Harmony

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NOTATIONAL SEMANTICS IN MUSIC VISUALIZATION AND NOTATION

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ABSTRACT

This paper examines a range of methods of exploiting the inherent semantic qualities of graphical symbols, colour and visual communication. Moody's Notations Theory is used as a starting point in the discussion of expanding the range of techniques for visualizing sound and instrumental notation. Recent findings in the understanding of semantic primes, visual language, perceptual metaphors and "weak synaesthesia" are examined and connections to existing sound-based fields such as spectromorphology, action-based scores, graphical and animated notation. The potentials for the use of colour to represent timbre both for descriptive analytical and prescriptive compositional tool in electroacoustic music is explored. Works by Cathy Berbarian, Luciano Berio, Aaron Cassidy, Vinko Globokar, Juraj Kojs, Helmut Lachenmann, Ryan Ross Smith and the author are discussed.

1. INTRODUCTION

The expansion of the possibilities for the musical score afforded by modern printers and computer screens has provided the opportunity to represent parameters of musical phenomena that were previously poorly captured by traditional Western music notation: most importantly continuously evolving parameters such as timbre and amplitude, and the depiction of complex sound events such as those found in electronic music.

The musical score is a time critical form of visualisation that, in the majority of cases, corresponds to sounds that unfold at a more-or-less defined temporal rate. For this reason there is a strong imperative for scores to employ symbols that signify sonic events with maximal efficiency. Moody's *Physics of Notations Theory* (Moody 2009) defines a set of principles to evaluate and improve the visual notation, that are pertinent to musical notation (See Figure 1.)

While Moody's principals are useful to consider in the creation of any form of notation, they are particularly pertinent to creators of music that challenges existing paradigms. As composers continue to explore increasingly idiosyncratic approaches to creating music, Cognitive Fit implies that notation should also evolve to flexibly reflect the materials that are represented. Approaches such as acousmatic music, microtonality, pulseless music, algorithmically generated music, guided improvisation, interactivity and mobile structure often poorly represented using traditional music notation.

Cognitive Fit:	use different visual dialects when required.
Semiotic Clarity:	there should be a one-to-one correspondence between semantic constructs and graphical symbols.
Perceptual Discriminability:	symbols should be clearly distinguishable.
Visual Expressiveness:	use the full range and capacities of visual variables.
Complexity Management:	include mechanisms for handling complexity.
Cognitive Integration:	include explicit mechanisms to support the integration of information from different diagrams.
Semantic Transparency:	use symbols whose appearance is evocative.
Graphic Economy:	keep the number of different graphical symbols cognitively manageable.
Dual Coding:	enrich diagrams with textual descriptions.

Figure 1. Moody's Physics of Notations theory (as summarized by Genon, et al. 2011:224)

Notation to capture the nuances of such explorations may require novel, semiotically clear, well defined visual languages that make full use of the range of forms of visual representation available to the composer, such as: colour, animation, hypertextual access, temporal coordination and multimedia integration (Vickery 2012a).

Colour provides a great potential for the formation of Perceptual Discriminability in a musical score. One obvious approach, for example, might be to employ a colour scheme that maximizes the distinctness of separate musical phenomena such as instruments, voices or sound sources. Similar requirements have been studied for the creation of data visualisation (Tufte 1990), transport maps (Green-Armytage 2010), and websites (Stanicek 2009). Recent research, however, has indicated strong perceptual correspondences between colour and a range of sonic phenomena (Prado-Leon, Schloss, and Palmer 2011), suggesting there may be more intrinsic semantic value to be gained from colouring the score.

This paper explores the implications of recent research in visual representation with particular ref-

erence to achieving semantic soundness though the use of perceptual metaphor and crossmodal correspondence.

2. SHAPE, COLOUR AND THE SCORE

Synaesthesia, a condition in which an individual experiences sensations in one modality when a second modality is stimulated (Ramachandran and Hubbard 2001:4), has been the subject of scientific enquiry for over two hundred years (Campen 1999:11). In the late 1960s Luria proposed that there are 'remnants' of synaesthesia in ordinary individuals "that many ordinary people have, which are of a very rudimentary sort (experiencing lower and higher tones as having different colorations)" (Luria 1968:22). In 1996 Marks noted that "there are natural correspondences between experiences in different sense modalities, and that these seem to be nothing less than "hard wired." (Marks 1996:61). Ramachandran and Hubbard have also proposed that "there may be natural constraints on the ways in which sounds are mapped on to objects" (Ramachandran and Hubbard 2001:19), citing Köhler's bouba/kiki experiment (Köhler 1929:224) as an example. In this experiment, "because of the sharp inflection of the visual shape, subjects tend to map the name kiki onto the (pointed, star-like) figure (…), while the rounded contours of the (other) figure make it more like the rounded auditory inflection of bouba" (Ramachandran and Hubbard 2001:19).

This phenonmenon has come to be known as Weak Synaesthesia (Martino and Marks 2001) or simply Crossmodal Correspondence (Deroy and Spence 2013). Martino and Marks differentiate between strong and weak forms of synaesthesia as follows:

Strong Synaesthesia:

One stimulus is perceived, the other is experienced as an image;
the correspondences are both idiosyncratic and systematic;
the definition of the correspondences is absolute;
associations are literal and semantic.

Weak Synaesthesia:

Both stimuli are perceived;
the correspondences are systematic;
definition of the correspondences is contextual;
associations are metaphorical and semantic.

(Martino and Marks 2001:63)

One of the key concepts underlying Traditional Western Notation (as well as many visual representations of sound such as the spectrogram) is the vertical spatial depiction of frequency in which higher frequencies are also vertically higher on the page. This interpretation has been shown to be supported by apparently basic latent mapping inherent cross-modal understandings in infants as young as 1 year old (Wagner, Winner, Cicchetti, and Gardner 1981) and pan-culturally (Eitan and Timmers 2010:419). Eitan and Timmers suggest that "pitch metaphors, while culturally diverse, may be based upon basic underlying mappings, stemming from bodily-based inter-modal interactions with the physical environment" (Eitan and Timmers 2010:407).

Walker has proposed that cross-modal correspondences are ordered in clusters as shown in Figure 2. Walker claims that "the same core correspondences should emerge whichever sensory feature is used to probe them, confirming that the en bloc alignment of the dimensions is context invariant" (Walker 2012:1806). Likewise Eitan and Timmers have suggested that "such implicit and automatic correspondence of positions and directions on the vertical spatial plane with non-verbal behavior may engender a ''second-order" mapping of ''high" and ''low" auditory pitch into features such as valence, mood or social hierarchy, as well as physical features like size and mass" (Eitan and Timmers 2010:407). They propose that:

> *The percept of pitch involves two contrasting magnitude representations. On the one hand, as pitch ''rises" its metaphorical height, intensity, and visual lightness increase; on the other hand, however, its metaphorical mass, size, and quantity decrease.* (Ibid:420)

These findings suggest guidelines that might inform the creation of "semantically transparent" notation for non-traditional musical sound sources.

Exploring these ideas, the work *unhörbares wird*

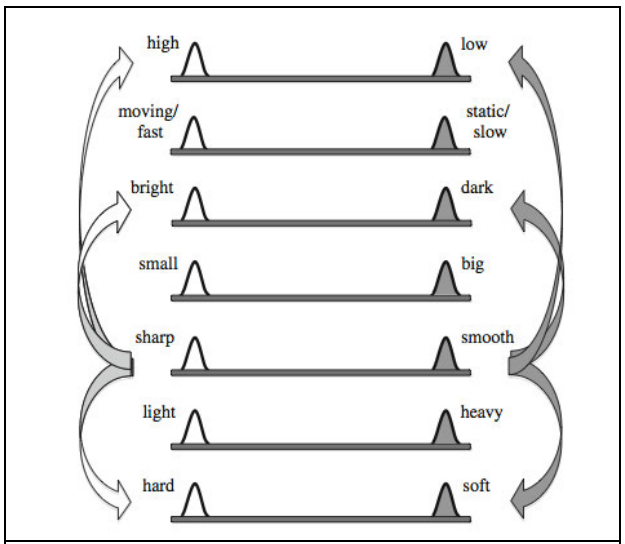

Figure 2. Proposed *En Bloc* alignment of cross-sensory features contributing to cross-modal perception (Walker 2012:1793)

hörbar [2013] (the inaudible becomes audible) used a spectrogram as the basis for the score for flute, clarinet, viola, cello, percussion and electronics. Using a spectrogram as the basis for a score poses a number of challenges, as Grill and Flexer have indicated, spectrogram "visualizations are highly abstract, lacking a direct relationship to perceptual attributes of sound" (Grill and Flexer 2012:591). In particular the "spatial" representation of the sonogram lacks the relational quantifiers of a traditional score that presents the representation of sonic events in the context of a tempo and frequency grid. This raised issues concerning the identification of parameters such as pitch, timbre, dynamics and orchestration, the issue of synchronization of multiple performers and importantly the resolution of the spectrogram itself (See Figure 3.)

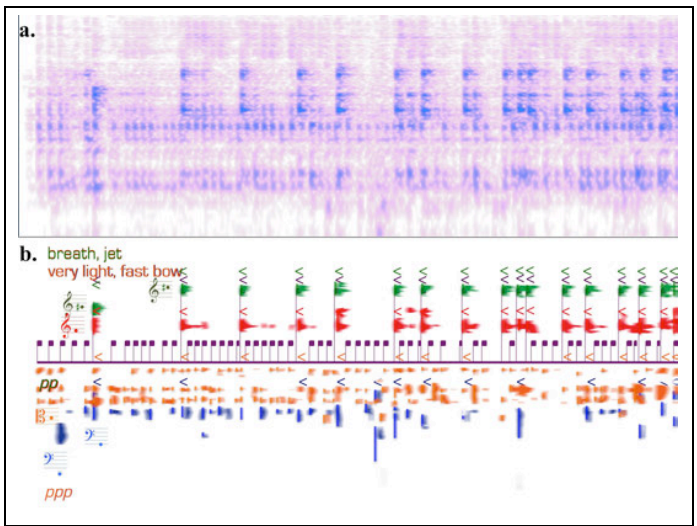

Figure 3. The opening 20 seconds of *unhörbares wird hörbar* [2013]: a.) shows the spectrogram upon which the work is based and b.) shows the score using graphical features of the sonogram as "noteheads".

In order to maintain a level of "graphic economy", a resolution of roughly 60ms/px was used for the spectrogram-score. This resolution allows the performer to view elements of the sonogram that represent what Curtis Roads refers to as "basic units of music structure (…) complex and mutating sound events on a time scale ranging from a fraction of a second to several seconds" (Roads 2002:3-4) while at the same time reading at an acceptable scroll rate of 2.35 cm/s (Vickery 2014a).

It was necessary to represent "Perceptual attributes" of the sonogram in a manner that that was maximally efficient and semantically sound, and therefore prominent features of the spectrogram are indicated using:

"floating" traditional staff/clef/pitch symbols to specify pitch;

the thickness of each player's line to represent dynamics; and

transparency of the line (along with textual indication) to denote specific forms of timbral variation, from regular instrumental sound to diffused tones, "coloured noise" (Eimert 1955:4). in Stockhausen's terminology

The prominent shapes depicted in the original spectrogram are mostly retained, allowing the performer to calculate glissandi, minor fluctuations in pitch and timbral variation based on their interpretation the of colour, shape and size of the "noteheads".

The performers are synchronized by presentation of the scrolling score on networked iPads. This allows the acoustic instruments to remain coordinated with a spatialised re-sonification of the spectrogram that is played simultaneously.

The orchestration of individual instrument parts was colour-coded: flute - green, clarinet - red, viola - orange, cello - blue and percussion – purple with the aim of maximizing the distinctness of each part. Research at The Visual Perception and Aesthetics Lab at the University of California Berkeley, however, suggests that there is a high degree of correlation between mappings of colour-to-sound in non-synaesthetes. Griscom and Palmer have proposed that there are systematic relationships between colour and a range of musical phenomena including timbre, pitch, tempo, intervals, triads and musical genres (Griscom and Palmer 2012, 2013).

Human vision utilizes only three types of colour-sensitive cone cells - red, green and blue – and hues with frequencies between these (such as yellow, cyan and magenta) are perceived through stimulus to multiple cone cells. For example the frequency of yellow light falls between red and green and is detected by stimulus to both the red and green cone cells and as a result appears "lighter" than purple even though it frequency is not as "high". In this way, visual perception differs greatly from auditory perception. Figure 4. shows the a notional colour spectrum based on human visual perception.

The notional colour spectrum provides a palette from which colours representing sonic features or instruments might be chosen in a musical score. For most people this chart appears segmented into families of similar hue (yellows, oranges, tan, green-blue etc) and distinct but related hues may

Figure 4. A notional colour spectrum based on human visual perception from white to black (based on CIELAB colour space (Hoffman 2003) and Bruce MacEvoy's Artist's Value Wheel (MacEvoy 2005).

Figure 5. Colour as an indicator of timbral variation in the viola and cello parts of *unhörbares wird hörbar:* a. corresponding spectrogram and b. viola and cello parts.

lend themselves to the representation of timbral variation within a sonic feature or instrument.

As the number of represented features increases, however, so does the difficulty of discriminating between hues required. Green-Armytage suggests a palette of 27 tones based on white, yellow, orange, lime, green, turquoise, blue and purple and their lighter or more saturated counterparts, as a template for colour representation (Green-Armytage 2001).

Grisolm and Palmer have explored the idea of using cross-modal associations to define semantically sound mapping a range of instrumental timbres against colours in a two dimensional red/green: yellow/blue field. Grisolm and Palmer have also demonstrated that "color choices for multiple timbres are well predicted by an average combination of the component timbres" (2013). Interestingly they have observed, for example, that the yellow-blue value is correlated with attack time, whereas average red-green value is correlated with spectral brightness (2013).

Such observations may provide indications of how best to represent timbral information in coloured scores. Figure 5. shows detail from the score of *unhörbares wird hörbar* at 3m 35s, demonstrating the use of colour to indicate timbral variation in the viola and cello parts.

In another work The *Lyrebird: Environment Player* [2014b] a Max patch was built along these lines to visualise sonic features of field recordings. The score represents the frequency and amplitude of the single strongest detected sinusoidal peaks as rectangles drawn on a scrolling LCD object.

Brightness, noisiness and bark scale data derived using Tristan Jehan's `analyzer~` object are used to determine the luminance, hue and saturation of each rectangle. In contrast to a spectrogram, only principal sonic features are depicted, however timbral features are reflected in the changing colour of the rectangles. Figure 6. shows a simple example in which one of the long-crescendo F#s from the clarinet part of Messiaen's *Abîme des Oiseaux* is shown represented as a spectrogram (using Chris Cannam's *Sonic Visualiser* software) and the *Lyrebird Environment Player.* This example illustrates the representation of continuous timbral and amplitude changes over the duration of the note.

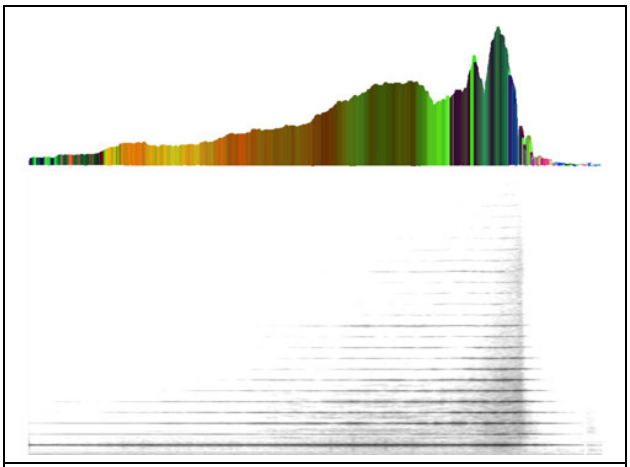

Figure 6. One of the crescendo F#s from the clarinet part of Messiaen's *Abîme des Oiseaux* represented as a spectrogram and the *Lyrebird Environment Player.*

This approach also has application for the analysis of electroacoustic music, somewhat alleviating the problem of "demonstrating coindexation and seg-

mentation due to the difficulty in illustrating differences in timbre" (Adkins 2008) in a spectrogram and provides an (almost) realtime feature analysis of the recording in which contours and timbral shifts are readily recognizable.

Figure 7. shows a representation of Pierre Schaeffer's *Étude aux Chemins de Fer*, clearly delineating segments of the work created with varied source materials by consistently colouring sound objects of the same materials. The insert shows the whistle that occurs at approximately 112 seconds into the work and illustrates the "Doppler" effect that is heard through a change of both vertical height (pitch) and colour (timbre).

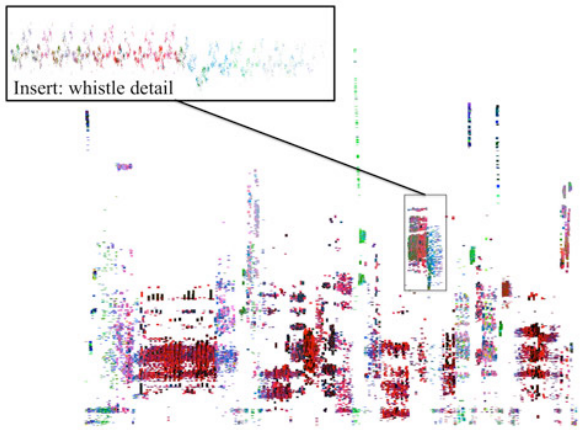

Figure 7. Pierre Schaeffer's *Étude aux Chemin de Fer* represented in the *Lyrebird Environment Player*, illustrating segmentation by colour (timbre). The insert shows the Doppler effect on a whistle that occurs at approximately 112 seconds in greater detail.

3. VISUAL METAPHOR

Moody refers to the evocative appearance of Semantically Transparent notation, implying that such notation should ideally be inherently sensible to the reader. In addition to current research into "weak synaesthesia", other fields of research potentially contribute to the creation of semantically transparent scores. Wierzbicka has investigated the concept of "Semantic Primes", innately understood concepts that cannot be expressed in simpler terms (Wierzbicka 1996), visual language, the creation of semantic graphical symbols for non-verbal communication (Horn 1998) and the concept of perceptual metaphors, which proposes that physical experience and embodiment bring about heuristic understandings that can be expressed in metaphors (Marks 1996). Marks claims "metaphors reflect processes of thinking and, consequently, appear not just in language but in perception as well" (Marks 1996: 39). Arnheim expressed a similar concept that he termed isomorphism, "according to which processes which take place in different media may be nevertheless similar in their structural organization" (Arnheim 1949:157).

A useful starting point in discussing semantically transparent notation from the standpoint of semantic or perceptual metaphor is Patel, Schooley and Wilner's collection of visual principals that convey meaning in graphic symbols (See Figure 9.). It was developed to evaluate Picture Communication Symbols, "a popular augmentative and alternative communication symbol set" (2007:65).

Gestalt:	Proximity, Similarity, Common region, Connectedness
Semantic Attributes:	Increment, Anthropomorphis, Possible outcomes, etc.
Cartoon Conventions:	Emotion, expression, Motion, Physical phenomena, Speech balloons, Embodied experience, Cartoon metaphors, Arrows
Compositional Distinctions:	Symmetry, Asymmetry, Repetition, Singularity, Juxtaposition, Exaggeration,
Line Interpretation:	Horizontal lines, Vertical lines, Active lines, Converging lines, Diverging lines

Figure 8. Visual Principals that Convey Meaning in Graphic Symbols (Patel, Schooley and Wilner 2007).

These visual principals are pertinent to music of a more textural nature. They suggest a way of conceiving of sound not unlike Denis Smalley's "spectromorphology", which provided "a list of terms, some of them technical, some more metaphorical, which can be used to interpret the function-significance of an event or context" (Smalley 1997:115).

The terminology employed by Smalley is often quite abstract (for example: "emergence" or "transition") and yet comprehensible by composers and listeners, at least in part through heuristic understandings based on "physical experience and embodiment".

Similarly Kramer argues for the presence of a level of semantic understanding of abstract structures in tonal music, based "gestures that sound characteristically like transitions, climaxes, contrasts, and other such conventions" (Kramer 1986 p. 140).

Blackburn and other have extended Spectromorphology into the visual field hypothesis as both a descriptive analytical and prescriptive compositional tool in electroacoustic music by Giannakis (2006), Thoresen (2007), Blackburn (2009, 2011), Pasoulas (2011), and Tanzi (2011).

Blackburn cites the cross-modal quality of acousmatic sound "that "it is frequently reported that, in

concert, acousmatic music has the powerful effect of conjuring imagery, shapes, trajectories and spaces, which we as listeners proceed to describe verbally" (Blackburn 2011:5). She proceeds to outline "a new graphical vocabulary based on spectromorphology" (2011:5) that conforms to many of the principals outlined by Patel, Schooley and Wilner (see Figure 9.). Blackburn's graphical vocabulary not only visualizes individual "sound units" but shows how they can be "strung together to form longer phrase lengths" or "morphological strings" (Blackburn 2009).

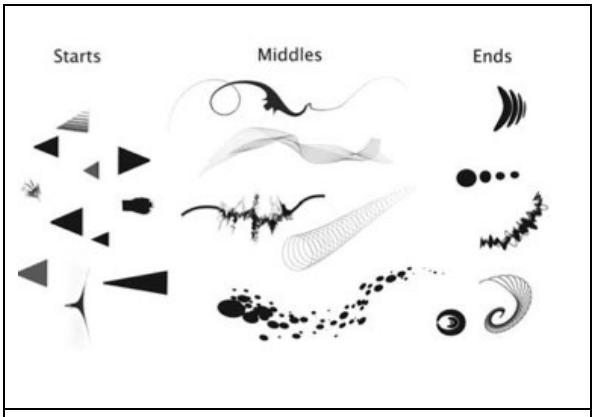

Figure 9. Spectromorphological shapes explored by Manuela Blackburn (2011).

Blackburn also emphasizes the use of perceptual metaphors, stating that words that are "more readily visualized ie. *spiral, flock, stream* and those with a clear associated physicality ie. *fly*, *drift*, *attack*, appear better suited for informing sound material creation" (Blackburn 2009).

This approach is equally applicable to instrumental music. In *Agilus Mimoid, Symmetriad* (2012) the instrumental score establishes a set of visual conventions that reflect a similar line of enquiry. The notation is proportional both horizontally and vertically: the duration of the note is equivalent to its spatial length (and scroll-time) and intervals and relative pitch of the instruments are always represented by the same vertical height.

This leads to the interesting condition that instruments performing the same pitch are notated "on top" of one another. In a traditional score this situation is avoided, however the networked scrolling score allows for the each individual's parts to be "brought to the front" while maintaining synchronization. This state of affairs allows the performer to view the full score and their own part simultaneously, providing a proportional visual representation of the other parts (see Figure 10a.).

Figure 10b. shows a passage from the work exploring semantic attributes – the broadening of an ensemble unison into a "cloud" of sounds of varied pitch and then "falling". The performers are only given the starting pitch and highest or lowest pitch of the "cloud" and are left to determine the exact note used to represent the visual figure themselves.

In Figure 10c. "coloured noise" is represented semantically by a textured line, suggesting a continuously changing timbre, for each instrument accompanied by textual performance instructions.

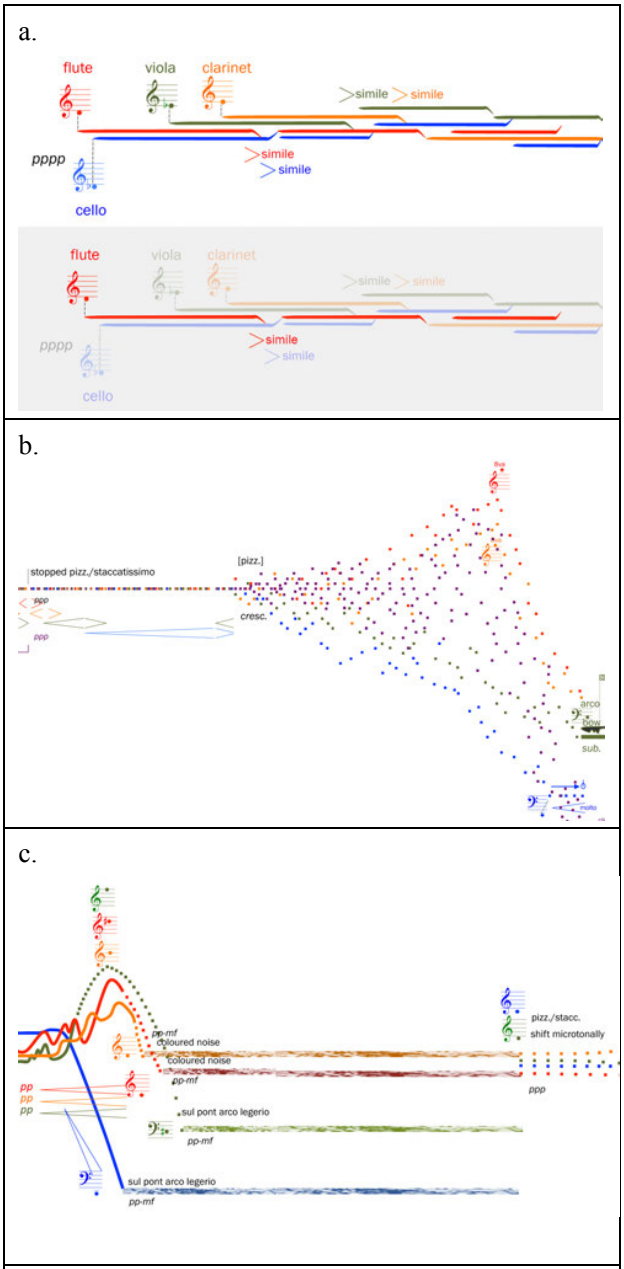

Figure 10. Excerpts from the score of *Agilus, Mimoid, Symmetriad* (2012b): a. vertically and horizontally proportional notated and score and part view; b. notation with semantic "cloud"-like and "falling" attributes; c. textured lines used to represent continuously changing "coloured noise" texture.

Patel, Schooley and Wilner also propose the use of "Cartoon Conventions" to communicate visually. In a broad sense, this includes any manner of visual

representation of the physical world, and as such encompasses tablature-based forms of notation. Examples of tablature notation include systems commonly used for guitar and gamelan notation, but can also be found more experimental scores such as Berbarian *Stripsody* (1966), Berio *Sequenza V* (1966), Globokar *?Corporel* (1985) or Lachenmann *Pression* (1969-70).

Kojs defines musical scores that employ tablature to direct physical movements "Action-based music" which "*emphasizes the artistic exploration of mechanical actions which are used to control all aspects of composition, including its conception, form, instrumentation and instrumental design, performance and score* (Kojs 2009: 286). (See Figure 11).

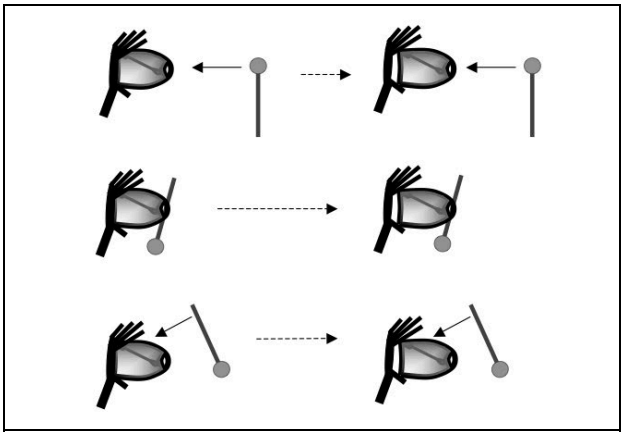

Figure 11. "Cartoon Conventions" used Juraj Kojs' *At and Across* for Slovak sheep bells and cyberbells (2007)

Berbarian's *Stripsody* embodies the principals of cartoon conventions as a mode of convention. The score is peppered with actual cartoon characters, speech bubbles and "action words" accompanying knock out punches and so forth. Lachenmann's *Pression* on the other hand actually depicts a cello fingerboard and defines the actions of the work against the tablature style physical depiction of their execution.

Such works might equally be represented with an fixed fingerboard image with animated notation superimposed upon it. Ryan Ross Smith's *Study no. 8 for 15 percussionists* (2013) (Figure 12.) is a animated tablature score depicting the movement of the mallets of 15 individual performers each represented by a figure. The smooth pendulum-like movement of the mallet symbols in this work allows the performers to anticipate the point at which they will strike the small grey circles on each side of the figure representing the instruments. This approach is relies on kinaesthetic understandings of motion rather than visual synchronisation.

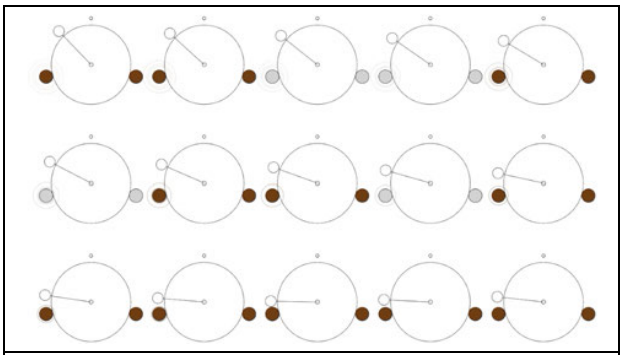

Figure 12. Excerpt from Ryan Ross Smith's *Study no. 8 for 15 percussionists* (2013)

When tablature and notation are combined it is often because additional non-traditional physical actions are required by the composer. One example is the polyphonicization of different components of performative technique that are normally unified into the single goal of "note production". An early example of this technique is Berio *Sequenza V*, in which the trombonist is directed to move the slide according to one contour while blowing (regardless of the outcome) at times defined by a separate stave.

The works of Aaron Cassidy expand this approach, often notating different components of instrumental technique on up to ten independent, simultaneous staves. This radical approach is the product of "experimentation with the polyphonicization of the various components of performative, physical action involved in producing sound in/on an instrument (…) the final resulting sounds of the piece are not in fact denoted in the score as such but instead arise as "aural byproducts" of the interaction of the (…) decoupled layers" (Cassidy 2000).

In Cassidy's *What then renders these forces visible is a strange smile (or, First Study for Figures at the Base of a Crucifixion)* (2007-08), the solo trumpeter is expected to simultaneously read 10 systems prescribing rhythmic values for embouchure tightness and articulation, breath pressure, tuning slide position and rhythm and positioning values for each valve. (See Figure 13.)

Works exploring polyphonicization of actions such as Cassidy's perhaps deliberately confront the limitations of traditional music notation, not to mention music reading itself. However, if these aims are set aside, the representation of multiple parameters using the techniques outlined by Patel, Schooley and Wilner and exploiting the semantic potentials of colour and shape, affords the potential of substantial simplification of complex multi-parametric scores.

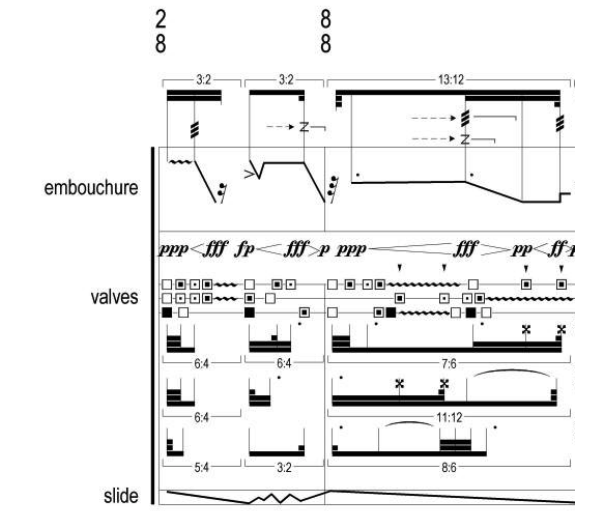

Figure 13. Aaron Cassidy What then renders these forces visible is a strange smile (or, First Study for Figures at the Base of a Crucifixion) (2007-08).

4. CONCLUSION

Many of the evolving techniques and preoccupations of composers demand more continuous control of multiple musical parameters. The methods of representation and evaluation issues discussed here, especially when coupled with the affordances of the screen score, provide opportunities for composers, in instrumental and electroacoustic domains to capture the nuances of such works.

The issue of efficient and semantically sound notation is crucial for the development of effective notation for the screenscore. It is hoped that the current expansion of interest in "weak synaesthesia" will continue to contribute to the understanding of semantic "short-cuts" to communication in music notation.

The real-world applications of the emerging variety of methodologies for presenting notation on screen remain unexamined. One possible strategy for the evaluation of these techniques is the use eye-tracking technology to observe the connection between what is seen and what is performed and heard. Further work by this author will attempt to establish an understanding of the interaction between readers and the screenscore.

5. REFERENCES

[1] Arnheim, R. (1949). The Gestalt theory of expression. *Psychological Review* 56, 156-171

[2] Blackburn, M. (2009). Composing from Spectromorphological vocabulary: Proposed application, pedagogy and metadata. http://www.ems-network.org/ems09/papers/blackburn.pdf

[3] Blackburn, M. (2011). The Visual Sound-Shapes of Spectromorphology: an illustrative guide to composition. *Organised Sound* 16:5-13

[4] Campen, C. (1999). Artistic and psychological experiments with synesthesia. *Leonardo* 32 (1): 9–14.

[5] Cannam, C., Landone, C., and Sandler, M. (2010). Sonic Visualiser: An Open Source Application for Viewing, Analysing, and Annotating Music Audio Files. *Proceedings of the ACM Multimedia 2010 International Conference*. Firenze, Italy.

[6] Cassidy, A. (2000). Asphyxia. http://www.aaroncassidy.com/music/asphyxia.htm"

[7] Deroy, O., and Spence C. (2013) Weakening the case for 'weak synaesthesia': Why cross-modal correspondences are not synaesthetic. *Psychonomic Bulletin & Review* 20: 643–664.

[8] ,Eitan, Z., and Timmers, R. (2010). Beethoven's last piano sonata and those who follow crocodiles: Cross-domain mappings of auditory pitch in a musical context. *Cognition* 114:405–422 (419)

[9] Genon, N., Amyot, D. and Heymans, P. (2011). Analysing the Cognitive Effectiveness of the UCM Visual Notation System Analysis and Modeling: About Models. *Lecture Notes in Computer Science Volume* 6598 221-240: 224

[10] Giannakis, K. (2006). A comparative evaluation of auditory-visual mappings for sound visualization. *Organised Sound* 113: 297–307.

[11] Green-Armytage P. (2001). Colour zones, connecting colour order and every- day language. 9th Congress AIC, Rochester, *Proceedings of SPIE*, 4421: 976–979.

[12] Green-Armytage, P. (2010). A Colour Alphabet and the Limits of Colour Coding. Colour: *Design & Creativity* 510: 1–23.

[13] Grill, T., Flexer, A. (2012). Visualization of Perceptual Qualities in Textural Sounds. *International Computer Music Conference 2012*, Ljubljana, Slovenia