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PRAGMATIST IRONIST ANALYSIS AND (RE-)EMBODIED INTERACTIVITY: EXPERIMENTAL APPROACHES TO SENSOR-BASED INTERACTIVE MUSIC SYSTEMS INSPIRED BY MUSIC ANALYSIS

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Why is musical embodiment important? Often we hear discussions about the role of embodiment in how music, so far, has been made and is *mostly* experienced. This idea of music embodiment is analogous to one of the two interpretive approaches to performance that Arved Ashby distinguishes in *Absolute Music* (2010).[1] Borrowing ideas from William James (1907)[2] and Umberto Eco (1992)[3], Ashby contrasts pianist Arthur Schnabel's approach to interpretation with Glenn Gould's, remarking that 'Schnabel recordings and Gould recordings diverge not only in the manner of interpretation, but even in their apparent purpose.'[4] Interpreting Beethoven sonatas, for instance, Schnabel strove to realize the 'true' intentions of the composer, while Gould more open-endedly through experimentation probed the 'true' *possibilities* of each composition. As Ashby explains, in James's view 'the rationalist notion of truth involves copying as closely as possible a fixed reality that is "complete and ready-made from all eternity."'[5] This describes Schnabel's approach, which seems fueled by a sort of metaphysical imperative or *credo.* By contrast, James describes an '*instrumental* theory of truth' – which he calls *pragmatist* – 'where ideas become true only "in so far as they help us get into satisfactory relations with other parts of our experience"'.[6] This describes Gould's approach to performance, in which there is also a parallel to David Lewin's (1969, 1987)[7] approach to music analysis as

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[1] Arved Ashby, *Absolute Music: Mechanical Reproduction* (Berkeley, 2010).
[2] William James, 'What Pragmatism Means', in Susan Haack (ed.), *Pragmatism, Old, and New: Selected Writings* (Amherst, NY, 2006 [1907]).
[3] Umberto Eco, *Interpretation and Overinterpretation*, ed. Stefan Collini (Cambridge, 1992), 23-88.
[4] Ashby, *Absolute Music*, 92.
[5] Ashby, *Absolute Music*, 96, quoting James, 'What Pragmatism Means', 297.
[6] *Ibid*.
[7] David Lewin, 'Behind the Beyond: A Response to Edward T. Cone', *Perspectives of New Music*, 7/2 (1969), 59-69; David Lewin, *Generalized Musical Intervals and Transformations* (New Haven, 1987).

Richard Rorty (1989)[8] calls this an *ironist* position, which is a way of practising or asserting pragmatism. *Ironist* means a perpetual roving through ever new means of formulation, never being willing to settle permanently on any one formulation about matters deemed most important. This ironist position means: each theory about things, each analysis, or even each language for articulating such theory or analyses, is regarded not as an end in itself, but rather as a springboard for further inquiry and reformulation.[9]

This contrast of approaches (Schnabel's metaphysical rationalism versus Gould's pragmatism or Rortyan irony) parallels the contrasting approaches to music embodiment I discuss in this essay. The later sections of the essay explain how and why I pursue one of these two approaches. Although the predominant orientation to music embodiment has been *rationalist* (emphasizing targeted and stable aspects of musicality), my work advocates a *pragmatist-ironist-experimental* (PIE) orientation to music embodiment (emphasizing flexible and progressive musicality), an approach that seeks to *expand* and *extend* how music is embodied.

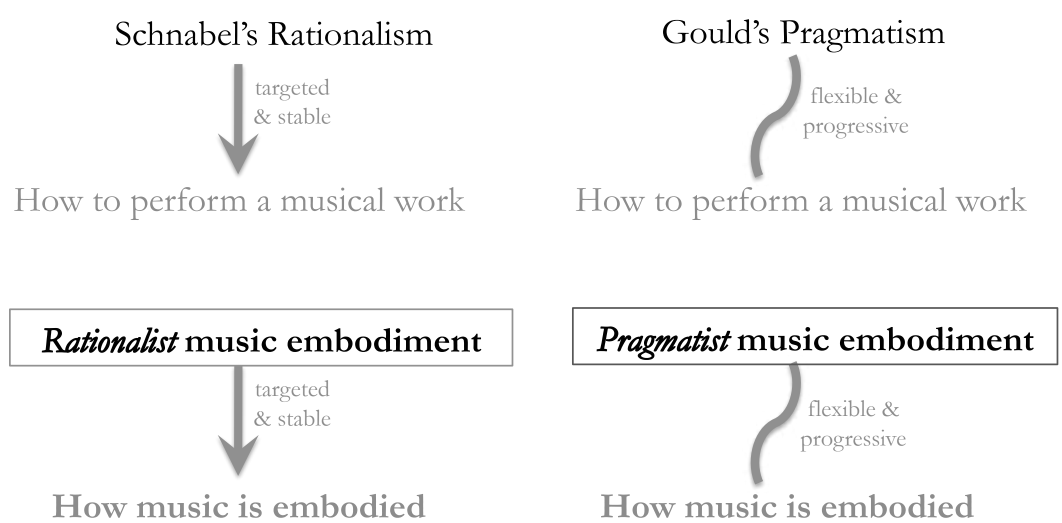

Figure 1. Comparison between rationalist and pragmatist approaches to performance and to embodiment

As I explain below, my own way of pursuing this (PIE) starts from music

[8] Richard Rorty, *Contingency, Irony, and Solidarity* (Cambridge, 1989).
[9] Kevin Korsyn (2003) originally presented this Rortyan interpretation of David Lewin's work. See Kevin Korsyn, *Decentering Music* (Oxford, 2003).

analysis and listening, using these as a basis for theorizing and systematizing, which serve as a basis for developing interactive music technologies which, when used, alter, enrich and extend how music is embodied, which finally feeds back to enhance what we hear when we just listen.[10] For instance, a fluctuating quality that is initially only vaguely sensed when listening can be formalized quantitatively and then programmed into an interactive music system as a parameter that can be manipulated spontaneously by a performer's body. This enhances both the performer's and the observer's sensitivity to this fluctuating quality, even in other subsequent music listening situations. (For this reason one of the systems I've developed is actually called *Fluxations*. This and another system I developed called *FluxNOISations* are discussed below.)

Thus I contend that the pragmatist-ironist-experimental approach to music embodiment can both propel and be propelled by the more cerebral and sedentary activity of music analysis. I am proposing that what is discovered in, or inspired by, analysis be implemented in interactive systems so that these insights can become a part of how music is embodied. This, I argue, experimentally extends and enhances musical embodiment, extending possibilities for artistic expression, and feeding back to enhance mere listening and analysis.

To appreciate this endeavour and its motivation, it is important to understand how and why, in regard to music embodiment, it swims against the tide of the prevailing orientation. This will also clarify why I call my endeavor *pragmatist-ironist-experimental* (PIE).

Rationalist Orientation to Musical Embodiment and Research Exploring Musical Gestures as Ostensible Cultural or Cognitive Universals

From an epistemological perspective, the rationalist orientation to music embodiment is a quest for invariant truths that underlie music. The quest feeds a desire to pinpoint the inherent 'nature' of music.[11] When the quest for the invariant or inherent 'nature' of music embodiment is empirical, as it often is, it

[10] The large-scale receptive-creative feedback process is explained and demonstrated in Joshua Banks Mailman, 'Cybernetic Phenomenology of Music, Embodied Speculative Realism, and Aesthetics Driven Techné for Spontaneous Audio-Visual Expression', *Perspectives of New Music*, 54/1 (2016).

[11] An alternative is proposed by Andrew Mead, who explains a more flexible view of the nature of music (that its past and present nature arises partly from interesting but by no means necessary cultural-historical accidents). He articulates concern over 'theorists [who] would appear to seek invariant truths that underlie music.' Andrew Mead, 'Cultivating an Air: Natural Imagery and Music Making', *Perspective of New Music*, 52/2 (2014), 91-118 at 93.

typically focuses on how music has been made and experienced. Within this trend, some even go so far as to attempt to reduce musical meaning to physical gesture.[12] More generally there has emerged a whole industry of empirical research focused on pinning down (rationalizing) exactly how music is already embodied and visualized by musicians, dancers, and others: an attempt to discover the 'true nature' of music embodiment, for the sake of scholarly, artistic, or commercial ends.

It is rational that emphasizing observation, stability, or what seem the most 'natural' musical behaviors, can enhance the development of musical instruments, systems, or interpretive understanding, by inquiring into how bodies typically mediate our relation to musical sound. Arnie Cox emphasizes that listeners relate mimetically to the musical sounds they are hearing, by using their own past experience of producing the same or similar sounds.[13] He does argue that musical embodiment is culturally mediated, not just innate, and that mimetic experience varies among individuals, cultures, and so on. Nevertheless, the emphasis is on a natural process of embodiment, that is, on basic, natural, habitual reactions, which can be studied empirically like other natural behaviours, even culturally mediated ones which are not innate. Thus Cox prioritizes the motor actions used to produce sounds by acoustic means (because these are the most pervasive, reliable, and therefore familiar), which is how Cox's mimetic hypothesis hinges on listeners' past experience. In so far as their past experience is conventional, this leads to a conservative view.[14] It assumes a predominantly stable relationship between sound, body, and cognition, with past experience being the de facto yardstick for what is considered natural

There are three other factors that interact with this: (1) the traditional (neo-) Platonist 'crystal' world view of music and of cognition, one that assumes musical experience to be a *logically closed system*;[15] (2) the common experience

[12] See the discussion of Manfred Clynes and Marc Leman below.

[13] Cox explains how such mimesis may be explicit or implicit. Arnie Cox, 'The Mimetic Hypothesis and Embodied Musical Meaning', *Musicae Scientiae*, 5 (2001), 195-209.

[14] Yet Cox's thesis is also consistent with (supports) the more progressive view. That is, although listeners typically relate mimetically on the basis of conventional musical practices obviously, this doesn't preclude the possibility of being influenced by less conventional or eccentric practices as well, as explained further in note 56.

[15] Ignazio Licata and Gianfranco Minati, 'Creativity as Cognitive Design: The Case of Mesoscopic Variables in Meta-Structures', in Alessandra M. Corrigan (ed.), *Creativity: Fostering, Measuring and Contexts* (New York, 2010), 95-107, http://cogprints.org/6637/1/CreativityasDesign-NOVA.pdf. Licata and Minati consider a system *logically closed* if (1) the relations between its state variables can be completely described; (2) interaction between the system and its environment can specified to any level of precision; and (3) equations could represent the evolution of the system. They propose that *logically open systems* better model creativity, including the design of 'mesoscopic levels of description for representing processes of emergence of detected properties', an activity that occurs in some music analyses, such as my own (Joshua

that music elicits emotion; and (3) the strong urge to understand scientifically how emotions in general are triggered or swayed. Perhaps not surprisingly in the recent research trends alluded to above (and discussed more below), we find a sort of 'love triangle' or sympathetic vibration between music, embodiment, and emotion – a dangerously tantalizing perfect storm.

For example, Tom Cochrane writes that 'via a variety of resources (such as rhythm, timbre, melodic line), music is able to resemble the dynamic and visceral qualities of bodily feelings ... [and] music can potentially play the same role as bodily changes in realizing the musician's emotional state.'[16] In the last century, even Andrew Mead argued for 'kinesthetic empathy' as an aspect of musical understanding.[17] But it is another thing to argue that musical meaning is exhausted by, or is primarily reduced to, emotional or bodily expression. And indeed just this threatens to become a reactionary cross-disciplinary orthodoxy. The recent trends seem aimed at showing how body motion, music, and emotion are all codes for one another – a stable cross-modal system of mutual mimesis, a holistic language of emotional communication tracked by a dedicated mechanism in the brain, a cognitive Rosetta stone.

As examples of such recent trends, I have in mind approaches that stress musical gesture based on ostensible cultural or cognitive universals.[18] Some of

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Banks Mailman, *Temporal Dynamic Form in Music: Atonal, Tonal, and Other* [Ph. D. thesis, Eastman School of Music, University of Rochester, 2010a]; Joshua Banks Mailman, 'Trajectory, Material, Process, and Flow in Robert Morris's String Quartet *Arc*', *Perspectives of New Music*, 52/2 (2014), 249-83; and Mailman, 'Cybernetic Phenomenology of Music').

[16] Tom Cochrane, 'Expression and Extended Cognition', *Journal of Aesthetics and Art Criticism*, 66/4 (2009), 329-40.

[17] Andrew Mead, 'Bodily Hearing: Physiological Metaphors and Musical Understanding', *Journal of Music Theory*, 43/1 (1999), 1-19.

[18] See, for example, Joel Krueger, 'Affordances and the Musically Extended Mind', *Frontiers in Psychology*, 4 (2014), 1003; Margaret Wilson, 'Six Views of Embodied Cognition', *Psychonomic Bulletin and Review*, 9 (2002), 625-36; Pieter-Jan Maes, Marc Leman, Caroline Palmer, and Marcelo M. Wanderley, 'Action-based Effects on Music Perception', *Frontiers in Psychology*, 4/1008 (2014); Rolf Inge Godøy, 'Motor-Mimetic Music Cognition', *Leonardo*, 36 (2003), 317-19; Marc Leman, *Embodied Music Cognition and Mediation Technology* (Cambridge, MA, 2007); Cox, 'The Mimetic Hypothesis and Embodied Musical Meaning'; Bruno H. Repp, 'Musical Motion: Some Historical and Contemporary Perspectives', in A. Friberg, J. Iwarsson, E. Jansson, and J. Sundberg (eds.), *Proceedings of the Stockholm Music Acoustics Conference (SMAC)* (Stockholm, 1993), 128-35; Mark L. Johnson, 'Embodied Musical Meaning', *Theory and Practice*, 22 (1997), 95-102; George Athanasopoulos and Nikki Moran, 'Cross-Cultural Representations of Musical Shape', *Empirical Musicology Review*, 8/3-4 (2013); Genevieve L. Noyce, Mats B. Küssner, and Peter Sollich, 'Quantifying Shapes: Mathematical Techniques for Analysing Visual Representations of Sound and Music', *Empirical Musicology Review*, 8/2 (2013); Robert Fulford and Jane Ginsborg, 'The Sign Language of Music: Musical Shaping Gestures (MSGs) in Rehearsal Talk by Performers with Hearing Impairments', *Empirical Musicology Review*, 8/1 (2013).

this research relates to quasi-innate, unreflective, or uncritical, understandings of musical performance in terms of neurophysiology[19] or conscious conception of shaping.[20] Other research considers the possibility of a self-evident 'sign language' of musical gestures.[21] All of this research emphasizes stable, predictable aspects of musical embodiment, from observing how it 'naturally' occurs, in the absence of proactive intervention. Such a loose clustering of research tendencies might be characterized as *observational-stable-natural* oriented, though this is by no means a strict category or organized research programme.

Part of what makes this rationalist line of thinking seem both innocent and attractive is that precedents can be found in the artistic pedagogical principles of, for instance, Dalcroze Eurhythmics, and also Rudolph Laban's theory[22] of movement for dance, which focuses on the role of apparent *effort* exerted within a space – a supposed natural correlation between physical effort and sonic intensity.[23] It proposes 'effort [as] the origin of any human bodily movement … [a concept that] tries to capture the mental attitude of the movement, such as intentional and motivational aspects.'[24] 'Effortful interaction' is now even being proposed as a paradigm for designing digital musical instruments.[25]

In terms of intellectual history, it is an odd twist of fate that the recent impetus to universalize music through the body seems frighteningly perennial in the early twenty-first century. Recall that the inclination to fashion a universal rational basis for music traces back to Plato, and Pythagoreans before him, the collateral damage being that it disparages what it cannot unify. The hallmark of this Pythagorean-Platonist rationalization was its disembodiment, whose exclusionary rigidity Embodied Cognition theory set out to discredit, or counteract.[26] Now the tables have turned but, disappointingly, the vista is

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[19] E. Kohler, C. Keysers, M. A. Umilta, L. Fogassi, V. Gallese, and G. Rizzolatti, 'Hearing Sounds, Understanding Actions: Action Representation in Mirror Neurons', *Science*, 297 (2002), 846-8.

[20] Noyce, Küssner, and Sollich, 'Quantifying Shapes'.

[21] Fulford and Ginsborg, 'The Sign Language of Music'.

[22] Rudolph Laban, *The Language of Movement: A Guidebook to Choreutics* (Boston, 1974).

[23] Chris Salter, *Entangled: Technology and Transformation of Performance* (Cambridge, MA, 2010).

[24] Egil Haga, *Correspondences Between Music and Body Movement* (Ph. D. thesis, University of Oslo, 2008) 69-70.

[25] Nicholas Ward, *Effortful Interaction: A New Paradigm for the Design of Digital Musical Instruments* (Ph. D thesis, Queen's University Belfast, 2013).

[26] George Lakoff and Mark Johnson, *Philosophy in the Flesh* (New York, 1999).

narrowing again, only from a different angle. Embodiment threatens to be the new universalizer.

The universalizing of musical gesture is an important example. As Marc Leman explains: '[t]he sensorimotor basis of gestural communication may account for the fact that music from a largely unknown culture in Africa, for example, can have a meaning for Western listeners. This meaning then draws upon gestural forms of communication which can be picked up because the physical constraints of human bodies are universal.'[27] Leman also writes that 'corporeal articulations may be seen as an expression of a corporeal understanding of music as intentional being.'[28]

Such possibilities and priorities spawn initiatives such as Rolf Inge Godoy et al.'s[29] statistical study of *sound tracings*, free-air movement of the hands imitating the perceptual qualities of sound (participants were instructed to move as if they were making the sound), research supporting the hypothesis of 'gestural sonic objects'.[30] As Leman[31] explains it, this embodied approach to music semantics suggests the body as mediator between external stimuli and mind, such that a semantics of music arise from a consistency in the way music relates to our bodies, based on gestural affordances[32] of musical sound, which are based on motor equivalence between sounds.[33]

Even the emotional power of music has been attributed to such gestural bases of music. David Lidov's (2004) theory,[34] which draws on Peter Kivy's (2002)[35] synesthetic theory of musical expression, suggests that musical gestures reflect aspects of neurological emotional responses. As Oded Ben-Tal puts it: 'each emotional response has its own neurological process or "dynamic

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[27] Leman, *Embodied Music Cognition and Mediation Technology*, 21.
[28] *Ibid*., 77
[29] Rolf Inge Godøy, Egil Haga, and Alexander Refsum Jensenius, 'Exploring Music-Related Gestures by Sound-Tracing: A Preliminary Study', in Kia Ng (ed.), *Proceedings of the COST287-ConGAS 2nd International Symposium on Gesture Interfaces for Multimedia Systems* (GIMS2006) (Leeds, 2006), 27-33.
[30] Kristian Nymoen, Jim Torresen, Rolf Inge Godøy, and Alexander Refsum Jensenius, 'A Statistical Approach to Analyzing Sound Tracings', *Speech, Sound and Music Processing: Embracing Research in India*, 7172 (2012), 120-45.
[31] Leman, *Embodied Music Cognition and Mediation Technology*; Leman, 'An Embodied Approach to Music Semantics', *Musicae Scientiae*, 14/1 suppl (2010), 43-67.
[32] James J. Gibson, 'The Theory of Affordances', in Robert Shaw and John Bransford (eds.), *Perceiving, Acting, and Knowing* (Hillsdale, NJ, 1977).
[33] J. A. S. Kelso, A. Fuchs, R. Lancaster, T. Holroyd, D. Cheyne, and H. Weinberg, 'Dynamic Cortical Activity in the Human Brain Reveals Motor Equivalence', *Nature*, 392/23 (1998), 814-18.
[34] David Lidov, *Is Language a Music?* (Bloomington, IN, 2004).
[35] Peter Kivy, *Introduction to a Philosophy of Music* (Oxford, 2002).

envelope"'.[36] Furthermore Manfred Clynes's 'sentic forms' theory assumes a predefined set of forms, as Ben-Tal explains. 'These, according to Clynes, are dynamic shapes expressing emotions directly without symbolic transformation [Clynes & Nettheim 1982, 51]. The forms were derived from tracing finger pressure on a touch-sensitive device (sentograph). These were subsequently translated to the auditory domain through mapping of the shapes to both frequency and amplitude of an oscillator.'[37] By this thinking, expression in music is not so much formulated by the agential actions of creative musicians, but rather is transferred directly to listeners' minds through almost involuntary physical actions of musicians (composers and performers) who serve passively as mere conduits.

The supposed direct links between sound, physical gesture, and emotion have prompted virtually a feeding frenzy in the field of Music Information Retrieval (MIR), with Godøy and Alexander Refsum Jensenius suggesting that bodily motion can link musical score, acoustic signal, and aesthetic response to each other, so that body movement could be used in 'search and retrieval' of music.[38] This is taken as a call to arms by Kristian Nymoen, Baptiste Caramiaux, Mariusz Kozak, and Jim Torresen who 'believe some *intrinsic* action-sound relationships exist, and thus it is important to continue this research towards a cross-modal platform for music information retrieval'.[39]

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[36] Oded Ben-Tal, 'Characterising Musical Gestures', *Musicae Scientiae*, 16/3 (2012), 247-61 at 251.

[37] *Ibid*.

[38] Rolf Inge Godøy and Alexander Refsum Jensenius, 'Body Movement in Music Information Retrieval', *Proceedings of the 10th International Society for Music Information Retrieval Conference* (2009), 45-50.

[39] Kristian Nymoen, Baptiste Caramiaux, Mariusz Kozak, and Jim Torresen, 'Analyzing Sound Tracings – A Multimodal Approach to Music Information Retrieval', in *Proceedings of the 1st International ACM workshop on Music Information Retrieval with User-Centered and Multimodal Strategi*es (MIRUM '11) (New York, 2011), 44. Emphasis added. See also Mariusz Kozak, 'Listeners' Bodies in Music Analysis: Gestures, Motor Intentionality, and Models', *Music Theory Online,* 21/3.

Kozak ('Listeners' Bodies'), individually, expresses broader interests. He, like the rest of us music theorists, indicates his own awareness of musical patterns, trends, shapes (he calls them structures and gestalts) that arise above and beyond the individual physical actions of each performer. (The ones he focuses on tend to be a lot like what I have been describing as *dynamic forms* or equivalently the *flux of emergent properties*, properties that, upon hearing, *emerge* from the overall configuration of more basic events, such as individual notes as rendered by performers, to then project higher-level flux.) Kozak claims to show that these higher-level entities are embodied (because they are neither explicitly in the score nor explicitly in the sound), but he actually only shows that listeners, when prompted, are capable of using physical gesturing to reflect their awareness of these higher-level entities (and that this can lead to further analytical results). This doesn't indicate the higher-level entities are embodied any more than it indicates that all cognition is embodied, including the

Such ‘intrinsic action-sound relationships’ would help some designers of new interfaces for musical expression such as Rodrigo Medeiros et al.,[40] who worry that ‘meaningful connections between musician actions and the generated sound should be provided to the audience. The emotional exchange and communication between the performer and the audience is an important factor in the performer satisfaction … [An] audience ... can get frustrated by [a] lack “observable primary causation”’ which is called ‘transparency’. There has even been an effort to develop digital ‘ubiquitous instruments’ (UbIs), which are apps whose operation is ‘natural and obvious to anyone interested in performing or composing music on mobile phones’.[41] Similarly, interactive systems have been designed based on, for instance, an excitation model,[42] whereby the system requires input of more physical energy to produce sonic output of greater amplitude, speed, or density, so the music produced consists of sonic gestures corresponding as straightforwardly as possible to performers’ physical gestures.[43]

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cognition of mathematical equations, celestial harmonies, ragas, pitch-class constellations, and Schenkerian backgrounds (as well as Platonic forms, if such exist). This line of reasoning (which doesn’t seem to be Kozak’s) is indeed plausible (especially in view of Lakoff and Nunez’s (2000) take on the multi-embodied cognition of mathematics) and is the basis of the argument made in the final pages of this essay: that *formalism* is itself flexibly multi-embodied and thereby enables a path to escape the threat of universalizing conformity presented by the *observational-stable-natural* regime. Nevertheless, I want to mention something else. Not quite in line with but yet related to what I discuss about *associative learning*, *kinesthetic learning, grounded cognition,* and *“rewiring the brain*,” it seems plausible that prompting people to express their listener cognition through instinctive physical gesturing (as Kozak does) is likely to feed back into improvements to their own listening acuity. That is, even in that closed system of listening-and-response, recursively, physical actions tend to strengthen and deepen the cognition that prompts and regulates them. In the absence of inputs from the outside (such as from score analysis), however, I suspect that the benefits of such instinctive gesturing, though significant and worthwhile, may be limited.

[40] Rodrigo Medeiros, Filipe Calegario, Giordano Cabral, and Geber Ramalho, ‘Challenges in Designing New Interfaces for Musical Expression’, in Aaron Marcus (ed.), *Design, User Experience, and Usability. Theories, Methods, and Tools for Designing the User Experience* (Berlin, 2014), 643-52.

[41] Nathan Bowman and David Reeder, ‘Mobile Phones as Ubiquitous Instruments: Towards Standardizing Performance Data on the Network’, *Proceedings ICMC/SMC* (Athens, 2014), 520-26.

[42] Garth Paine, ‘Towards Unified Design Guidelines for New Interfaces for Musical Expression’, *Organised Sound*, 14/2 (2009), 142-55.

[43] David Wessel and Matthew Wright, ‘Problems and Prospects for Intimate Musical Control of Computers’, *Computer Music Journal*, 26/3 (2002), 11-22.

Some of these are legitimate concerns for the commercial music industry that happen to converge with rationalist-metaphysical philosophical tendencies. Indeed, the inclination to focus on self-evident universal codes of musical meaning appears to have gained new impetus. The impetus is spurred by the advance of embodied music cognition studies, which grants more importance to the body, which is presumably less malleable than the mind. From this train of thought it would follow that the limited fixed attributes of the body are the primary sources that condition what music can exist and how it can be understood or appreciated, and that therefore those limitations should be the focus of the study of embodied music cognition.

Rationalist vs. Pragmatist Embodiment

Above and beyond mere entrepreneurial agendas, belief in the intrinsic value of such invariant truths is, in the end, a metaphysical stance that perhaps ought to be resisted. Not only does it run the risk of limiting what may or may not be admitted as music, [44] but it also serves as an instrument of conformity and marginalization.[45] For if music and the body are primarily expected to co-vary in predefined ways, the potential multidimensionality, the potential hyper-counterpoint, of audio-visual embodied music experience and expression is reduced. To fetishize the 'natural' is to clip the wings of artifice. It contracts our aesthetic horizons.

The 'natural' has never been an effective limit on artistic experimentation. Though art uses reason, it need not abide by a rationalist approach to music embodiment. While many may be most interested in observing the most 'natural' ways music is embodied, others may be most interested in *expanding* how music is embodied, extending the role of embodiment in changing the way music is

[44] This is the danger that Mead ('Cultivating an Air', 94) warns of regarding the seeking of invariant truths that underlie music.

[45] In 'Critical Ontology for an Enactive Music Pedagogy', *Action, Theory and Criticism for Music Education* (in press), D. Van der Schyff, A. Schiavio, and D. J. Elliot explain how an uncritical embrace of detached 'reason', fetishizing of technology and progress, in the modern world has taken an ominous turn where, as Herbert Marcuse puts it, 'rationality is being transformed from a critical force into one of adjustment and compliance. Autonomy of reason loses its meaning in the same measure as the thoughts, feelings and actions of men are shaped by technical requirements. ... Reason has found its resting place in the system of standardized control, production, and consumption'. Herbert Marcuse, *Some Social Implications of Modern Technology. Technology, War and Fascism: Collected Papers of Herbert Marcuse Volume One,* ed. David Kellner (London, 2004), 49.

made and experienced. My work therefore advocates, as explained above, a *pragmatic-ironist-experimental* orientation to music embodiment, seeking to *expand* and *extend* how music is embodied.

Although much music cognition research on embodiment has focused on stable universals there is also significant research supporting the idea that, through embodied cognition, the mind adapts to and learns new correlations through experiencing or observing appropriate feedback – a process called *associative learning* and often, more specifically, *kinesthetic* learning. This affects, or ought to affect, the design of interactive music systems. Rather than getting interactive music systems to adapt to what is easiest or natural to perceive (the rationale of research projects discussed above), the pragmatist-ironist-experimental orientation considers interactive music systems as creative constructions, exploiting and exploring how embodied cognition is flexible. Such constructed interactive music systems enable experiences that prompt embodied cognition to *progress* beyond where it was before experiencing the particular system. The progress arises from *associative learning*.[46]

Associative Learning

As Pieter-Jan Maes et al.[47] explain in their study of action-based effects on music perception: 'through systematically repeated experiences, sensory events are associated with particular motor acts and excitatory links between both are

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[46] Maes et al., 'Action-based Effects on Music Perception'; Krueger, 'Affordances and the Musically Extended Mind'; Wilson, 'Six Views of Embodied Cognition'; Jessica Phillips-Silver and Laurel J. Trainor, 'Hearing What the Body Feels: Auditory Encoding and Rhythmic Movement', *Cognition*, 105 (2007), 533-46; Pieter-Jan Maes and Marc Leman, 'The Influence of Body Movements on Children's Perception of Music with an Ambiguous Expressive Character', *PLoS ONE*, 8/1 (2013): e54682; Lawrence W. Barsalou, 'Grounded Cognition', *Annual Review of Psychology*, 59 (2008), 617-45; Lawrence W. Barsalou and Kajka Wiemer-Hastings, 'Situating Abstract Concepts', in Diane Pecher and Rolf A. Zwaan (eds.), *Grounding Cognition: The Role of Perception and Action in Memory, Language, and Thought*, (New York, 2005), 129-63; Katja Wiemer-Hastings, Jan Krug, and Xu Xu, 'Imagery, Context Availability, Contextual Constraint and Abstractness', *Proceedings of the 23rd Annual Conference of Cognitive Science Society* (Mahwah, NJ, 2001), 1134-9; Evan Thompson and Francisco J. Varela, 'Radical Embodiment: Neural Dynamics and Consciousness', *Trends Cognitive Science*, 5/10 (2001), 418-25; William F. Thompson, Phil Graham, and Frank A. Russo, 'Seeing Music Performance: Visual Influences on Perception and Experience', *Semiotica*, 156 (2005), 203-27; Michael Schutz, and Scott Lipscomb, 'Hearing Gestures, Seeing Music: Vision Influences Perceived Tone Duration', *Perception* 36 (2007), 888-97; Jay Juchniewicz, 'The Influence of Physical Movement on the Perception of Musical Performance', *Psychology of Music*, 36 (2008), 417-27.

[47] Maes et al., 'Action-based Effects on Music Perception', 3-4.

created, resulting in the development of "internal models" … sensory-motor relationships, and the integration of these relationships into internal models that may influence perceptual processes and accordingly shape the musical mind.'[48] How can this happen for the observer-spectator? 'Studies [show that] … merely observing … body movements can help selectively direct attention to certain cues, and accordingly to impose a certain structure onto the music… [and] alter aesthetic judgments.'[49]

With appropriate feedback/feedforward involving 'iterative cycles of motor entrainment'[50] and hardware-software development, the performer-operators (and observer-spectators) of an interactive music system may, according to the common coding theory,[51] experience perceptual binding[52] due to sensorimotor coupling – a close coupling between perception and action. As Maes et al. explain, the 'theory states that the planning or execution of an action, and the mere perception of the (multi) sensory consequences of that action, are similarly represented (coded) in the brain, thereby recruiting both sensory and motor brain areas' and thus exemplifying Hebb's Law: 'neurons that fire together wire together.'[53] Related to the Aristotelian law of contiguity, such perceived 'contingency', or statistical covariance, is central to grounded cognition.[54] Such effects perhaps result from the compounding of 'upward causation' and 'downward causation',[55] whereby consistent cross-modal contingencies are learned and then successfully enjoyed in the observer-spectator's subsequent experiences.[56]

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[48] *Ibid.*, 7.
[49] *Ibid.*, 8.
[50] Krueger, 'Affordances and the Musically Extended Mind', 1003.
[51] W. Prinz, 'A Common Coding Approach to Perception and Action', in O. Neumann and W. Prinz (eds.), *Relationships Between Perception and Action: Current Approaches* (Heidelberg, 1990), 167-201; Bernhard Hommel, Jochen Müsseler, Gisa Aschersleben, and Wolfgang Prinz, 'The Theory of Event Coding (TEC): A Framework for Perception and Action Planning', *Behavioral and Brain Sciences*, 24 (2001), 849-37.
[52] Thompson and Varela, 'Radical Embodiment'.
[53] Maes et al, 'Action-based Effects on Music Perception', 2.
[54] See Barsalou, 'Grounded Cognition'. Such effects perhaps result from the compounding of 'upward causation' and 'downward causation' (Thompson and Varela, 'Radical Embodiment', 418-21) whereby consistent cross-modal contingencies are learned and then successfully enjoyed in the observer-spectator's subsequent experiences.
[55] Thompson and Varela, 'Radical Embodiment', 418-21. In regard to embodied cognition, 'upward causation' (bottom-up) is neural activity influencing cognitive operations and phenomenological experience (global organism-environment phenomena); 'downward causation' (top-down) is environment-situated conscious cognition affecting local neural activity.
[56] This is also supported by Cox's (2001) statement cited above: that listeners relate mimetically to the musical sounds they are hearing, by using their own past experience of producing (or in this case observing) the same or similar sounds. Except now, crucially, we are no longer assuming

The role of physical instruments and other interactive technologies is too great to ignore. As the radical embodied cognitive scientist-philosopher Anthony Chemero puts it: '[i]nteracting with technology alters and extends your lived body […often forming a synergy…], just as happens when a blind person uses a cane to cross the street or when you feel the street through your bicycle… [T]hese [extended] human-tool synergies are real-time alterations of the lived body […in that the…] participants and tools they are using competently form temporarily unified systems.'[57]

According to grounded cognition theory, the role of introspection cannot be discounted. This implies that neither can we ignore activities such as improvising, composing, and dancing, because these are conditioned by 'off-line' introspection, 'internal states', and 'internal models' as well as bodily actions, hence the involvement of such cognitive phenomena as 'upward causation', 'downward causation', inverse models, forward models, and feedback/feedforward cognitive systems. These contribute to our experiencing and learning of the dynamics of our environment, whether natural or artificial.[58]

Interactive music systems (IMSs) are technologies for experiencing cause-and-effect. Yet there is no reason an interactive music system must be designed to emulate obvious cause-and-effects, i.e. those to which we are already accustomed. Instead they may strive beyond the obvious and habitual for the sake of expanding one's awareness, challenging one's imagination. This is the experimental pragmatist approach to musical embodiment, which resonates with Rorty's (1989) ironist concept as applied by Korsyn (2004) to the music analysis endeavors of Lewin (1987). Lewin's work is ironist in that he seemed to view each analysis and each theoretic formulation not as an end in itself but rather as a springboard for further inquiry. Like Gould in regard to performance, Lewin neither insisted on, nor aimed for, a single definitive analysis, which would, for instance, try to account for everyone's experience. He aimed for and achieved analyses that expand people's experience of the music, including his own.

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conventional experience of music making. Listeners can relate mimetically on the basis of unconventional music practices they have experienced as well.

[57] Anthony Chemero, 'Synergy and Synaesthesia', in Daria Martin (ed.), *Mirror-Touch: Thresholds of Empathy with Art* (Oxford, 2017), 177-90, at 183..

[58] Barsalou and Wiemer-Hastings, 'Situating Abstract Concepts'; Wiemer-Hastings et al. 'Imagery, Context Availability, Contextual Constraint and Abstractness'; Barsalou, 'Grounded Cognition', Thompson and Varela, 'Radical Embodiment', 419-21 .

As remarked above, I contend that the pragmatist-ironist-experimental approach to music embodiment can both propel and be propelled by the more cerebral sedentary activity of music analysis. What is discovered in, or inspired by, analysis can be implemented in interactive systems so that these insights can become a part of how music is embodied. This experimentally extends and enhances musical embodiment, increasing possibilities for artistic expression, listening, and analysis.

I have approached this by developing sensor-controlled interactive systems that enable the spontaneous control of music-generating algorithms by moving your body. To date I have developed two such systems, with the help of a collaborator (Sofia Paraskeva). The systems, called *Fluxations* and *FluxNOISations*, employ an infrared video camera with motion tracking technology and wireless sensor gloves. Together these provide a constant stream of input data detailing the position of the body in three-dimensional space, as well the relative positions of body parts such as elbows, shoulders, wrists, feet, head, and so forth. As illustrated in Fig. 2's diagram, this stream of data feeds into music-generating and graphics-generating algorithms that I have programmed. In other words, at all times, the system is aware of the x, y, z coordinates of the single performer's left elbow, left hand, left foot, right elbow, right hand, and so forth, and the position of the torso in the room. Based on this input, the system

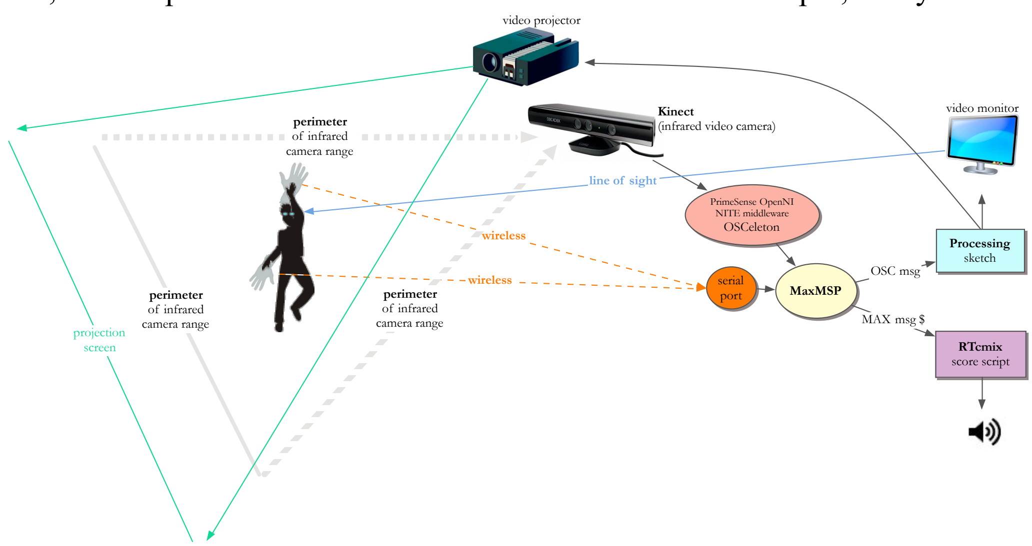


Figure 2. Hardware / software setup for interactive systems: *Fluxations* (Mailman & Paraskeva 2012) and *FluxNOISations* (Mailman 2013), same setup for both.

enables rhythmic, timbral, textural, and pitch related qualities of the music, as well as live graphics, to be steered spontaneously by the body movements of the performer. An example of this is my improvised audio-visual work *Montreal Comprovisation No.1* (2012),[59] captured on video.[60]

Inspiration and Systematizing Prompted by Analysis of Music Compositions

Now I will provide some examples of how analysis of musical works has inspired various aspects of the *Fluxations* interactive system. Listening to and then analysing the tenth movement, *Adagio sereno*, of Elliott Carter's Fifth Quartet I noticed that the composer's pre-compositional plan causes, on the surface, a gradual change in the interonset times between attacks. I encourage the reader to listen to this short movement.

If one were to listen to 0:25 to 1:03, focusing solely on the time interval between successive attacks, and place lines corresponding to these points in time, it would look like Fig. 3.[61]

The lines start somewhat evenly spaced, and then gradually bunch up into clusters. This visualizes the aspect of the composite rhythm I am asking the reader to listen for. The interonset times gradually change from relatively smooth and evenly spaced to more volatile and clumped. This flux of interonset rhythm gives dynamic form to the excerpt, and indeed to the entire movement.

Fig. 4 shows the fluctuating range of interonset intervals, oscillating smoothly back and forth between similar and divergent. Roughly, the spans centring on 0:07 (m.251), 0:35 (m.258), 1:23 (m.267), and 1:58 (m.276) have relatively similar interonset intervals and those around 0:23 (m.255), 1:03 (m.263), and 1:37 (m.276) have more divergent interonset intervals. The latter can be called rhythmic volatility, as opposed to rhythmic smoothness. (This fluctuating rhythmic

[59] The video of *Montreal Comprovisation* No.1 is accessible on vimeo at http://vimeo.com/fluxations/mc1.

[60] More details of the *Fluxations* interactive system are explained in Joshua Banks Mailman, 'Improvising Synesthesia: Comprovisation of Graphics and Music', *Leonardo Electronic Almanac*, 19/3 (2013), 252-84; and Joshua Banks Mailman and Sofia Paraskeva, 'Continuous Movement, Fluid Music, and Expressive Immersive Interactive Technology: The Sound and Touch of Ether's Flux', in Osvaldo Glieca and Marilyn Wyers (eds.), *Sound, Music, and the Moving-Thinking Body* (Cambridge, 2013).

[61] An audio-synchronized video illustrates this flux. Use password *body* at the following: http://vimeo.com/fluxations/carterqt5tenflux. The timings refer to the Arditti Quartet recording: Auvidis/Montaigne 782091 (1998).

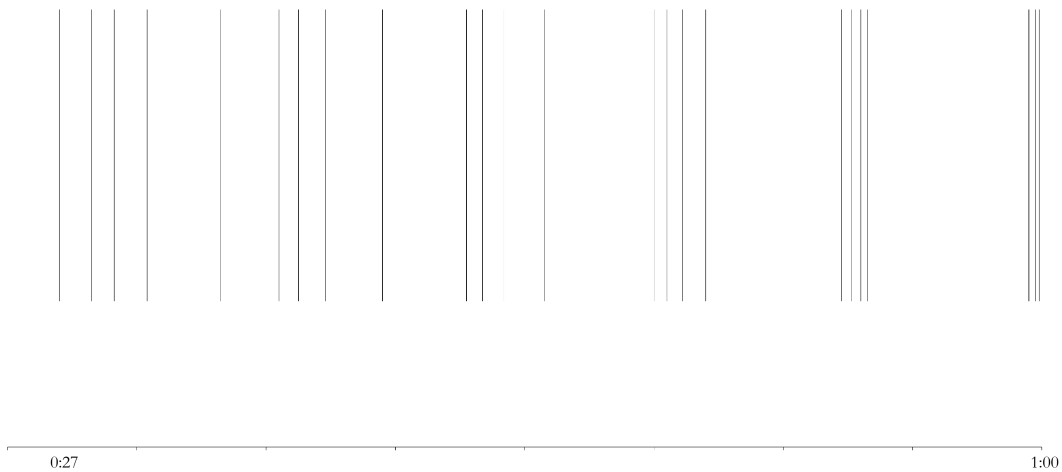


Figure 3. Graph indicating the interonset times of the composite rhythm of a passage from Elliott Carter's Quartet No.5, movement 10. Their spacing becomes increasingly volatile, that is, less evenly spaced, more clumpy.

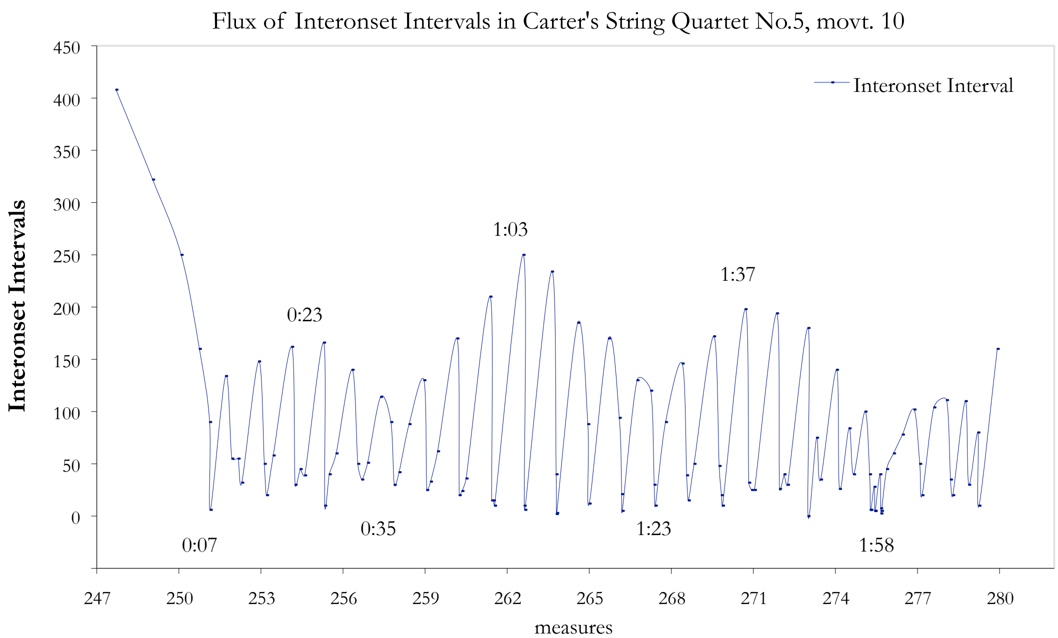


Figure 4. The fluctuating range of interonset intervals in the entire 10th movement of Carter's Quartet No.5.

volatility can be measured as the standard deviation of interonset times, which is helpful for music analysis but not the main point here.)

This somewhat obscure but relevant, fluctuating musical feature (rhythmic volatility, which is the divergence of interonset intervals within a time span) can be

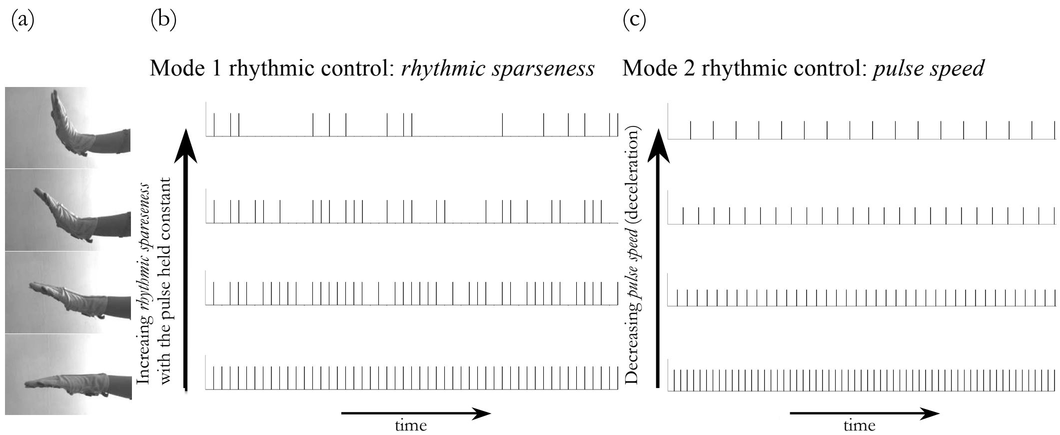


Figure 5. (a) wrist-mounted flex sensor controlling rhythmic flow; (b) flux of rhythmic sparseness as a simulation of flux of interonset volatility, and (c) flux of pulse speed (interonset speed)

controlled by the body, by allowing the body to control the degree of rhythmic volatility. The feature is algorithmically simulated by controlling the likelihood that randomly chosen onset times go unarticulated, as visualized in Fig. 5(b). I call this rhythmic sparseness. In the figure, going from bottom to top, the underlying pulse remains at the same tempo but the volatility is increasing because the increase in sparseness is achieved stochastically, that is, through increasingly probable omission of randomly selected pulse points.

This leads to an important issue for fully embodied music interactivity. In the *Fluxations* interactive system, rhythmic volatility (vs. smoothness) is controlled through flexing the wrist, as shown on the far left in Fig. 5(a). This could have been mapped differently, vice versa, for instance. Yet the mapping decision was principled, not arbitrary. When designing a full-body interactive system, it is crucial to keep in mind the ability of parts of the body to maintain certain positions (as distinguished from more visually conspicuous positions which require more effort or strain) and which states (qualities) in the musical stream one wants to be able to maintain (as distinguished from musical states that are more marked for contrast). The more effortless body positions have to be mapped to more regular musical states in order for the system to function in a satisfactory way. Likewise the more visually conspicuous and effortful positions are mapped to states (qualities) used for contrast, that is, as a distinction from the norm. In between these extremes, the system interpolates linearly, exponentially, or by some other smooth monotonic (non-backtracking) function. It is designed to be both ergonomic and appropriately theatrical.

Consider again the positions of the wrist; notice that it is far easier to hold one's wrist in straight position (bottom picture) than in the extreme bent position (top picture). Thus the straight position is mapped to the less marked, default musical state of a steady pulse. By contrast, the backward flexed (*dorsiflexion*) wrist is visually more conspicuous and effortful and thus mapped to the more marked irregular musical state of syncopation, that is, rhythmic volatility. (Effort and bodily constraints are considered merely as indirect factors rather than the main focus.) The important point is that a fluctuating quality (in this case two such qualities) was (1) initially discovered through listening, (2) corroborated or verified through analysis, (3) systematized quantitatively (the rhythmic *volatility* of any span can be modelled as the standard deviation of interonset intervals), and then (4) programmed into an interactive music system as a parameter that can be manipulated spontaneously by a performer's body.

There are also interesting issues to consider in regard to how default (more relaxed) versus marked (more exerted) states of the body might be mapped to various musical states, as well as the consideration of maintaining at least some basis of consistency when multiple mappings are at play. In a different mode of operation of *Fluxations* (which the performer can switch to and from in real-time), the wrist flex controls the speed (the tempo) of regularly spaced onsets, as shown on the right in Fig. 5(c). In this case the straight wrist is mapped to the fastest tempo (smaller interonset intervals) and the backward flexed (*dorsiflexion*) wrist is mapped to the slowest tempo (greater interonset intervals), while intermediate positions are mapped to intermediate speeds, on a linear scale between the two extremes. The rationale for this mapping is slightly more complex as it satisfies two criteria simultaneously. One consideration is that the flexed wrist is visually more marked and more effortful so it might make sense to map this to the faster speed, which is marked in the sense of having more energy. Alternatively, the backward flexed (*dorsiflexion*) wrist could also be seen as a signal for halting, or slowing down, with the straight wrist as a sign of motion forward. Furthermore, the extreme slowest speed chosen for the system (about 1.5 seconds) cannot be used as a default for any length of time as it would be musically uninteresting to continue algorithmically generated music at such a glacial pace for more than a minute or so. Therefore, the slow tempo would not be optimal as a default, and thus should be assigned to the backward flexed (*dorsiflexion*) wrist rather than the straight one. Finally, this mapping also allows some basis for consistency with the mapping for rhythmic volatility, in that both mappings have sparser temporal density correlating to the flexed wrist and more concentrated temporal density correlated to the straight wrist.

One additional point should be stated outright: the continuity or smoothness of the body's motion in space is mapped to continuous (smooth) differences of magnitude in the stream of generated music, whether these magnitudes are probabilistic (as in rhythmic volatility) or deterministic (pulse speed).

Viscosity of Texture

Let us consider another example, this time relating to texture. In listening to and then analysing Robert Morris's *In Concert* (2001), shown in part in Fig. 6, I found that its beginning and ending change texture smoothly from very viscous to very fluid and back, which means from a preponderance of long duration notes to short duration notes to long ones again. The change from viscous to fluid is seen in the score, in Example 1, from m. 1 to m. 29. The span mm. 2-4 is especially viscous, the span mm. 23-29 especially fluid. The textures of the passages in between (mm. 4-22) fluctuate in an intermediate state between these two relative extremes.[62]

I devised the following equation to model these textures. Where u is the duration of an event (such as a note) within a span S, the *viscosity* is the sum of the squares of the durations of all the notes in the span divided by the sum of the durations of the span:[63]

$$Viscosity(S) = \frac{\sum_{e \in S} (u_e)^2}{\sum_{e \in S} u_e}$$

[62] This modelling of texture was first presented in my Ph. D thesis, Mailman, '*Temporal Dynamic Form in Music*'. It was also briefly discussed in a more recent essay: Mailman, 'Improvising Synesthesia'.

[63] Viscosity of a texture emerges from the durational influence of all the events in a span of music. Yet longer duration notes have less chance of occurring (they have less opportunity to occur) so their occurrence has to be counted that much more when computing the weighted average. That is, a particular duration has to be weighted in inverse proportion to its opportunity to occur. Its opportunity to occur is the inverse of its own duration, thus $1/u^2$, and the inverse of this is just u^2. So the durational influence of each event e is its duration u_e weighted by u_e (the inverse of its relative opportunity) thus $u_e \times u_e$ which is $(u_e)^2$. The appropriately weighted average is then the sum of these $\sum_{e \in S} (u_e)^2$ divided by the sum total of duration $\sum_{e \in S} u_e$. I have previously discussed viscosity in relation to Crawford Seeger's String Quartet (see Joshua B. Mailman, 'Emergent Flux Projecting Form in Ruth Crawford Seeger's Quartet (1931)', paper at Society for Music Theory Conference, Indianapolis, November 2010.

Example 1 Three excerpts from the beginning of Robert Morris's *In Concert* (2000): (a) bars 1–4; (b) bars 17–19; (c) bars 23–29

Thus, instead of merely categorizing different textures, the equation models the texture continuously as it changes, just as an attentive and open-minded listener does. The flux of viscosity, as computed by the model taking the score as input, is shown in Fig. 6.

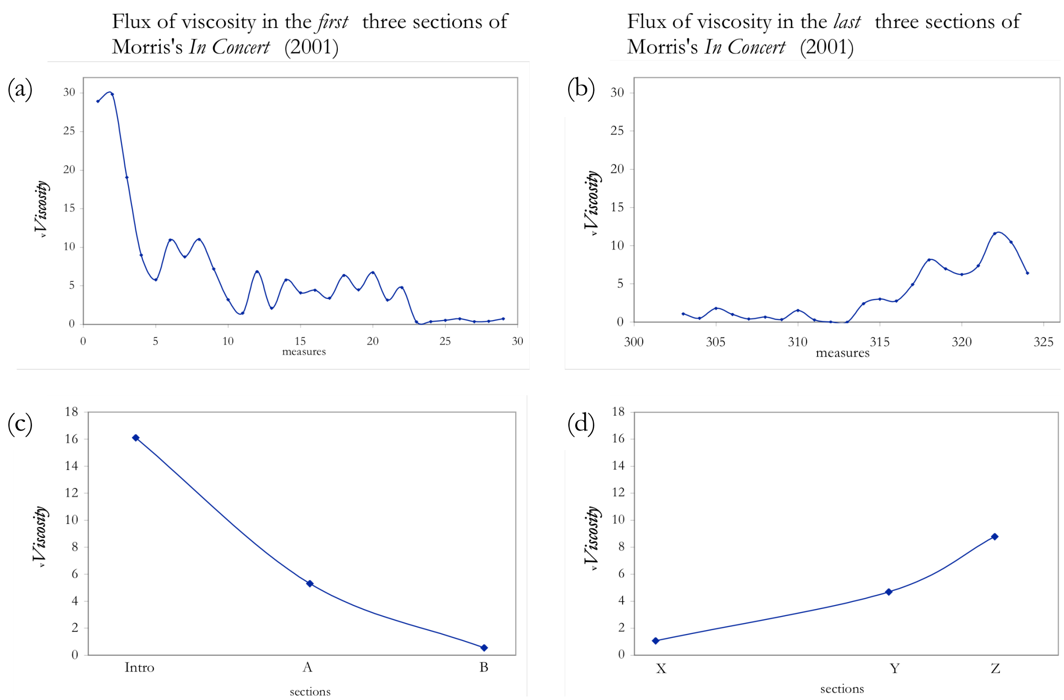


Figure 6. The fluid form of the beginning and ending of Morris's *In Concert* (2000), depicted in terms of the textural vessel: viscosity. This is shown computed measure-by-measure (top) and section-by-section (bottom).

This aspect of the texture is quantifiable and can thus be mapped to linear (or otherwise quantifiable) motions of the body. Three sample textures are visualized in Fig. 7(a) (left), thereby illustrating the quantitative nature of this aspect of texture. Since it is quantifiable in this way (as a continuous quantity), it can be embodied: body positions and dispositions in continuous space can control the degree of viscosity.

In *Fluxations* this aspect of texture is controlled by the downward versus upward position of the body, as detected by infrared video and motion-tracking software, and as illustrated in Fig. 7(b) (right). Notice that the crouched posture (shown in the upper picture) is mapped to greater viscosity (less fluidity), whereas the upright posture, even more so with an arm raised (shown in the lower picture),

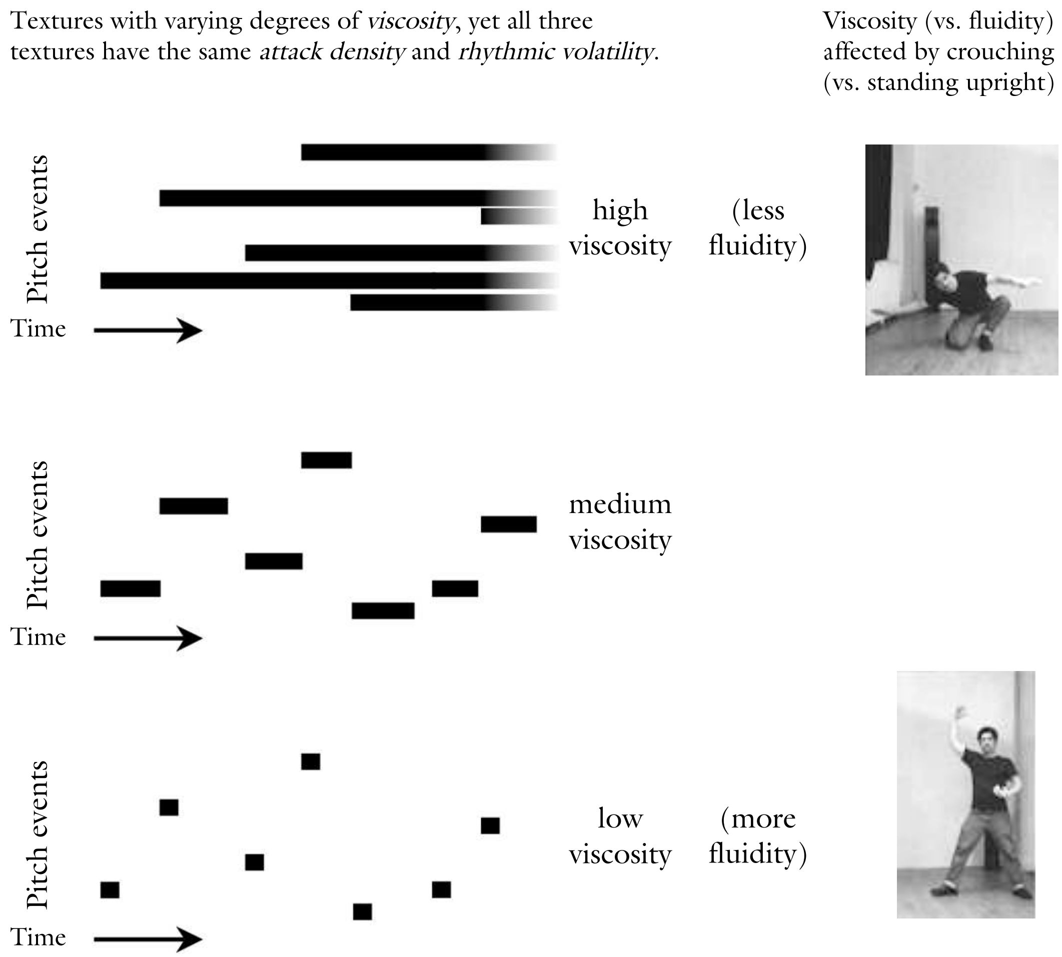


Figure 7. *Fluxations*' interactive control of texture: (a) Varying degrees of *viscosity* influence the texture significantly. (Note that all three examples have the same attack density and rhythmic volatility. (b) In the mapping used in *Fluxations*, viscosity (vs. fluidity) is controlled by crouching vs. standing upright

is mapped to lower viscosity (greater fluidity).[64] In effect, the body moving lower to the ground creates a more viscous texture and more upright a more fluid one, with the more extreme staccato fluidity correlating to a hand raised above the head.

As with the wrist mapping discussed above, this could have been mapped vice versa. Yet, once again, this decision was principled, not arbitrary. One moves through the room more easily in the upright position, compared with the

[64] As input for this parameter, the algorithm takes the height of the highest part of the body, the head or the hand, whichever is higher at that moment.

crouched position. The changes of pitch collection (transposition and expansion) that are effected when the body moves around the room (explained below) are more readily heard when the texture is more fluid (less viscous); when pitches sustain for a long time and therefore overlap, as in the more viscous textures, this muddies their perception. Thus, as a heuristic, the mapping that was chosen (*up* for greater fluidity; *down* for greater viscosity) can be imagined as like being immersed in liquid that is thinner and clearer toward the top and gradually thicker, or muddier, toward the bottom. By moving and listening in this artificial yet responsive environment, one is able to experience shifts of musical texture in an embodied way, since one is using spontaneous movements of his or her own body directly to effect those shifts.

Harmonic Space

Chords, or specifically pitch-class sets, are typically envisioned as among the more abstract, or disembodied, aspects of musical experience. Yet this facet of music, too, as informed by analysis, can be embodied through interactive system design. Consider Steve Reich's *Music for 18 Musicians*, which goes through the following shifts, each made smooth through gradual fading in and fading out of constituent pitches:

(1) It starts with pitches D and A, as shown in Ex. 2(a) [65], then

(2) gradually expands its pitch content on the cycle of fifths, first to include E (Ex. 2[b-c] and then B and F# (Fig. 9[d-e]); it then

(3) shifts one notch clockwise at m. 21 (C# replaces D, as shown in Ex. 2[f-g]), and then

(4) expands clockwise at mm. 37-45 to include G#, initially with D, and then with C# (Ex. 2[h]).

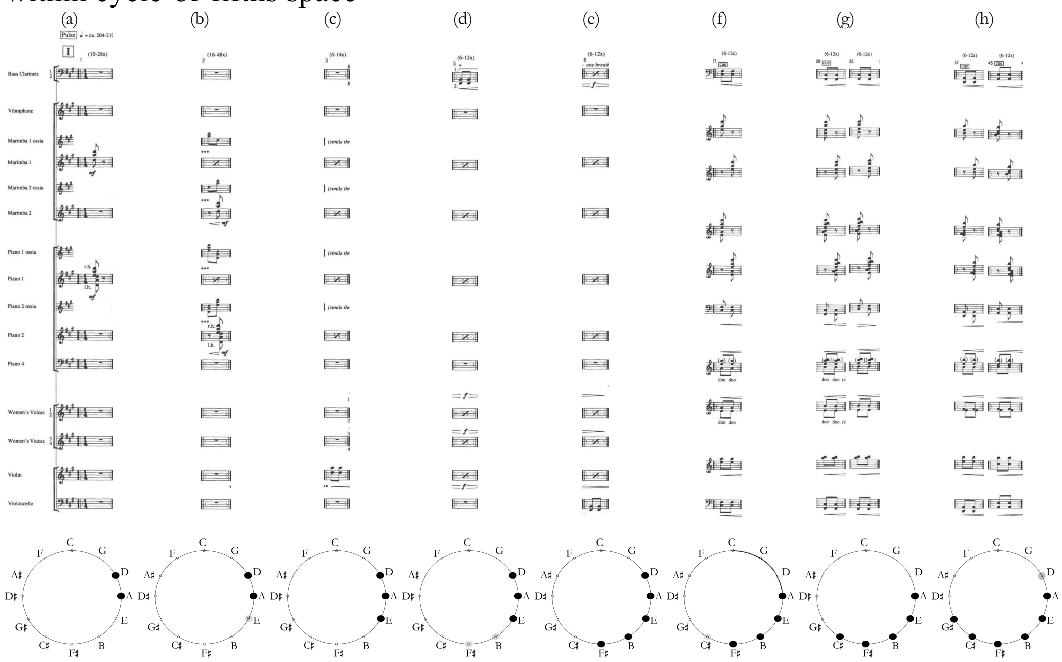
Meanwhile there is much fluctuation and duplication in registral (octave) presentation of the various pitch-classes involved. All of this takes place within the first minute or so of the piece.[66]

Not limited to the minimalist aesthetic, virtually the same process of incremental expansion on the circle of fifths governs the opening of Liszt's *Mephisto*

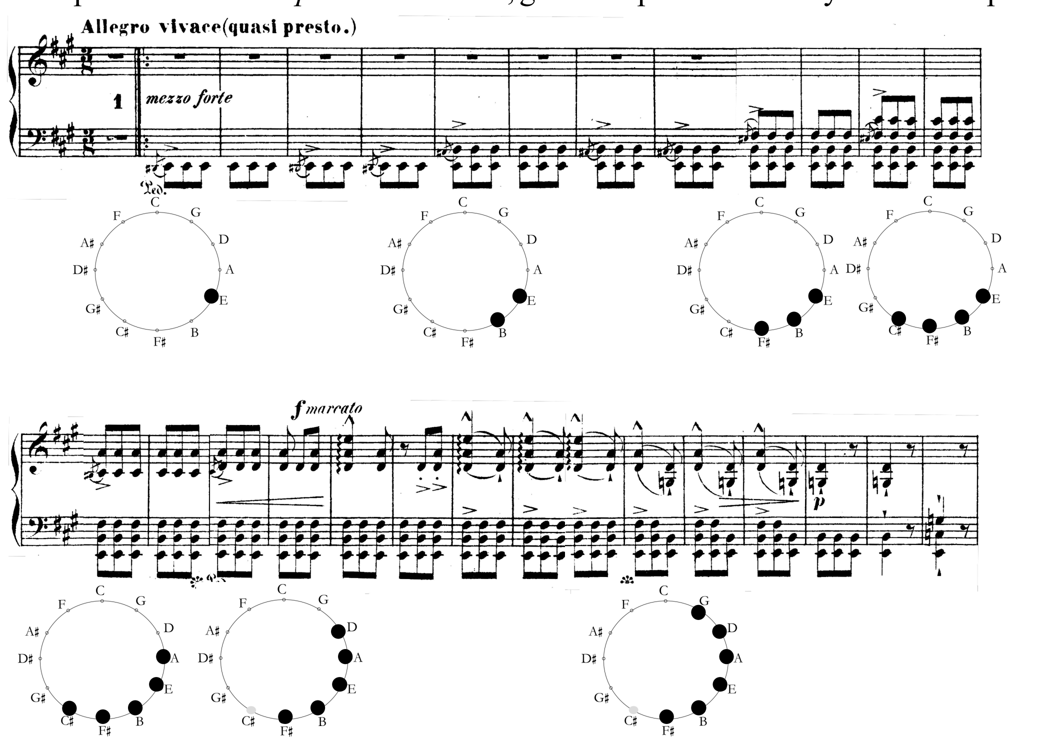
[65] There is also a virtually inaudible E in an inner voice, which becomes more prominent once its voicing is doubled.

[66] An audio-synchronized animation illustrating these cycle-of-fifths pitch-class shifts can be viewed at http://vimeo.com/fluxations/reichmem using password *body*.

Example 2. In Reich's *Music for 18 Musicians* (1974-76), gradual expansion within cycle-of-fifths space



Example 3. In Liszt's *Mephisto Waltz* No. 1, gradual expansion within cycle-of-fifths space



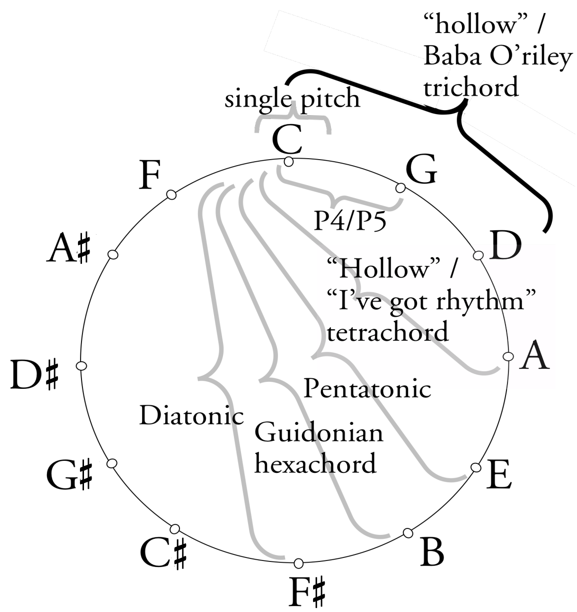


Figure 8. Circle-of-fifths harmonic space: Hollower to fuller harmonic) spaces generated by the circle of 5[ths]

Waltz No.1, as shown in Ex. 3.[67] It's a panstylistic principle of pitch-based dynamism (form-bearing flux) in music.

Fig. 8 diagrams the various cardinalities of pitch-class sets comprising purely contiguous segments on the circle of fifths. These are the same pitch-class sets (assuming transpositional equivalence) heard in the Reich and Liszt excerpts. Experientially these small and large cardinalities might be characterized as hollower versus fuller harmonies. In the *Fluxations* interactive system the cardinality of the cycle-of-fifths pitch-class set (the hollowness vs. fullness) is controlled, as shown in Fig. 9, by forward and backward position, with the far back position narrowing to one pitch class (most hollow) and forward filling out the cycle-of-fifths (becoming fuller).[68] For instance when the performer-

[67] An audio-synchronized animation illustrating these cycle-of-fifths pitch-class shifts can be viewed at http://vimeo.com/fluxations/lisztmephisto1 using password *body*.

[68] The *Fluxations* system has five other harmonic spaces besides cycle-of-fifths. (Wireless remote-control gloves enable switching between these spaces.) Each harmonic space is based on one of the six interval classes. Each space presents a single pitch class when the performer-improviser is in the furthest-back position, and presents the full chromatic when the performer-improviser moves closer to the camera. Each one, however, fills in its space differently, according to the interval class it is oriented to. (One of them passes through the whole-tone collection, another the octatonic, another the hexatonic, and so forth.) As mentioned above, a Kinect infrared video camera provides a stream of depth images of everything in its capture field; open-source middleware parses this data to track the distance of the human body from the camera, which serves as a stream of input to the music-generating algorithm discussed here.

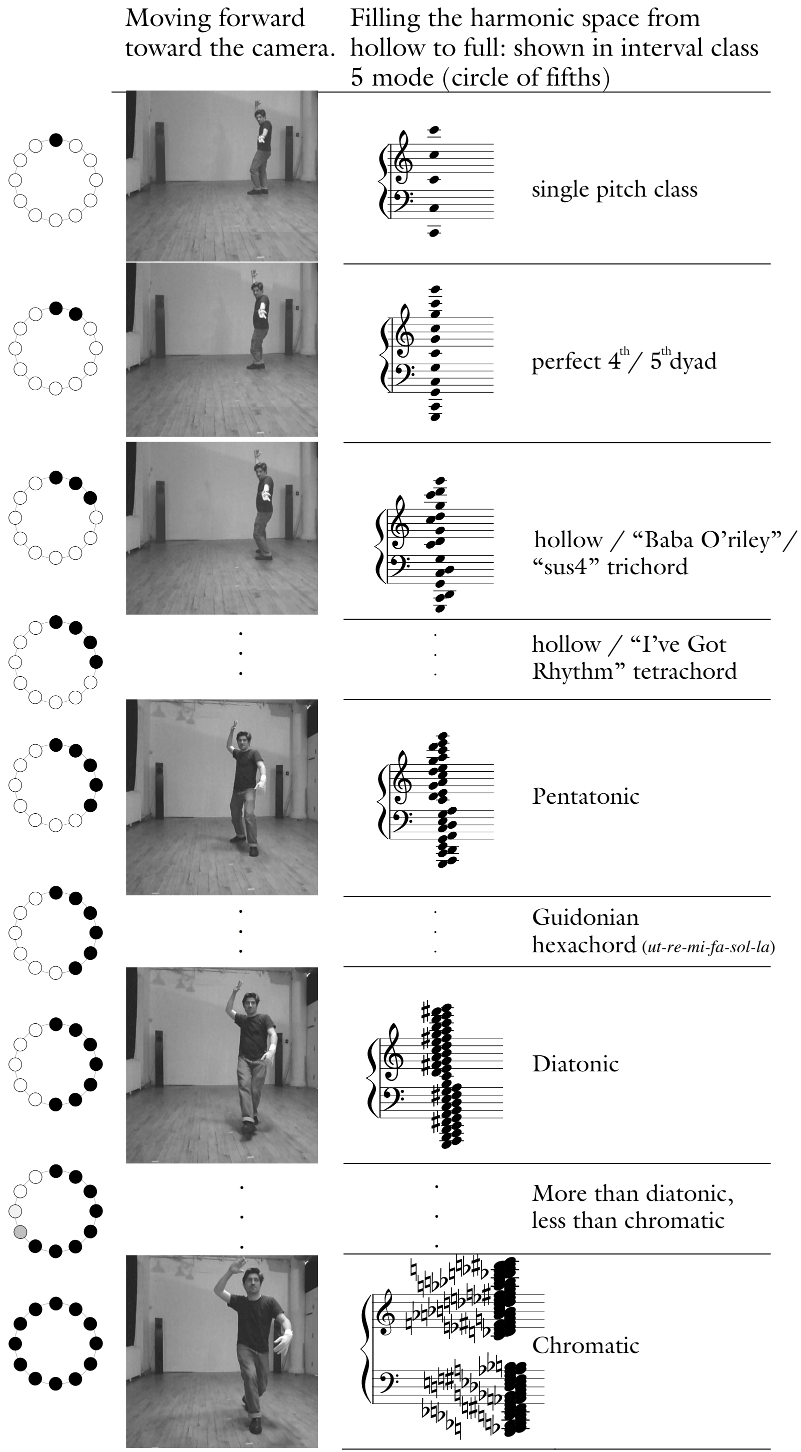
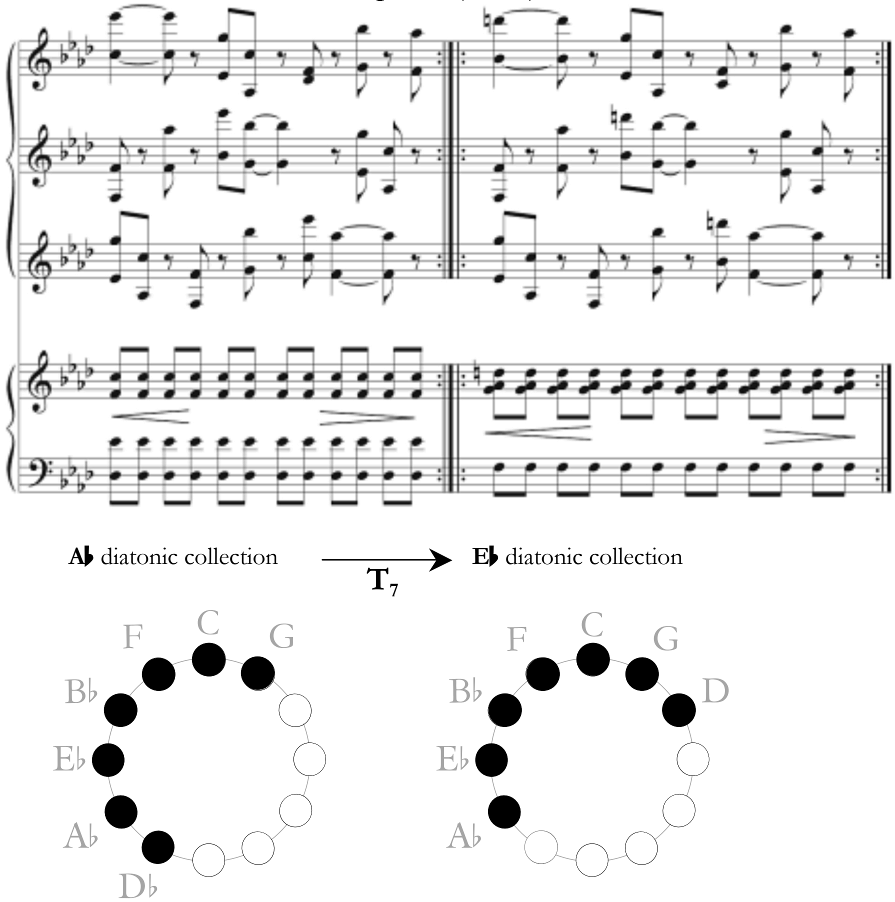


Figure 12. Filling in (populating) the circle-of-5ths space by moving forward in physical space (toward the depth-sensing video camera

improviser is closest to the camera (at the bottom of Fig. 9) the entire chromatic is arpeggiated. Backing further away from the camera (moving upward on Fig. 9), pitch classes are eliminated incrementally (hollowing out the harmony) so that the diatonic collection, then the Guidonian hexachord, the pentatonic, and so forth, are arpeggiated, until only one pitch class is included in such arpeggiations.[69] The performer-improviser can thus sculpt the chordal-harmonic basis of the music in real time, accessing the same kind of harmonic basis that gives dynamism to the Reich and Liszt excerpts.

Example 4. Entire diatonic collections shifting incrementally on circle-of-5[ths] space in Reich's *New York Counterpoint* (1985)



[69] The *Fluxations* interactive system also presents live graphics (Mailman, 'Improvising Synesthesia'). Specifically, in parallel to the expansion of pitch-class sets the color hue space is filled out as one approaches the camera. There is also an expansion of color hues (in this case from shades of only blue, to purple and green, and then eventually to the full rainbow of hues. The color diagram of this is online in Mailman, 'Improvising Synesthesia'. Also in the following video clip you can hear and see the change: http://vimeo.com/fluxations/cycleof5expand.

In addition to expansions and contractions on the circle of fifths, circle-of-fifth shifts (T_5/T_7 transpositions) of circle-of-fifth based chords create form-bearing flux in Reich's music. This occurs in Reich's *New York Counterpoint*, as shown in Ex. 4. Within this flux, the predominance of common tones creates continuity, thus smooth flux. In the *Fluxations* interactive system, such shifts (T_5/T_7 transpositions) are achieved by lateral movement as shown in Ex. 5. As one moves slightly in a lateral direction, the resulting T_5/T_7 transposition maximizes common tones (because the interval of transposition is the same interval that generated the pitch-class sets being transposed). Thus the continuity of physical space (the necessity of moving through intermediate positions to reach a distant position) is used as a way to navigate an analogous aspect of the chordal-harmonic pitch-class space.

In these and other ways, the *Fluxations* interactive system creates a responsive and immersive world of audio-visual cause and effect. Although it mimics some aspects of ordinary reality, it is not, and does not intend to be, a rational reconstruction of how music is typically embodied (for instance by singing, dancing, playing an instrument, or 'naturally' visualizing music). Therefore experience of this system (as participant or even as an observer) expands one's repertoire of ways in which music is embodied, not just by theorizing concepts, but by providing a new experience for the moving body.

A different system, *FluxNOISations*, enables control of three simultaneous streams of noisy sound: percussive wood, percussive metal, and watery-papery-pebbly sound (all of these being types of sounds that are more palpably material, more tangible to the body, than the sounds of *Fluxations*). Fig. 10 shows some of its mappings. Again, wrists, hands, elbows, feet, and torso position control the sounds and graphics.[70] The left hand and right foot control wood; the right hand and shoulders control metal. (This is different from *Fluxations* where the two hands control different facets of one stream of sounds.) Hand distance affects the granularity (separation or discreteness) vs. connectedness (overlap or blend) within the watery-papery-pebbly stream. Separated hands produce separated (discrete) pulsed sounds, which are made less separated and finally blended as the hands come closer. The torso's lateral movement affects the watery-papery-pebbly stream's right-left stereo pan, whereas the torso's frontward vs. backward position controls its tempo.

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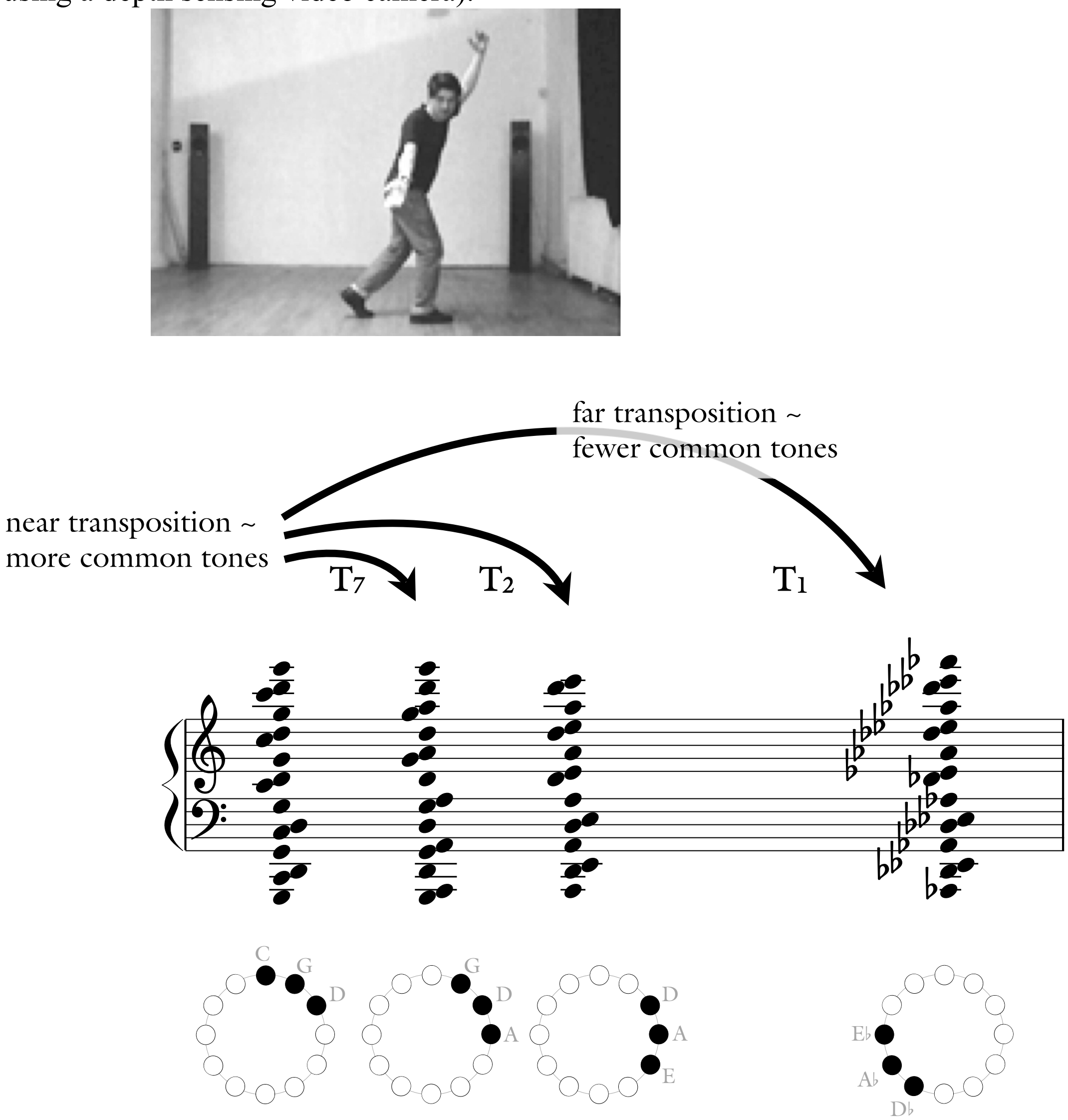
[70] The following video clips each illustrate a gradual change in the connectedness in the watery-papery-pebbly stream, in response to the change in distance of my two hands from each other: http://vimeo.com/fluxations/water and http://vimeo.com/fluxations/pebbles.

Example 5. Circle-of-fifths pitch-class transposition in *Fluxations* effected through lateral movement of the body (as detected by a motion tracking system using a depth sensing video camera).



FluxNOISations is an immersive responsive environment that mimics neither ordinary reality, nor the potentially communicative gestures of Dalcroze Eurhythmics or Laban movement, nor even the default way we typically make music or respond to music with our bodies. Furthermore, *FluxNOISations* imparts musical embodiment differently than *Fluxations* does (and they sound different, as *FluxNOISations* presents non-pitched 'noisy' material sound). Although neither system has been operated by many others besides myself, I can state, as

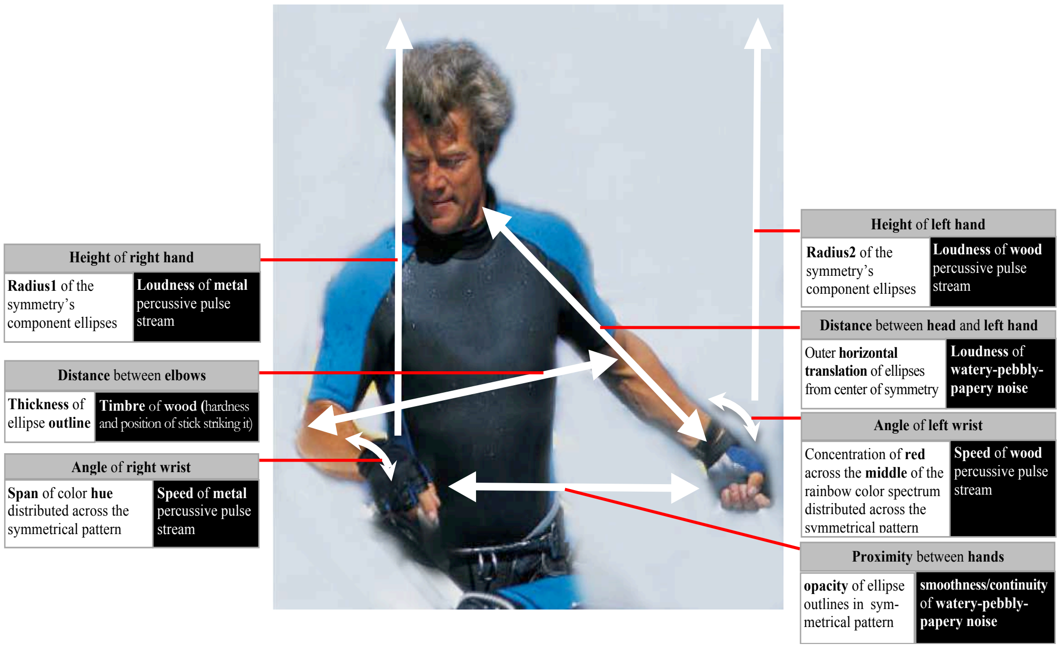


Figure 10. Interactive control of some of *FluxNOISations'* generative algorithmic input variables. Additional control variables not shown are (a) lateral movement of the body (left-right pan of watery-pebbly-papery noise); (b) forward-backward depth position of the body in space (pulse speed of watery-pebbly-papery noise); (c) proximity of feet (left-right pan of wood sound); and (d) frontal-vs-profile angle of shoulders (timbre of metal). All of these also control features of the graphics.

anecdotal evidence, that by moving in these immersive responsive environments I have learned to associate certain musical processes, transitions, and trajectories, with certain movements of the body, and vice versa, even when I am outside these environments. Moreover, sets of these associations are flexible in that I can mentally switch from one set to another, like switching between different spoken languages. Experience of the principled but unfamiliar and unrepeatable multisensory hyper-counterpoint from these systems has indeed expanded my horizons in regard to other music and other interactive art, including the analysed compositions that inspired this work in the first place.

Resisting Conformity to Universalized Music Embodiment

Viewed in terms of a metaphysical notion of 'truth', interactive systems such as *Fluxations* and *FluxNOISations* are hopelessly wrong-headed; they are predominantly idiosyncratic in relation to established codes of music-body-emotion correlation which have started to be rationalized as the universalizers of musical meaning and music-technological progress. Yet there is ample basis for dissent against this rationalization. In discussing interactive systems, Simon Penny explains that 'sensors must be chosen correctly and calibrated correctly to capture relevant environmental electro-physical variables and such data must be interpreted correctly … [to result in] output whose content, location and dynamics makes sense to a user as a meaningful correlate of their own behavior.'[71] But literal or instrumental operations of interactivity are not the whole story. Such self-evident operation 'one might argue, is exactly the opposite of what aesthetic interaction ought to be – it should not be predictably instrumental, but *should generate behavior which exists in the liminal territory between perceived predictability and perceived randomness, a zone of surprise, of poetry.*'[72]

Penny defines virtuosic systems as those that strive for this liminal territory. As Jonathan Harvey explains, fellow composers such as Brian Ferneyhough are 'as suspicious of the isolated expressive gesture which directly draws on well-established codes of signification, such as may be obtained through flirtations with tonality, as he is of dance-like body rhythms.'[73] This exemplifies art philosopher Arthur Danto's argument that there is a distinction whereby we view objects in everyday life with a 'practical attitude' but in artworks view them with 'psychic distance'.[74] Therefore, as Ben-Tal puts it, 'we view musical gestures with a *psychic distance* that allows us to perceive both their expressive and aesthetic aspects ... in the everyday, we treat most objects simply functionally, whereas in art they are objects of contemplation.'[75] As Markos Tsetsos elaborates in his exegesis of Plessner's *anthropology of senses*: '[o]nly humans perceive things as having mentally detachable properties … Art aims at the most thorough exploration of the infinite possibilities of "free configuration" (*freies Gestalten*, Plesner 2003e), concerning both corporeal motility and sensual matter (colour, shape, sound).'[76] We don't necessarily want music (or music embodiment or interactive music systems) to signify in a transparent, narrow, code-like, or universalized fashion.

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[71] Simon Penny, 'Towards a Performative Aesthetics of Interactivity', *The Fibreculture Journal*, 19 (2011), 72-109 at 80.
[72] *Ibid*., 82. Emphasis added.
[73] Jonathan Harvey, 'Foreword', in *Brian Ferneyhough*, *Collected Writings*, ed. J. Baros and R. Toop (Amsterdam, 1995), p. ix.
[74] Arthur Danto, *The Transfiguration of the Commonplace: A Philosophy of Art* (Cambridge, 1983).
[75] Ben-Tal, 'Characterising Musical Gestures', 254.
[76] Markos Tsetsos, 'The Specificity of Musical Meaning in Helmuth Plessner's Philosophical Anthropology of the Senses', in Emilios Cambouropoulos, Costas Tsougras, Panayotis Mavromatis, and Konstantinos Pastiadis (eds.), *Proceedings of the ICMPC-ESCOM 2012 Joint Conference: 12th Biennial International Conference for Music Perception and Cognition, 8th Triennial Conference of the European Society for the Cognitive Sciences of Music* (Thessaloniki, Greece, 2012), 1026.

Right here is where the utility of formalism enters, formalism being a highly significant factor in the creative inspiration of musical compositions and something that is, in turn, developed further through analysis of compositions. As Kevin O'Regan explains, '[t]he body is representational stock, anything representable being in some sense material and thus bodily, so perhaps the first of the deepest paradoxes surrounding musical formalism is that the abstraction of form, rather than negating the process of representation, actually proceeds from it … Everything, including formalism, occurs through the body … formalism itself is bodily.'[77] As O'Regan suggests, we may distinguish a more executive *cerebral formalism* from a more ecological *visceral formalism*, the two differing simply in how indirectly or directly each is embodied. This observation emerges also from the perspective of George Lakoff and Rafael Nunez, who explain how even mathematics – the usual gold-standard for supposedly disembodied cerebral formalism – is itself indirectly embodied, in that it arises from an extremely flexible virtuoso layering and interweaving of diverse cognitive metaphors (mappings), which themselves arise incrementally and cumulatively from bodily experience.[78]

How do these insights inform the advantages contributed by more executive *cerebral formalism*? Consider Mauricio Kagel's *Zwei-Mann Orchester* (1973), scored for two 'one-man bands'.[79] Kagel prescribes the bodily motions of the two performers and the fact that these gestures should activate sounds on (or through) a mechanical 'orchestermaschine'. Yet he does not prescribe the actual sounds, nor the manner by which they are made to occur: the design and construction of the 'orchestermaschine' is left up to the performers. They invent their own mechanical formalism to implement Kagel's formalist choreography.

Kagel's *Zwei-Mann Orchester* radically deconstructs the customary connections between the sound, the compositional score, and the body of the performer. The result is still embodied, though mediated by a contraption. Through the compositional score the music is *dis*embodied to then be playfully *re*-embodied. By disembodying and re-embodying the connections between body movement and sound, Kagel's double 'one-man band' contraption circuitously mediates our experience of the music's embodiment; it serves as an instrument of poetic indirection, enriching, not diminishing, the artistic experience.[80]

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[77] Kevin O'Regan, 'Intentionalizing the Body: Emotional Music, Bodily Production and Formalism', paper at *International Conference on Music and Emotion*, Durham, UK, 2009, 3-7.
[78] George Lakoff and Rafael Nunez, *Where Mathematics Comes From* (New York, 2000).
[79] A performance can be viewed at http://www.youtube.com/watch?v=oM5SttMyulE.
[80] One might choose to explore these ideas in terms of Deleuze and Guattari's notion of deterritorialization/re-territorialization via affect, in which case Klein's discussion of molar and molecular in Lutosławski's music could be referenced. See Michael L. Klein, *Music and the Crises of the Modern Subject* (Bloomington, IN, 2015).

Yet the instrument of poetic indirection need not be something as mischievous as what Kagel invites. It may rather be whatever abstract, 'formalist', conceptual apparatus informs the composition, improvisation, or interactive system design. Such an approach, like my interactive systems detailed above, exemplifies pragmatist-ironist praxis, which exploits technological flexibilities as opportunities to enliven experience by forging new or unexpected connections to be observed.

Music analysis, so informed and infused by compositional theory, is particularly good at engaging such instruments of poetic indirection: the abstractions, formalisms, and other conceptual apparatuses that underpin or illuminate our experience of compositions. Such illumination may be harnessed to enhance music embodiment. Precisely because music analysis tends to be a 'disembodied' activity – an activity that engages *cerebral formalism* – it provides the opportunity to enrich *pragmatist-ironist* praxis in regard to interactive music systems, expanding or enhancing music embodiment.

Perhaps music analysis (when practised so imaginatively as by Lewin) can reveal new truths about compositions precisely because it seems much less encumbered by bodily limitations. It does so by exploiting the technical flexibilities of (cerebral-) formalized music theoretical-analytical apparatuses. By contrast, Gould is one of the few musicians to have possessed comparable technical flexibility on an instrument, and thus enough to pursue the pragmatist-ironist project through performance. There is always the danger of technical limitations (of our minds or bodies) impeding imagination. Some such impediments can be overcome by off-loading certain processes to technologies (algorithms for instance), but only if encultured musical knowledge and ambitions of individualized creativity infuse their design.

Conclusion

A *pragmatist-ironist-experimental* approach to music embodiment is pursued by exploiting kinesthetic learning from immersion in new and unusual motion-to-sound mappings that are derived and inspired by analysing music (or possibly by some other relevant activity). In this way immersive interactive systems offer an opportunity systematically to learn new associations based on principles theorized in response to analysis. My own experience is that these systems essentially ‘rewire the brain’: even when I am not operating one of these systems, when I move parts of my body, I still imagine the corresponding sounds and sights I would hear and see if I were operating them.

Rather than committing to any particular way in which music is already embodied, the pragmatist-ironist-experimental (PIE) orientation acknowledges the open nature of embodied musical experience. It forges and uses interactive music technologies to continually redescribe and therefore reform how music is embodied, thereby expanding how it is heard, contemplated, and experienced.