

2011

# Visualising the Score: Screening Scores in Realtime Performance

Cat Hope

*Edith Cowan University*

Lindsay Vickery

*Edith Cowan University*

**Visualising the Score:**  
*Screening Scores in  
Realtime Performance*

Dr Cat Hope and Lindsay Vickery

Western Australian Academy of Performing Arts  
Edith Cowan University

**ABSTRACT**

This paper examines the screening of music notations and the impact of this configuration in a live music performance situation. Before the development of graphical computing, Traditional music notation, was rarely shared with the anyone other than other musicians, composers and analysts; let alone displayed during the performance. However, some composers experiment with scores and their visual presence in performance by employing automated 'score-players' or actual films specifically developed to be interpreted by musicians. This paper raises some questions and possibilities for this new way of sharing musical qualities of composition and performance.

## 1. INTRODUCTION

In relatively recent times, a range of new paradigms for the presentation of notation to live performers has emerged. The new-found and literal mobility of the musical score has been a product of developments in technology<sup>1</sup> that have resulted in what might be referred to as the “screen-score”; a musical score read on a computer or projection. Early experiments with traditional paper scores, such as multi-pathway “mobile scores” where page order could be changed for each performances, or where music reading conventions are altered, could be framed as artistic media “*pushing against their own boundaries* (Žižek 2000 p. 39), a process that became accelerated by technology.

MEDIUM	COMPOSER	PERFORMER	SCORE
Screen-score	generative	immanent	real-time score
	transformative		
	permutative		
Paper-score	sequential	interpretative	scrolling score
	permutative	explorative	mobile score
	sequential	interpretative	traditional score

**Table 1.** Paradigms for the presentation of notation to live performers<sup>1</sup>

Clay and Freeman note that terms to describe the range of new approaches have not yet been standardized (Clay and Freeman 2010 p.1). Yet four principal considerations governing the relationship between these new screen-based approaches and the traditional notated score may be devised:

1. Medium - the expanded range of approaches may give rise to either dynamic or static arrangement of materials analogous to traditional print text and computer-based hypertext.
2. Composer - the musical materials may be configured so that they are read sequentially, permuted, transformed or generated in real-time. The computer-generated score provides a seamless medium for such approaches.
3. Performer - the relationship between the performer and the score may be characterized as interpretative (of a traditional score), explorative (of a “mobile score”) or ‘immanent’ in that reading may be expected to occur more “in the moment”. The computer-generated score may permit true extemporization focusing the performer “*within themselves, where they actually are*” (Cage, 1985 p. 134)
4. Score - Traditional musical notation implies the abstraction of taking a continuous ‘scroll’ of music and splitting it into sections that can be arranged on successive pages. The scrolling score uses the computer to actualize the scrolling paradigm of linear music on screen. In the mobile score, the notation remains fixed on paper, but “*the order of musical sections is outlined either just before or during performance*” (Kim-Boyle 2010 p. 4). The real-time score “*refers to any notation, either traditional or graphic, which is created or transformed during an actual musical performance*” (Clay and Freeman 2010 p.1).

<sup>1</sup> The rapid improvements in graphics processing capacity, smaller, lighter and cheaper screens, data projection and so on.

The “screen-score” itself can be one or more photographic images, film or a GUI. These scores are usually put into motion by way of software on a computer, however we will argue the underlying concept of the screen-score emerged before this kind of technology was available. Screen-scores are notated music compositions devised to be performed; and are not to be confused with visual representations of music or the musical interpretation of visual art.

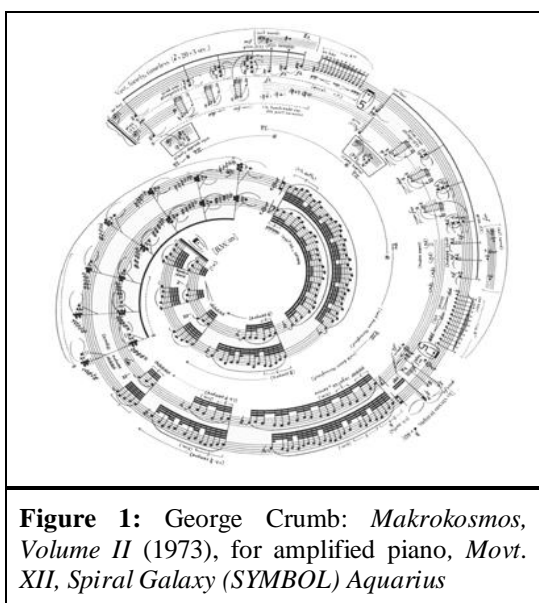
## 2. CHANGING THE SCORE

In the Platonic conception, art works are seen as a duality comprising the “real” Idea and the “symbolic” Representation (Fourie 2010 p. 203). Although some art forms, such as film and perhaps dance, arguably bring the idea and its representation closer to some form of unity, Art Music has traditionally maintained a strict separation between the scored representation and the embodied performance. Since the development of European music notation as we have known it (in the tenth century by the Italian monk Guido d'Arezzo), the process of composition parted from that of performance and the notion of a musical ‘work’ as an abstracted standalone entity emerged. The notated score became a code for the trained musician to translate into the performed ‘temporal’ music.

Even before the advent of graphical computing, composers had begun to explore the idea of the score as an autonomous art-work. Scores by Roman Haubenstock-Ramati, Sylvano Bussotti, George Crumb and others began to diverge from the horizontal systems of traditional notation and explore the notion of a closer correlation between the Idea and its representation. This development, because of its conceptual implications, arguably made these scores of greater interest to the audience.

During the compositional process a reciprocal relationship develops between the idea (thought) and the slowly evolving manner of writing it down. This relationship of continuous mutual influence lasts during the whole time of composition, and has the effect that, if the original idea of the work is musically pure and true, the resulting piece will be the best possible in terms of both music and notation.

(Haubenstock-Ramati 1976 p. 97-98)

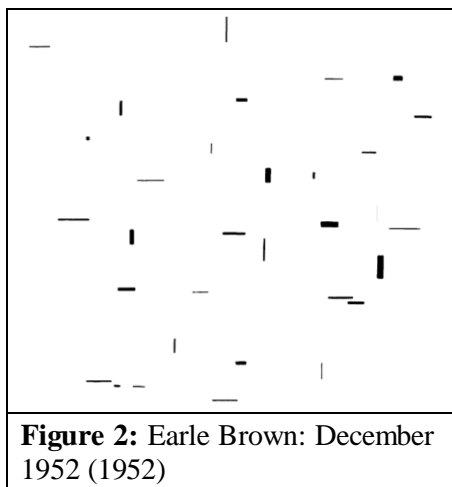


**Figure 1:** George Crumb: *Makrokosmos, Volume II* (1973), for amplified piano, *Movt. XII, Spiral Galaxy (SYMBOL) Aquarius*

George Crumb’s meticulously drafted scores often present Western notation in a symbolic fashion illustrating the work’s programmatic content.

Composers also extended the conventions of notation in the search of a way to share new compositional concerns such as extended techniques, or aleatoric choices. In some case this involved abandoning notational conventions completely, in favour of novel means of representation: so-called graphical notation. As Cornelius Cardew put it:

Notation and composition determine each other. Differentiate between creating a language in order to say something and evolving a language in which you can say anything. (Cardew 1961 p. 21)



**Figure 2:** Earle Brown: December 1952 (1952)

Earle Brown's *December 1952* is thought to be the earliest example of this approach. The work is an example of asemic graphical notation – it does not privilege any manner of reading or interpretation.

To most trained music readers it presents more like a painting of the Neo-Plasticism school than a musical score. This observation is not irrelevant. Brown himself stated:

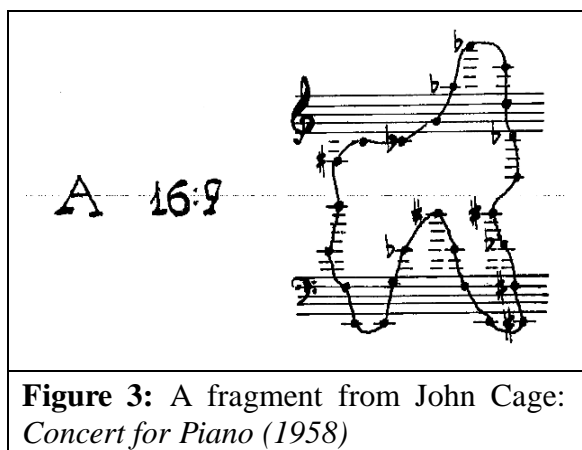
I was once very envious of painters who can deal directly with the existent reality of their own work without this indirect and imprecise “translation” stage.

(Brown 1986 p. 186)

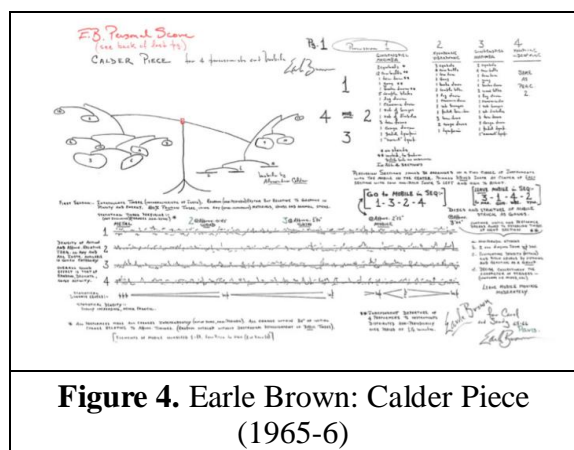
Cage and others also amplified the existing ambiguities of musical notation to create scores in which the semantic interpretation is indeterminate.

One cannot determine exactly what effect the notation causes. The observer-listener is able to stop saying I do not understand, since no point-to-point linear communication has been attempted.

(Cage 1970 p. 135)



**Figure 3:** A fragment from John Cage: *Concert for Piano* (1958)



**Figure 4.** Earle Brown: *Calder Piece* (1965-6)

Figure 3. shows an example of ambiguous, but graphically striking notation from one of the 63 pages of Cage's graphical notation magnum opus *Concert for Piano* (1958). The accompanying instructions state:

Following the perimeter, from any note on it, play in opposite directions in the proportions given. Here as elsewhere, the absence of indications of any kind means freedom for the performer in that regard.

(Cage 1958 Inside cover)

Such notation presumes that “the performer’s mind is (...) inspired by the graphics through some sort of mental resonance”

(Hajdu 2004 p. 5).

A simultaneous development in notation was that of the mobile score, the idea that a music notation (graphic or otherwise) could be reordered or reorganised for, or even during, each performance. Mobile Scores most commonly offered performer choice in the pathway(s) taken through the work. The ability for performers to read rhythm from right to left, or for composers to express harmony from top to bottom, was no longer required.

This notational “problem” in 1952 not only led to my finding a notation which was much more suitable for my musical language in a technical sense, but also discovering the “graphic” potential for dealing with the problems of “mobility” and immediacy which had been of great interest to me since the influence of Calder and Pollock in approximately 1948.

(Brown 1986 p. 192)

Graphically notated works raise the score from a prosaic codified, and universal medium for transmitting musical information, to the level of an individual, idiosyncratic artwork. This is illustrated by the fact that graphical scores are publically exhibited<sup>2</sup>, and books featuring such works have been published (Young 1963, Cage 1969 and Sauer 2009). Yet strangely the scores are seldom presented to the audience in the context of their actual performance.

### 3. THE EMERGENCE OF THE SCREEN-SCORE

In the Visual Arts, numerous projects sought to explore the visualization of music. Interestingly there was little cross-over between the “visualised music” (images as interpretation of sounds) and the “sonified image” (a musical reading of an image) of the musical score.

Despite the progress of musically generated visual abstractions prior to the advent of graphical computing, these are projects that apparently had little influence on the course of musical composition. The experiments of Kandinsky, Schoenberg and Scriabin<sup>3</sup> did not engender a new medium for musical presentation.

---

<sup>2</sup> For example: “Pictures of Music” at The Block Museum Northwestern University, Illinois (<http://www.blockmuseum.northwestern.edu/picturesofmusic/index2.html>), Notations 21 at The Hutchins Gallery <http://notations21.wordpress.com/notations-21-exhibit-visuals/>

<sup>3</sup> Kandinsky’s total theatre work *Der gelbe Klang* (1909) synaesthetically combined dance, music and coloured light. (Stein 1983 p. 61). Scriabin’s *Prometheus* (1910) used a colour organ to project coloured lights during the performance and included notated score for the lights (Poast 2000 p. 217). Schoenberg’s *Die gluckliche Hand* (1913) included specific indications of colors to be projected onto an on-stage screen and made very detailed color sketches for this production (Ibid)

Similarly, it is strange to observe that, in the Avant Garde scene of the 1950s and 60s, the work of numerous abstract filmmakers such as the Whitneys, Fischinger, Harry Smith, Joseph Cornell, Maya Deren, Kenneth Anger, Stan Brakhage and Jordan Belson, did not exert more influence on the experimental works of the New York School and the Fluxus movement.

<b>Loise-Bertrand Castel</b>	<i>Ocular Harpsichord</i> (1734)
The earliest recorded “color organ” (Snibbe 2000 p. 23)	
<b>Bainbridge Bishop</b>	<i>Color Organ</i> (1877)
A machine allowing coloured light to be blended on a small screen (Peacock 1988 p. 401)	
<b>Vladimir Baranoff</b>	<i>Piano Optophonique</i> (1916)
<b>Rossiné</b>	
Used painted glass discs, which rotated as light passed through them. (Piringer, J. 2001 p. 26)	
<b>Thomas Wilfred</b>	<i>Clavilux</i> (1922)
Performed displays of prismatic colour that many compared to the shifting lights of the Aurora Borealis (Lyons 1995 p. 173)	
<b>Arseny Avraamov</b>	<i>Hand-drawn motion picture soundtracks</i> (1930)
Achieved by means of shooting still images of drawn sound waves on an animation stand. (Holzer 2010)	
<b>Len Lye</b>	<i>A Colour Box</i> (1935)
Cameraless animation, abstract films painted and scratched directly onto film (Manovich p. 258)	
<b>James and John Whitney</b>	<i>Five Film Exercises</i> (1943-4)
Sounds and images were synchronised optically produced by light shot through a stencil system. (Brougher 2005 p.125)	
<b>Oskar Fischinger</b>	<i>Lumigraph</i> (1953)
A taut cloth sheet that could be pressed into from behind with hands or objects to intersect thin sheets of light controlled by foot pedals. (Snibbe 2000 p. 23)	
<b>Table 2:</b> Pre-digital developments in Musical Visualisation	

Both Morton Feldman and Earle Brown have indicated indebtedness to their contemporaries in the visual arts such as Jackson Pollock, Alexander Calder and Mark Rothko (see Feldman 1988 and Brown 1986). Feldman created numerous works that are notated using graph paper, such as the *Projections* (1950-3) and *Durations* (1960-1) series. The graph works are uniformly performed from the full score, making them eminently suited to projection, however the performance practice of these works has remained faithful to the “paper and music stand” medium of traditional notation. Similarly, Browns “open works” from *Twenty Five Pages* (1953) onwards, with their interchangeable sections and variable page orientations, seem tailor-made for, and yet did not utilize projection.



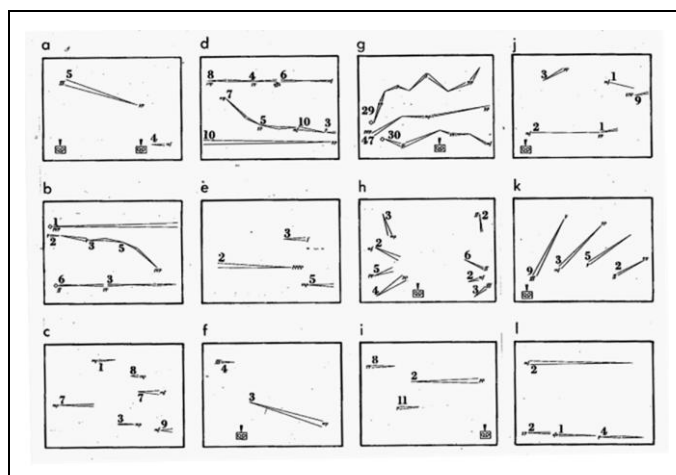
Several of Cage's works do include projected visual elements, however their presentation was not particularly integrated into other structures simultaneously unfolding in the space. The best known is the multimedia work *Variations V* (1965), which, in addition to one of the earliest interactive dance systems included:

films with distorted television images by Nam June Paik mixed with images of the dancers shot by Stan VanDerBeek during rehearsal. VanDerBeek spliced these clips into a kaleidoscopic collage that was projected onto a giant screen across the back of the stage.

(Miller 2001 p. 546).

David Tudor's *Bandoneon! (a combine)* (1966) is also an interesting early example of a multi-media work (and perhaps of "no-input" composition), in which "non-note" sounds from a bandoneon are run through an array of analogue circuitry resulting in audio and video output. Here we do find a visual element drawn directly from the sounds of the "performance" (or perhaps "non-performance").

*Bandoneon!* is a combine incorporating programmed audio circuits, moving loudspeakers, TV images, and lighting instrumentally excited (...) *Bandoneon!* uses no composing means, since when activated it composes itself out of its own composite instrumental nature. (Kuivila 2004 p.17)



**Figure 5:** Score components (Slides a. through l.) of Mauricio Kagel: *Prima Vista* (1962-3) (Excerpt)

Argentine composer Mauricio Kagel's in his work *Prima Vista* (1962-63) is a clear example of a graphical score composed with intent to be projected. This piece uses 25 slides randomly placed in the carousel of a slide projector, and is one of the earliest examples of score to be screened visible to both the musicians and audience. The projector enabled the performers to organise the slides randomly, and as the performers are grouped into teams, enabling the audience to engage with the game like nature of the work.

The reasons for the resilience of the paper medium in music until recent times are not entirely clear. In the past practical issues such as the expense, convenience or even the operating noise of projections systems may have played a part. Fifty years of unremitting visual stimulation from television and film may have additionally altered the visual sophistication and expectations of audiences and composers. It is also possible that there is dissonance between the visual imagery generated internally by the listener upon attending a musical work and the projected images imposed upon them.

#### 4. SHARING THE SCORE

One general effect of the digital revolution is that avant-garde aesthetic strategies became embedded in the commands and interface metaphors of computer software. In short, the avant-garde became materialized in a computer.

(Manovich 2001 p. 258)

The advent of cheap, portable and powerful computing has clearly been a “game-changer” in the development of the screened score. Not only does it afford relatively simple configurations of equipment to facilitate projection of the score, it provides a medium that permits novel approaches to the manipulation of materials, namely real-time algorithmic permutation, transformation and generation.

Sharing previously hidden aspects of the performance via video projection is becoming increasingly common in the presentation of New Music. Kate Maloney suggests that the increasing use of projection in musical performances is:

Potentially a response to the mystification caused by the increasing use of complex technology in sound performance, many contemporary artists seem interested in finding ways to minimize the inevitable concealment of their artistic process that results from performing with high-tech equipment such as laptops and digital processing units.

(Maloney 2005 p.13)

The process of sharing the score might also be seen as more generally demystifying classical music’s code of performance practice, which customarily involves the privileged relationship between the performer(s) and the notated score, which is usually concealed, (along with the performer(s)), from audience by opaque music stands.

Although perhaps admirably revelatory, the projection of the internal workings of the performance does not necessarily address the problems of audience comprehension or even curiosity. In the case that the notation system itself remains obscure to the audience, video project may simply add a further, potentially distracting, layer of opacity. Maloney notes that projections of the operating language of computer programs, such as the object orientated program MAX/MSP, often leave the audience confused and unsatisfied.

For the inexperienced MAX/MSP viewer, the projection merely offered a complicated graphic interface. The intricate patterns of lines, text boxes, and sliders cannot fulfill the desire for information they create. (Ibid)

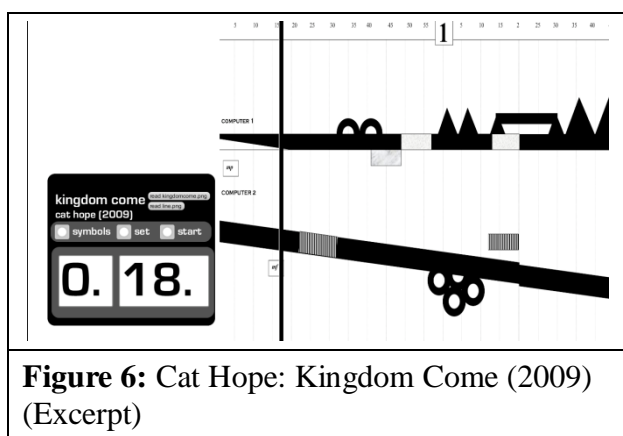
When graphic scores are employed, there is perhaps less specialist decoding required than for complex languages such as traditional musical notation and programming code. In many cases, non-standard graphical notation is nearly as unfamiliar to the performer as is to the audience and the ‘codes’ employed in realizing the symbols are a source of interest and speculation for the audience. Hence, an untrained (non-musician) audience member is likely to understand at least certain elements of the scores. This understanding means that the audience member will engage with the score in a way they would not using more traditional music notation.

But the effect of this engagement is not fully understood: does this sharing of the ‘performance space’ with a video projection enhance, or reduce the effect of the music being performed? Those who focus entirely on sound in a musical performance may argue visual representations are irrelevant and worse, distracting. Others may argue it has a pedagogical function, educating the audience in the art of interpreting graphic scores.

Another possibility is that a new kind of artwork is presented. Like a sound installation where the site of the sound is important, the screening of the mobile scores could be seen as creating a new kind of performance, just as the presence of music in cinema has enhanced that experience.

## 5. THE SCREEN-SCORE IN PRACTICE

The following examples of works developed for the new music ensemble Decibel are given to illustrate the advantages and potential pitfalls of the screen score.



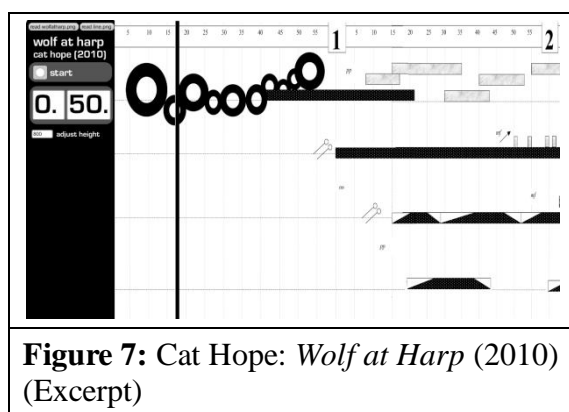
**Figure 6:** Cat Hope: *Kingdom Come* (2009) (Excerpt)

Beginning with *Kingdom Come* in 2009, Cat Hope has created a body of work that employ a single horizontal span of graphical notation to be read and performed as a continuous scrolling score.

The problem of ensemble performance of these works became immediately evident: as the works deliberately avoid a sense of pulse or meter, performers found it difficult to navigate through the

score with a counter (either to look at or in their head). In order to precisely realise the works, the musicians needed a way to proceed through the score at the same pace, aiming at important ensemble moments in a coordinated fashion. Like conventional notations, these works are read from left to right, but cutting the score into a number of A3 pages that need to be “turned” in performance made the score very difficult to render accurately. Although pulse and meter are not notated, there is a ‘pace’ that the performers share to proceed together through to the end.

To solve these issues a “score-player” was developed in MAX/MSP that allowed the image to pass by a line that gives the point at which the musicians should actualize the graphical notation. In this way, the “score-reader” operates in a paradigm not unlike the play-head on a tape recorder: lines can be read at a certain speed they sound right, they can be fast forwarded or reversed, stopped

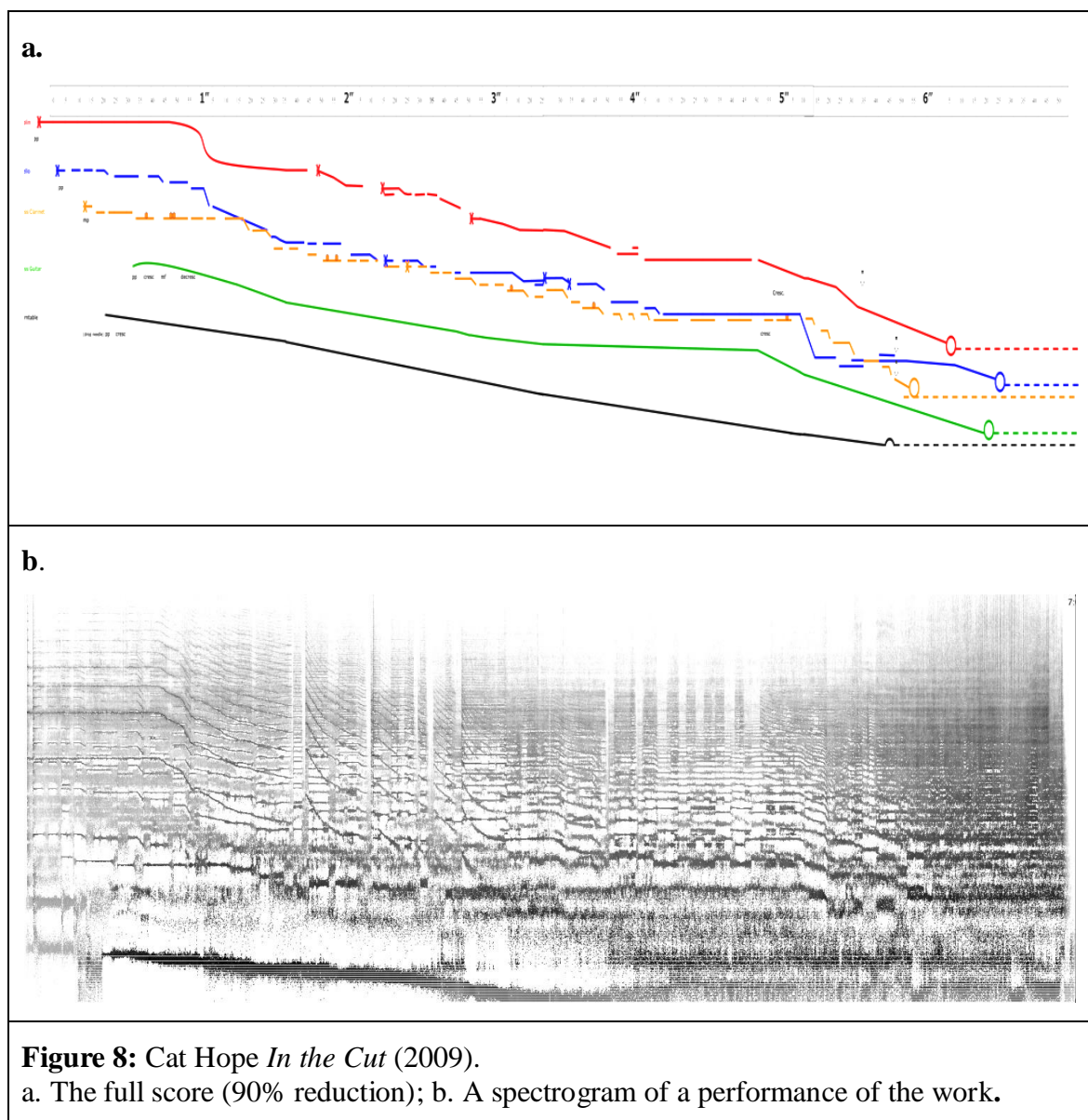


**Figure 7:** Cat Hope: *Wolf at Harp* (2010) (Excerpt)

and started at any time, but all parts move together. The scores were projected onto a screen to facilitate synchronized reading by the ensemble.

While this arrangement does facilitate the realization of these works more naturally, it also changes the way the audience responds to the work. The authors' experience has been that at least some of the audience become apparently fixated with the score, their focus on the sounds themselves being overcome by the visual stimulus. This early experiment raised the question - is it worth screening the score at all? Does this detract from the music, demystify the process, become a part of the work or is it the case that:

by giving an audience associative imagery, you encourage a type of listening that is more visual than it is auditory. (Ibid p.12)

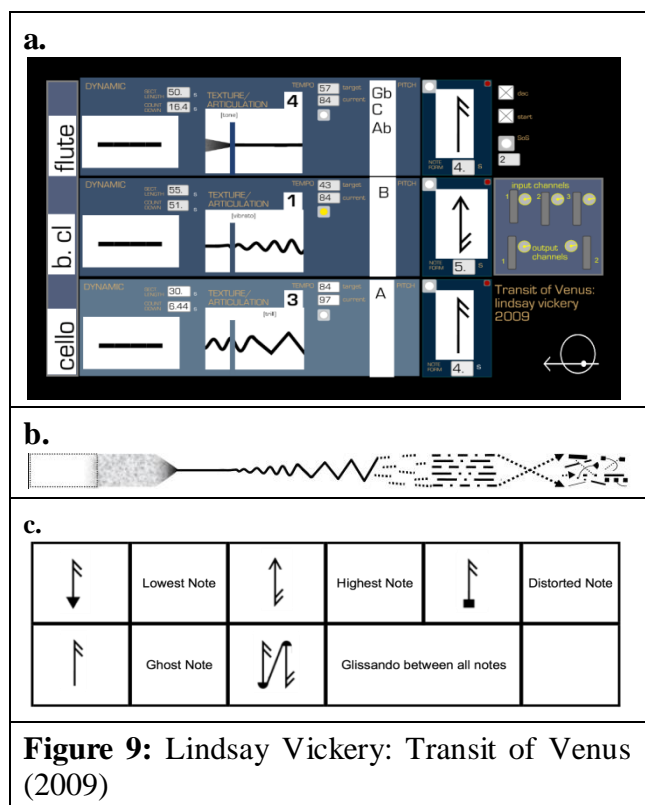


*In the Cut* (2009) is a work for 5 instruments, each represented on the score by a different colour. Unlike some graphic scores, *In the Cut* is relatively easy to read for the untrained musician's eye. A horizontal line is a continuous pitch, when it stops, the player stops, when

it angles downward, the player descends in pitch. Pitch is only represented proportionally; the highest line on the page is the highest pitch, and vice versa. This score could not be notated using traditional notation, as it is unpulsed and almost analogue in nature, written with continuous lines with only occasional interruptions. This simplicity and lack of complex rhythmic codes mean the score is easy to follow and understand for any viewer. Conversely the actual sound of the work is inherently complex, with interactions between incrementally changing frequencies of the parts creating dynamic complexes of sound including beating patterns, interactions with the acoustical space and other phenomena (see Figure 8).

Through the exercise of projecting this score in a concert, a few observations were gathered. Most importantly the simplicity of the score encouraged the listener to conceptualise how they hear the work in a simplistic fashion: they perhaps even experience the sounds differently because they are visualized in this manner. Another issue related to the unfolding of the work's dramatic narrative. The window of score before and after the play-head was quite large, enabling the audience to see 'what was coming'. For a very conceptual piece such as *In The Cut*, this was not ideal, as the final idea (detuned instruments) was revealed up to 30 seconds before it arrived: the audience got to read the "last page" before they reached it.

Lindsay Vickery's *Transit of Venus* (2009) is a work for three performers with multiple independent click tracks and a projected graphical score. In addition to following the tempo of their individual click track, each player must also follow a set of symbols that dictate the direction of their dynamics, changes in the texture that they play, the pitch class resources that they should use to realize the score, and finally the period of time over which these changes should occur (Figure 9a.).



The work alternates between two principal modes. The first presents a scrolling continuum of musical textures (Figure 9b.). This means that if the performer is performing a single tone and receives the indication add vibrato, they should transition from the first texture to the second continuously over the indicated time-period. The second is a free section during which the continuum and the metronomic click are suspended for all three performers. During these periods each performer follows the note-form indications (Figure 9c.) that appear for short periods on the right of the screen. The graphical arrangement of the score-player for *Transit of Venus* atomizes and separates the functions of

the traditional score, where performance indications are vertically unified. This configuration allows independence to be established between parameters such as texture, pitch, dynamics and articulation. Each parameter is controlled in an asynchronous and nonlinear manner, creating the potential for a very large number of possible realizations of the work. In this way, the work's configuration of information is only made possible by the computer medium.

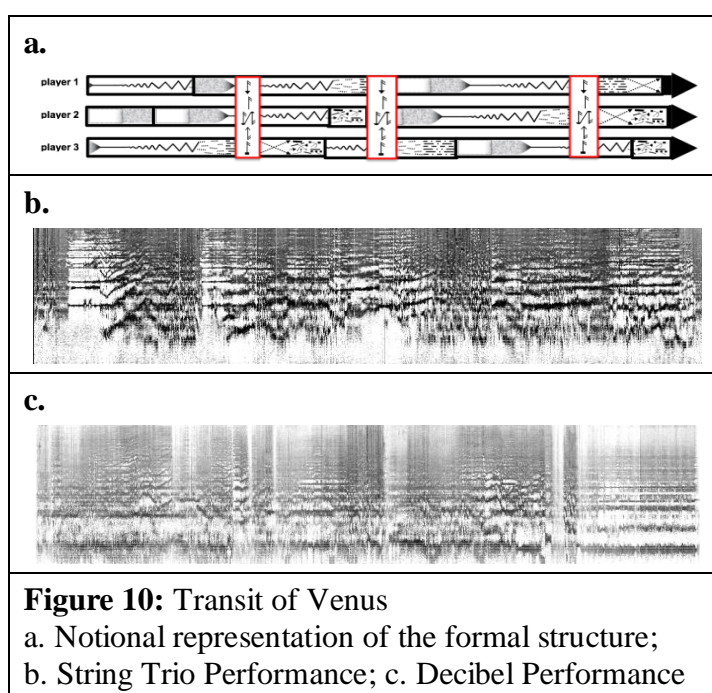
Figure 10a. is a notional representation of the structure of a performance of *Transit of Venus*, showing the order of texture continuum material presented to players and interruptions by free sections throughout the work. *Transit of Venus* is a nonlinear work, in that the tempo, and scroll-rate of the continuums is variable in each performance and each performer moves in and out of synchrony in relation to the other two. Figures 10b., 10c. and 10d. are spectrograms of different performances demonstrating a range of realizations of the work.

In performance, the score has been projected so as to be visible by both the players and the audience. As a result the audience can observe the performer's realization of the score. Like *In the Cut*, this configuration provides a mixed blessing for the reception of the work. The audience is in some sense invited to participate, albeit passively in the actualization of the score's instructions. However in contrast to *In the Cut*, the complexity of the score-reader's many moving parts means that it is not necessarily clearly understood by the audience. In

addition the density of the information that is being transmitted probably acts to distract the audience from the experiencing the actual sound of the work. Considering that the independence of the individual instrumental parts makes it difficult for the performers to experience the integrated sound of the work, projecting the score runs the paradoxical risk of creating a work that no one actually really "hears".

## 6. CONCLUSION

For centuries the relationship between the composer, the score and the performer remained remarkably constant. The advent of random access computing has created a range of new opportunities for revolutionising the interaction between the parties involved in musical performance.



The essential quality of scores is that it is a system of symbols which can convey, guide, or control the interactions between elements such as space, time, rhythm, people and their activities and the combinations which result from them.

(Hanoeh-Roe 2003 p. 146)

The screen-score is a valuable tool for conveying the essential qualities of notated music. Making images of the score accessible to the audience does, however, bring with it certain problems that detract from the screen-score's value. Screen presentation of the score is necessary or at least enhanced if it:

- Allows an already existing work to operate more fluently than the media available at the time of composition
- Conforms to the composer's conceptualization the work as comprising visual and auditory components
- Adheres to or more closely corresponds with the composer's intentions in regard to permits conceptual or structural goals to be realized
- Assists the comprehension of the work by the audience
- Does not unduly add to the cognitive load of attending the work
- Does not detract from the dramatic performative aspects of the work

The screen-score may be considered a novel direction in New Music or perhaps a continuation of the medium Visual Music pioneered by the Whitneys, Fischinger and their colleagues. Its consolidation in the performance practice of the future provides both opportunities, and also the potential for some unexplored and potentially negative consequences.

## REFERENCES

- [1] Aarseth, E. J. (1997). *Cybertext: Perspectives on Ergodic Literature*. Baltimore, Maryland: Johns Hopkins University Press.
- [2] Brougher, K. (2005). *Visual Music Culture Visual Music: Synaesthesia in Art and Music Since 1900*. New York: Thames and Hudson.
- [3] Brown, E. (1986). The Notation and Performance of New Music. *The Musical Quarterly*, 72(2), 180-201. .
- [4] Cage, J. (1958). *Concert for Piano*. New York: Peters.
- [5] Cage, J. (1969). *Notations*. New York: Something Else Press.
- [6] Cage, J. (1970). *Form is Language*. In R. Kostelanetz (Ed.), *John Cage*. New York Praeger Publishers.
- [7] Cage, J. (1985 ). *A Year From Monday*. London: Marion Boyars Publishers.
- [8] Cardew, C. (1961). Notation—Interpretation, etc.. . *Tempo (New Series)* 58(3), 21-33
- [9] Clay, A., & Freeman, J. (2010). Preface: Virtual Scores and Real-Time Playing. *Contemporary Music Review*, 29(1), 1.
- [10] Feldman, M. (1988). Between Categories. *Contemporary Music Review*, 2(2), 1-5.
- [11] Fourie, P. J. (2010). *Media Studies: Policy, Management and Media Representation (Vol. 2)*. Cape Town: Juta Academic.
- [12] Hajdu, G. (2004). *Composition and Improvisation on the Net*. Paper presented at the SMC'04 Conference Proceedings, IRCAM, Paris.
- [13] Hanoch-Roe, G. (2003). Musical Space and Architectural Time. *International Review of Aesthetics and Sociology of Music*, 34(2), 145-160
- [14] Haubenstock-Ramati, R. (1976). Notation - Material and Form In B. Boretz & E. T. Cone (Eds.), *Perspectives on Notation and Performance* (pp. 96-101). New York: Norton.
- [15] Holzer, D. (2010). A Brief History of Optical Synthesis: a Brief History of Optical Synthesis, from [http://www.umatic.nl/tonewheels\\_historical.html](http://www.umatic.nl/tonewheels_historical.html)
- [16] Kim-Boyle, D. (2010). Real-time Score Generation for Extensible Open Forms. *Contemporary Music Review*, 29(1), 3 - 15.
- [17] Kuivila, R. (2004). Open Sources: Words, Circuits and the Notation-Realization Relation in the Music of David Tudor *Leonardo Music Journal*, 14, 17–23.
- [18] Lyons, A. (1995). *Time Space Texture: An Approach to Audio-Visual Composition* Doctor of Philosophy The University of Sydney Sydney.
- [19] Maloney, K. (2005). *Sounding Images and Imaging Sounds - Audiovisual Interactivity in Performance*. *Sightlines* 2-27.
- [20] Manovich, L. (2001). *The Language of New Media*. Cambridge, Mass.: MIT Press.
- [21] McElhone, K. (2008). *Mechanical Music*. Colchester: Shire.
- [22] Miller, L. E. (2001). Cage, Cunningham, and Collaborators: The Odyssey of Variations V. *Musical Quarterly* 85(3), 545-567.
- [23] Moritz, W. (1998). The Film Strip Tells All. *Animation World Magazine* 3(6).
- [24] Peacock, K. (1988). Instruments to Perform Color-Music: Two Centuries of Technological Experimentation *Leonardo*, 21(4), 397-406.



- [25] Piringer, J. (2001). Elektronische Musik und Interaktivität: Prinzipien, Konzepte, Anwendungen. Diploma, Institut für Gestaltungs und Wirkungsforschung der Technischen Universität Wien: Wien
- [26] Poast, M. (2000). Color Music: Visual Color Notation for Musical Expression. *Leonardo*, 33(3), 215-221
- [27] Sauer, T. (2009). *Notations 21*. New York: Mark Batty Publisher
- [28] Snibbe, S. S., & Levin, G. (2000). Interactive Dynamic Abstraction, Paper presented at the Non-photorealistic Animation and Rendering 2000, Annecy, France.
- [29] Stein, S. A. (1983). Kandinsky and Abstract Stage Composition: Practice and Theory, 1909-12 *Art Journal*, 43(1), 61-66
- [30] Young, L., & Mac Low, J. (1963). *An Anthology of Chance Operations*. New York: Jackson Mac Low.
- [31] Žižek, S. (2000). *The Art of the Ridiculous Sublime*. Seattle, Washington:: University of Washington Press.