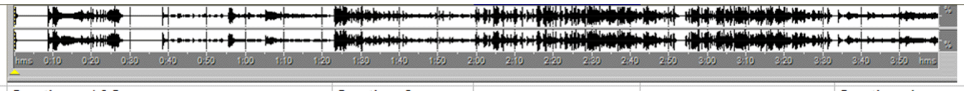
Reduction to short score involved:

- The recording of the major features from each section of the work.
- The grouping of those major features into categories.
- An examination of the progression of major features from section to section.

The list of major features grouped into the following categories:

- Texture
- Frequency related organisation
- Time related organisation
- Special features
- Semantic reference versus a syntactic reference

A table was created to plot the way these categories change from section to section. The net result of the reduction process was to create a four page short score from the eight screens of the interactive study score (see an example - Figure 6.10).



Section	Sections 1&2	Section 3			Section 4
Sub-Section		Episode 1	Episode 2	Episode 3	
Texture	Attack-continuant model	"Spectrally pitched" attack-continuant	Spectrally dense & rhythmic	Drum punctuation announces this dense & rhythmic episode	Scaffolding & triggering sounds used over sustained sounds
Frequency Organisation	Pitch centricity: (A#+50)	Pitch centricity: B		Pseudo cadence G-E	"Spectral harmony"
Time Organisation			"Spectral motives" of HF rhythmic patterns	Almost literal repetition of "Spectral motives"	Elaborated HF rhythmic motives
Special Features	Opening compound chime sound, contrasting low choofs				Bell sound used for punctuation
Semantic vs Syntactic	Mostly untreated sounds		Increased use of processing		Scaffolding sounds are the original sound transposed

Figure 6.10: Tabulation of categorical features for sections of Wind Chimes – Page 1: 0’ – 4’

The categories that emerged from grouping the major features of the work contained both confirmation of findings of previous researchers and some surprises. The emergence of two categories, one related to frequency organisation and one concerning organisation in time, was really no surprise and probably is a reflection of notions first espoused by Vanderveer (1979) that frequency information tells us something about the nature of the resonating body and time-related information tells us something about the nature of its excitation. In acousmatic music, frequency relationships create integration (or contrast) and time relationships create patterning.

The category labelled with the term “texture” could have been equally well described as “structural features”. In this category we find terms like “attack-continuant model”

and “spectrally dense and rhythmic” and “scaffolding and triggering sounds used over sustained sounds”. These are all terms describing the way different sections are structured and perhaps the way different sonic elements are “layered”. Indeed the notion of fore-ground, middle-ground and background hasn’t been highlighted since this may be too simplistic for acousmatic where integration is a fundamental structural technique. An analogy to traditional contrapuntal textures seems more appropriate than to homophonic textures. Some writers have chosen to elaborate further on the fore-ground/background idea (Van Leeuwen, 1999).

The category of “semantic vs syntactic” features is an obvious but important one for acousmatic music. The way these forces compete or reinforce each other through the course of the work is critical to this genre of music. Their interpretation is provided in the “insights” section below.

Finally the “special features” category is a catch-all for a lot of the unique, but important, aspects that cannot be allocated to the above categories. For Smalley, the use of compound sounds and the re-use of material are a couple of special features that stand out.

In general, one can conclude that the interactive study score is extremely useful in the analytical process in “freezing” the work in time and helping to describe, in a visual form, the segregated sound events that have been discovered. The combination of spectrogram display, graphical symbols, textual and numerical data is also a useful combination of data in the communication of event information, as is the inclusion of two resolutions of spectrogram data.

A better format to trial in the future may be to have full-screen spectrogram representations and superimpose symbols and data actually on the spectrogram. While it could be argued that this may erode the depiction of integrated single events, since some events may be spread across the whole spectrum while others may occupy a small segment of it, annotating the spectrogram could assist with the representation of relationships between frequencies and time information. Colour coding could also be useful.

The tabulation of a short score, through time-span reduction, assisted with the identification and communication of trends across larger portions of the work. The

development of an annotated study score certainly facilitated the creation of the short score.

Insights

What new insights result from the application of the constructed framework and methodology?

Summarised here are the main conclusions regarding the insights gained into the organisation of Denis Smalley's *Wind Chimes*:

- In *Wind Chimes*, Smalley is playing with the internal spectral structures of what we normally think of as single sound events. The listener is drawn into an expansive internal sound world within which Smalley performs his microsurgery.

- Smalley has taken some traditional tonal music concepts and pushed them higher in the frequency spectrum, or in some cases embedded them deeper in the spectrum.

- Smalley uses the notion of compound sound events extensively where several simple sounds add together to produce a complex composite.

- *Wind Chimes* makes extensive use of the attack-resonance model. An attack, which could be an agglomeration of sounds, can be extended into a resonance phase through the prolongation, or addition, of selected component frequencies.

- At times, the form of the work is like an expression of the attack-resonance model on a macro scale. Sound events tend to aggregate at certain time points, then there is a relaxation of activity revealing long sustained sounds that have their own fascinating micro-colourations.

- Over time, the initial attack-continuant framework becomes transformed into more of a compression-relaxation style. The tension increases within the work as sections, and phrases within sections, begin to overlap with each other. There is any increased density of activity as the work progresses.

- The term "pitch centricity" has been coined to try and convey an observation that, although Smalley doesn't use an extensive tonal music organisation of pitch materials, he does manipulate pitch to create certain points of gravitational pull that frequencies may be attracted to.

- Transpositions tend to be by thirds or sixths - wider than the critical band. On the other hand, Smalley uses smaller intervals between simultaneous sounds, less than a major second, to create beats and to provide colouration.

- The overall form of the work is that it moves from the concrete to the abstract. It progresses along the scale from a Source-Cause Discourse that is "about chimes" to a Typological-Relational Discourse that explores frequency and time relationships. This is achieved through an increasing use of signal processing and sonic manipulation as the work progresses.

- The primary strong binding force is frequency. Where simultaneous sounds share a frequency component they tend to fuse together. Where sequential sounds share a frequency component, or are very close together in frequency, they tend to link together to form a stream. Frequency components are extruded from one sound, elongated, then overlapped with the same frequency within another sound to fuse the events together to create a new gesture.

- The second strong binding force is time. Simultaneous events fuse together to form compound sounds, and nearly simultaneous events combine to form an association where one sound seems to trigger the other implying some common cause, or a cause-effect relationship.

- The form of the work is sectional and episodic. Smalley makes use of a lot of repetition of sound events, but the repetition is varied. The repeated sound events are either a processed version of the originals, or a literal repetition set within a new context of different surrounding sounds.

- Finally, the interpretation of the analytical data has resulted in the emergence of certain syntactic traits: compound sound events; stratification of the frequency spectrum; pitch centricity and harmonic fields; organisation in time;

semantic and syntactic progression. Each one of these phenomena will be briefly recapitulated below.

Compound sound events

Smalley uses compound sound events where the technique may consist of a “compound attack” containing a number of different sound sources, or a "compound sustain" to add colour, variety and complexity, or a "compound gesture" where sound elements are accumulated around a single point in time, but are not exactly coincident.

Stratification of the frequency spectrum

The use of many compound events can use a large proportion of the frequency spectrum, so how does Smalley avoid a crowded, muddied sound, and the ensuing effects of masking? He does this through a skilful selection of contributing sounds where each one occupies its own segment of the spectrum in a way that doesn't overlap too much with others. In general, Smalley uses the whole spectrum, with sustained sounds in the lower register, pitched sounds in the middle register, and interesting noise colourations in the high frequency register.

Pitch centricity and harmonic fields

In some instances, Smalley has moved the manipulation of pitch higher within the spectrum of a sound. Rather than creating melodies that consist of notes with definite pitches from a scale, Smalley emphasises certain frequencies within the spectra of the sounds he employs, or he transposes sounds so that they gravitate to certain pitch centres.

Smalley has also re-interpreted traditional harmony and voice-leading practices by taking the principle of "common tones" between two successive chords in tonal harmony, and applying it as a principle of "common partials" between two successive sound events within the acousmatic musical texture. The common partials then become a binding agent between the sounds through a strong horizontal streaming tendency.

An extension of this principle is the principle of "stepwise motion" used in harmonic progression. Smalley creates a stepwise motion of sustained partials when some

dominant partials are changed to values that are close in frequency in subsequent sound events.

If we think of the relationship between speech and song, and extend that idea to ordinary, everyday environmental sounds, then we could say that Smalley is giving voice to ordinary sounds by bringing out the voiced components in those sounds. He achieves this by either reinforcing certain frequencies, transposing the whole sound to a particular pitch, or super-imposing selected sustained frequencies to fuse with those components present in the recorded sound.

Organisation in time

The attack-continuant paradigm is a strong structuring force throughout *Wind Chimes*. Pseudo-rhythmic figures are used within the broad attack-continuant framework. Sustained partials are overlapped with the next attack-continuant expansion, providing a "proximity in time" Gestalt glue throughout.

As noted above, simultaneous attacks create "compound sounds" by virtue of their "vertical integration". Nearly-simultaneous attacks create "compound gestures" that are so unique they generate interest and variety.

Repetition is also used in a number of ways. Repeating a sound at short, and ever-decreasing, time intervals produces a feeling of acceleration, propelling the listener towards the goal event. A more subtle technique, used over a wider time-frame, is the creation of a "pre-echo" or the faint anticipation of a sound. Repetition of sound in a new context is also extensively used.

Distinctive sounds make judicious return appearances throughout the piece. To describe the strategic use of these distinctive sounds, we have employed the term “scaffolding”. The skeletal framework is fleshed out through processing and progression. Loud percussive sounds like foot-stomps, struck piano frames, bass drums and so on are used, like punctuation, to mark specific sections.

Semantic and syntactic progression

The form of the piece is that it begins with concrete elements which are readily discernible, and progressively moves to an abstract musical space where the spectral and temporal relationships dominate. This is achieved through an increasing use of

signal processing, transposition, and an increase in density of sounds as the work progresses. There is a climax in the work and then it relaxes to a point where individual concrete sounds become recognisable once again, right near the end.

When the distinctive concrete sounds, used earlier in the work, reappear in an untreated form at periodic junctures throughout the work, they are generally used as structural signposts. We have used the term "scaffolding" to describe this phenomenon.

Smalley uses a classical Western musical narrative approach with periods of tension and release. On the micro scale, the tension-release pattern is mirrored in the predominant use of the attack-continuant model. On the macro time scale, the compression-relaxation accumulation of percussive short sounds followed by layers of long sustained sounds represents another variation of the tension-release pattern.

Forward motion is provided by connection between successive sounds. Proximity in the frequency domain is coupled with an increasing density of sound event activity - building excitement. These propulsive tendencies are reinforced through the increasing use of signal processing. We can see that schema employed at the micro level reinforce the macro level formal organisation.

Effectiveness of the Framework

Is the framework an effective approach to the analysis of acousmatic music?

The framework developed for the analysis of acousmatic music has been effective in that:

- It provides a systematic reference point for a thorough examination of acousmatic musical works by addressing the detail through the adoption of the SIAM procedure, and by addressing the "big picture" through the use of the listener interpretation-attention notion, which allows the analyst to discuss the work from the point of view of a number of different interpretations (psychological, semiotic, compositional).

- The SIAM framework has resulted in a number of new insights into the particular work *Wind Chimes* by Denis Smalley. Hopefully this has proven to be valuable information in its own right.

Of course, to be fully tested and refined into a robust methodology, the framework needs to be applied to other acousmatic works, and this would also enable comparative studies to be conducted. Some works may require changes and refinements to the framework that could accommodate more rhythmic pieces, for example. The "listener interpretation" scheme may need to be expanded to provide for phenomenological or philosophical approaches too.

These are some of the issues taken up in the final section on the implications for future research.

Implications for Future Research – or "Unanswered Questions"

Early on in the study it was discovered that there is a paucity of research on the perception and cognition of acousmatic music. In contrast, there has been a lot of research on the perception of Western tonal music and some interesting, although perhaps less voluminous, work on the perception of everyday environmental sounds. The current study has attempted to adapt these two bodies of work to create the SIAM framework, but there is a lot of scope for more experimentation on aspects of the perception of acousmatic music. One critical area for investigation is the role of grouping and hierarchy formation in acousmatic music.

Hierarchy in Acousmatic Music

Many writers have tried to come to terms with hierarchy in music, but it is an especially difficult topic in acousmatic music. James Tenney, while not specifically writing about acousmatic music, attempted to combine Gestalt principles with the articulation of a hierarchical classification system, up to the level of overall form (Tenney, 1988). Tenney's *Meta+Hodos A Phenomenology of 20th-Century Musical Materials and an Approach to the Study of Form* was first written in 1961, and his *META Meta+Hodos* was written in 1975. They were later combined, revised, and published in a second edition in 1988.

With respect to perceptual organisation, Tenney defined the following terms:

- *Element*: is a *temporal Gestalt unit* (TG) at the lowest hierarchical level. An element is perceived as being singular and not divisible into lower level TGs.

- *Clang*: is a TG at the next higher hierarchical level (2nd level).

- *Sequence*: is a TG at the next higher hierarchical level (3rd level).

Tenney describes their relationship in the following way:

> A clang thus consists of a temporal succession of two-or-more elements; a sequence consists of a temporal succession of two-or-more clangs. Note that a combination of two-or-more elements occurring simultaneously does not necessarily constitute a clang. (Tenney, 1988:101)

A complication immediately arises in the sense that it is possible to perceive simultaneous "elements", so Tenney identifies four different types of vertical texture: simple-monophonic; simple-polyphonic; compound-monophonic; compound-polyphonic.

In Tenney's view, hierarchy is determined by cohesion and segregation, which are influenced by proximity and similarity. Other secondary factors he describes as: "accent", "repetition", "objective set", and "subjective set". (Tenney, 1988:103)

Tenney discusses musical parameters and then moves on to formal perception and description. On the perception of form, Tenney writes:

> PROPOSITION IV: The perception of form at any hierarchical level involves the apprehension of three distinct aspects of form, at that and all lower levels. These three aspects of form will be called *state*, *shape* and *structure*. (Tenney, 1988:107)

This is not the place to elaborate on state, shape and structure, but Tenney does provide some clues as to how state, shape and structure may form the basis of encoding at different hierarchical levels. Perhaps some experiments on the perception of acousmatic music can be devised using Tenney's notions as a basis.

A different approach to hierarchy is taken by Van Leeuwen (1999). He writes on perspective, immersion, and social distance. With reference to a number of different types of music, including "soundscapes", Van Leeuwen makes the following points:

1. The semiotic system of aural perspective divides simultaneous sounds into groups, and places these groups at different distances from the listener, so as to make the listener relate to them in different ways.

2. The sound may either be divided into three groups (positioned as Figure, Ground, and Field) or two groups (positioned as Figure and Ground or as Figure and Field). When there is no perspective, there is only Figure. (Van Leeuwen, 1999:22-23)

Immersion is the opposite to perspective, and Van Leeuwen refers to it as "wrap-around" sound (Van Leeuwen, 1999:28). Sounds seem to come from everywhere at once and he cites examples such as evergreen forests and large churches.

In a real world sound environment, the "social distance" associated with sounds is closely coupled with the above notion of "perspective". But according to Van Leeuwen:

> ... the technology of amplification and recording has uncoupled the two, and allowed them to become independent semiotic variables. As a result a soft breathy whisper can now stand out clearly against loud drums or brass sections... (Van Leeuwen, 1999:24-25)

Van Leeuwen then goes on to list five forms of social distance: Intimate; Personal; Informal; Formal; Public. He then provides an illustration of a system network of aural perspective and social distance, and demonstrates how a work, for example a radio play, can be analysed according to such a network.

So, for the purposes of future investigation, does Van Leeuwen's work on perspective and social distance provide some basis for the design of perception experiments relevant to hierarchy and acousmatic music?

Lerdahl (1987) has also provided some interesting quotes that could form the basis of research questions to be addressed through perception studies of acousmatic music:

> If the elements of the novel organisation are arranged according to some foreign principle – say, serial (permutational) operations – is the resulting sequence as learnable as the previous one? (Lerdahl, 1987:156-157)

And

> For trees [elaborative hierarchies] of any interest to arise, the continua must be capable of arrangement in arrays of at least two dimensions, thereby creating a

> "cognitive space". Within this space, certain moves become possible... (Lerdahl, 1987:157)

What are such "cognitive spaces" for acousmatic music?

Here, further questions can be posed that may inform experimental design of acousmatic music perception studies related to the topic of hierarchies:

- What processes might activate a timbre hierarchy? How can information gained from these processes be combined with other sound parameters to define an event hierarchy?
- How do timbral hierarchies combine with pitch and rhythm hierarchies in acousmatic music?
- Does hierarchy resolve the conflict between fluidity required for sonority and fixity needed for syntax?

Further Experiments

The following questions may inform experimental design of more general perception studies of relevance to acousmatic music:

- Related to some previous experiments in musical grouping, the segmentation of an acousmatic work could be tested for musicians and non-musicians along the lines of the experiment performed by Deliège and El Ahmadi (1990).
- Is the transformation of timbre like the gap-fill phenomenon found with pitch perception?
- Similarity is one of the prime criteria for categorisation (Barsalou, 1992). Does surrogacy arise out of the natural propensity for categorisation?
- Is there a notion such as timbral dissonance for natural sounds and for abstract sounds? Are there timbral archetypes or prototypes?
- What types of mental models are there for acousmatic music? Experiments could be devised that explore episodic memory, for example, that relate to auditory "scene" representation.

- What non-verbal events can participants remember from a long audio "scene"? The memorisation of a series of random sound events could be compared with a series of semantically-related sound events, for example.

- Is short-term sensing identifying sound sources and attributes, while tracking over longer periods is associated with extracting some "message" from the audio stream?

- What are the inter-modal relationships between audition, language and vision? For example, an experiment could be devised where the participants verbalise their self-talk while listening to acousmatic music over headphones. For more on "musical imagery" see Godøy and Jørgensen (2001).

Patterning, Progression and Prolongation

Patterning in acousmatic music is associated with sequences of sounds. Progression and prolongation are also tied up with patterning. In order to devise experiments that may cover this area, we need to discuss these concepts a little further.

Sequences can be characterised on the semantic-syntactic continuum. Semantic sequences are of two main types:

1. *Environmentally consistent sequence*: This is a logical connection (or ordering) of the events that is consistent with the sequence of sounds as they occur in the environment. For example, a car door opens; then closes; we hear the sound of the starter motor; the engine idles; and the motor revs higher as the car moves off. We could describe this sequence as perhaps environmentally consistent with the "car sounds" schema.

2. *Contradictory sequence*: The ordering of sound events is not logical when compared with the environment. This may be represented along with two main schemas:

    a. Homogeneous Schema: For example we may employ the "car sounds" schema, but the sequence may be illogical: repeated closing of a car door is followed by the motor revving higher and then the starter motor sounds.

b. Heterogeneous Schema: We hear a sequence of sounds: a car, a baby, a crowd scene, and there is no logic to the sequence.

A syntactic sequence must generally display some form of sequential integration. As we have seen, such integration is achieved through similarity and/or proximity, either temporally, spectrally or both. Transformation is an important operation as incremental changes to either the temporal profile or spectral profile will maintain links in the syntactic chain.

A distinction should be made between progression and prolongation. Progression is goal-directed. In acousmatic music it is transformation that assists the feeling of progression. We move from source to target sound via small transformations and there is a feeling of movement away from the source to the destination.

Progression can also be achieved via connection in the frequency domain (spectral profile or spectral register) or the time domain (amplitude profile or temporal proximity). Connection between sequential events via frequency is like the principle of the use of common tones in functional harmony.

In summary it can be noted that syntax within acousmatic music will often be a patterned sequence of events or a related combination of events. A sequence may involve repetition, prolongation or progression. Functional harmonic progression in tonal music can be replaced by functional timbral progression in acousmatic music, through the application of the principle of common frequencies or the principle of transformation.

How these notions might be tested in perception experiments remains fodder for future work.

Implications of Future Research Resulting from the Current Study

The application of the SIAM framework remains to be tested on other acousmatic works. How robust is the framework on other Smalley works, and the whole of the acoumatic music repertoire? Must it be adapted or augmented for use with other works? Will it provide the desired common framework so that comparative studies can be carried out between different works?

Reduction of labour time might be achieved through some data reduction and/or automation techniques. By using models of the human auditory system, the number of frequency bands could be reduced and the estimation of salient pitches could be facilitated through the use of auto-correlation methods. There has been at least one published attempt at an automated auditory scene analysis method, but the difficulties are enormous (Ellis, 1998).

Modifications to the interactive study score may entail annotation directly on an enlarged sonogram rather than using a separate sound event panel. There may also be some 3-D representations that could be developed in connection with the auditory modelling techniques, mentioned in the previous paragraph, that could prove useful.

What has emerged in this study is a picture of composers like Denis Smalley whose technique is to split open the spectrum of a sound in order to fuse its fragments to other split spectra in a complex web of fusion and fission. The entwined contrapuntal textures that acousmatic music explores are not only tightly bonded in frequency and time, but they show a glimpse of reality and semantic meaning only to whisk it away in an instant into a fanciful world of pure sound as enveloping as the sounds that a developing child may experience within its mother's womb.

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