Electroacoustic Music as Embodied Cognition: ecological grammars, image schemas and conceptual blending in timbre and compositional structure

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Abstract

Electroacoustic music can be seen as a liminal form of expression, navigating between identifiable soundscape materials, on the one hand, and more extensively processed/synthesised abstractions, on the other. Clearly, the more obvious pole of electroacoustic music's ecological base is centred upon soundscape-derived practices. However, a less obvious connection can be discerned even amidst Schaeffer's (1966) attempt, in *reduced listening*, to create abstractions of sound materials, which, although attempting to be 'devoid of ecological meaning' (Kendall 2016), may still rest upon ecological organisational principles; see (Bregman 1990). This paper aims to resolve the apparent contradictions of these poles and to advance an embodied theory of timbre via a framework informed by embodied cognition, which draws heavily on concepts related to the ecological.

As such, it will interrogate the structural-extrinsic strand of Smalley's (1997) *spectromorphology*, from localised/individuated sound-gestures to composite gestures and environments, touching also on his space-form (Smalley 2007), alongside emerging concepts from other fields of timbre as ecosystem as opposed to individuated entity (Ferrer 2011). As embodied (gestural) and ecological (contextual-environmental) conceptions of timbre intersect, the interaction of more formal models of timbre–space with electroacoustic music's gestural language may be influenced by metaphors and *conceptual blends* (Fauconnier and Turner 2002) whose spatial structures and logics may help to define our musical structures.

1. Introduction: the Ecological and Embodied in Electroacoustic Music Theory

Electroacoustic music can be considered a liminal form ranging between identifiable soundscape materials and ecologies and more processed or synthesised abstractions. However, concepts and experiences of the ecological can be identified not only in the explicit use of soundscapes (Truax 1984; 1996) or clearly identifiable sources, but also in the less obvious case of *reduced listening* (Schaffer 1966), which, in spite of attempting to be "devoid of ecological meaning" (Kendall 2016), may still be seen as resting upon ecological organisational principles when such sound materials are grouped in perception; see (Bregman 1990). (Indeed, Bregman's (*ibid.*) auditory perception heuristics explicitly account for both environmental audio and music and include case studies of music (Chowning 1977) which is based upon timbral grouping and segregation.) Whilst not explicitly ecological, Landy's (2007, 34) "something to hold on to" factor addresses the challenges of reduced listening's

abstraction of materials in part via the 'consistency' of their structural treatment; can such consistency be explained, in whole or in part, through the structure of our auditory expectations as informed by our embodied environmental experience?

This paper will advance a model of electroacoustic music informed by the theoretical principles of *embodied cognition* (Varela *et al.* 1991; Lakoff and Johnson 1999; Rowlands 2010; Shapiro 2011), which foreground the relationship between perception, conceptualisation and bodily, and environmental, affordances and originated as a reaction to *formalist* theories of mind (Fodor 1975) and was inspired, to some extent, by the *ecological psychology* of Gibson (1977). Taking cues from Windsor (1994; 1995; 1997), Andean (2011), Kendall (2010; 2016) and Godøy (2006), this paper argues that ecological perspectives are hard to escape in electroacoustic music, even where Schaeffer sought to reduce them. This may be due to an ecological imperative in listening even more basic than the source-recognition aspect that Schaeffer sought to avoid; that of the perceived causality of sonic groupings (Smalley 1997). Bregman (1993) summarises his auditory scene analysis principles via their relationship with "environmental regularities", and this perspective is consistent with embodied models of cognition, which sees cognition as being shaped by an enactive coupling between an organism and environment (Varela *et al.* 1991; Lakoff and Johnson 1999; Rowlands, 2010; Shapiro, 2011).

Following this perspective, previous work by the author (Graham and Bridges 2014; 2015; Roddy and Bridges 2016; 2018) has argued that Smalley's model of electroacoustic music's structural dynamics exhibits compatibility with embodied cognition, in that it theorises sound structure via concepts of gesture, force and materiality which are environmental or embodied in origin. In particular (Graham and Bridges 2014; 2015; Roddy and Bridges 2016; 2018), these are seen as compatible with *image schema theory* (Lakoff and Johnson 1999), which treats the formal structures of cognition and conceptualisation as based upon sensorimotor action. A further development explores parallels between (Smalley 1997) and Johnson's (2007) *qualitative dimensions of movement*, which sees formal relationships as embodying concepts of *tension*, *projection* and degrees of *linearity*, see table 1, below.

Smalley (1997)	Embodied association/concept	Johnson (2007)
Motion-rootedness	Overcoming inertia	*Tension*
Motion-launching	Sudden rate-change or transient motion	*Projection*
Contour energy/inflection	Coherence of path	*Linearity*

Table 1: comparing embodied concepts in Smalley (1997) and Johnson (2007)

Smalley's spectromorphology does focus on certain low-level features of a sound, similar to the reduced listening principles. However, in doing so, it nevertheless embodies a dyad of intrinsic and extrinsic connections. As such, we could regard it is an ecological reduced listening, an ecologically-focussed local listening, sensitive to the global implications of local forms, as can be seen in Smalley's (1997, 115–117) discourse of "motion and growth processes" via gesture, force and inertia.

2. Timbre as Embodied Ecosystem and Structural Model

Indeed, some recent accounts of the concept of timbre itself have seen it as more properly involving sonic ecosystems as opposed to individuated sources (Ferrer 2011). This approach has clear utility for electroacoustic music, and may be seen as aligned with Smalley's (1997) search for forming principles connecting individual sounding gestures to the temporal and causal unfolding of music. Just as we can conceive of these sonic-structural principles as being ecological and embodied, the concept of timbre itself could be conceived of as ecological, from both its source-identification aspect, but also in terms of its formal structure of sonic relationships, considering timbres in terms of similarities and differences within a *timbre-space* (Grey 1977). From the perspective of embodied cognition, any conceptual structure such as timbre-space may have attributes (or, in a spatial structure, dimensions), which are informed by embodied experience. Although the early influential cognitive–perceptual studies of timbre may be seen as formalist rather than embodied in their approach (e.g. (Grey 1977), with its mapping of musical timbre to a three-dimensional space), previous work involving the author has proposed (Graham and Bridges 2015; Graham *et al.* 2017; Roddy and Bridges 2018) that their dimensionality may be considered through embodied models based on a hybrid of Lakoff and Johnson's (1999) concepts of embodied image schemata and an implicitly embodied discourse in Smalley's (1997) spectromorphology. A theory of sound compatible with embodied cognition, of which Smalley's work may be a key part, alongside other theoretical interventions (Godøy 2006; Godøy and Leman 2010; Kendall 2010), may provide potential avenues for dialogue and the development of integrating frameworks involving electroacoustic music theory and cognitive psychology, other types of music (including common practice music theory informed by music cognition (Brower 2000; Lerdahl 2001)), and diverse sonic practices, including instrument design and musical HCI (Tanaka, 2019; Holland *et al.*, 2019).

2.1 Ecological Timbre Space, and Space-time, in Smalley's Spectromorphology

Smalley's (1997) starting point is a coupling between the heard sounding body and its causal, ecological, context: "intuitive knowledge of the human physical gesture involved is inextricably bound up with our knowledge of music as an activity" (Smalley 1997, 109). This is the conceptual source of Smalley's intrinsic-extrinsic threads, connecting localised sound-gesture to global forms or ecologies. At a more basic level, he characterises the musical note, with *onset-continuation-termination* (attack-sustain-decay/release) as key to our process of parsing an auditory scene at a more formalistic or aesthetic level, with a degree of causal coherence and individuation as giving rise to what we might term a foregrounded *salience* versus a blurring with an environmental-level background defined as 'textural' in opposition to the individuated 'gestural' (*ibid.* 114). For 'textural', we might read 'timbral' in its broader aspects, and previous cognitive studies of timbral relationships have prioritised an atemporal (with the exception of its manner of articulation) timbre-space. However, some attempts have been made to bring the temporal dimension more explicitly into the coverage of timbral structure (Gatt 2020); an understandable imperative, given the temporal's importance within the majority of our musics. Patton (2007) has paired Smalley's spectromorphology with cognitive science (particularly the concept of *qualia*, or perceived characteristics of an object), in proposing a three-dimensional spatiotemporal morphological notation, with a Z

(depth) axis providing for types of spectral variance and harmonic/inharmonic and individuated/diffuse.

The author's previous work (Graham and Bridges 2015; Graham *et al*. 2017; Roddy and Bridges 2018) has used Patton's (2007) identification of distributed noise versus discrete harmonics or sinusoidal tones as extremities on the Z axis to inform an embodied perspective on the Grey (1977) timbre-space, corresponding with the Z axis in that model of presence/absence of attack transients, in addition to using parallels between Smalley (1997) and embodied cognition to inform the other dimensions (see figure 1 and table 2, below). However, the models advanced in this previous work have not addressed temporal progression beyond that of an individual timbre's profile.

Patton's (2007) *morphological notation* incorporates a temporal dimension based on overall temporal progression rather than localised, formal attributes of timbre. In the context of intrinsic-extrinsic connections, this dimension's organisational framing could be considered via the similarity and difference of envelopes (conceptualised as *energy-motion profiles*), with similarity between articulations giving rise to a causal-relatedness framing (see Bregman's (1993) auditory scene analysis heuristic and "environmental regularity" no. 2: the "gradualness of change" of sound properties of related sound events).
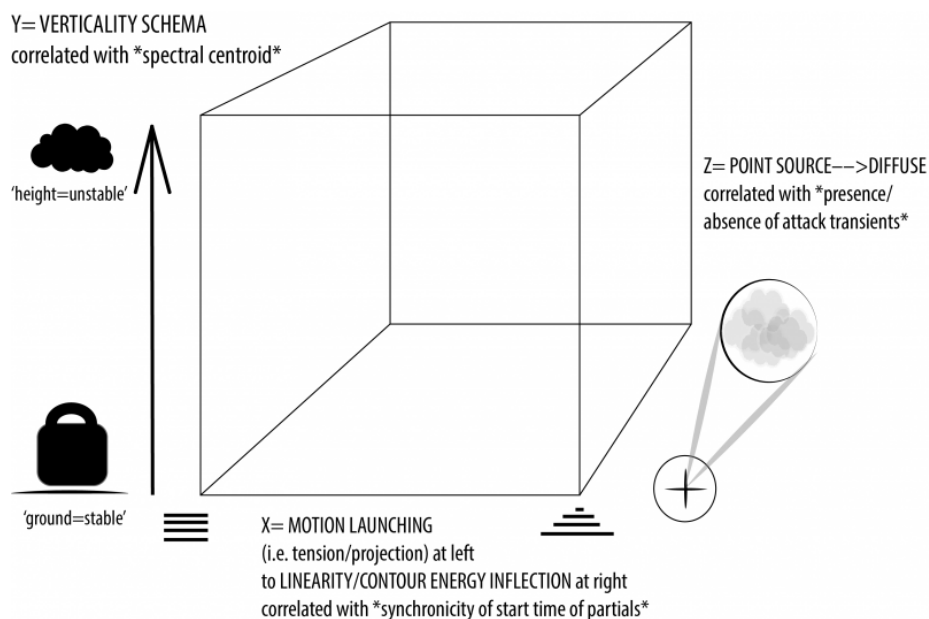

Figure 1. Applying embodied-cognitive rubrics to the classical three-dimensional timbre-space model of Grey (1977) and Grey and Gordon (1978); from (Graham *et al. 2017*; Roddy and Bridges 2018); image © B. Bridges 2017.

Dimension	Formalist timbre-space; after Grey (1977) and Grey and Gordon (1978)	Electroacoustic theory in Smalley (1997) and embodied cognition in Lakoff and Johnson (1999) and Johnson (2007)	Embodied timbre-space (Graham *et al.* 2017; Roddy and Bridges 2018)
X/horizontal	'Envelope': synchronicity of partials	Smalley: *energy-motion profile*: motion-rootedness/motion-launching/contour energy/inflection Johnson: *qualitative dimensions of movement*: tension/projection/linearity	Tension (fast attack/synchronous partial entry) versus steady state (linearity/contour energy and inflection) or inertia (dissipating)
Y/vertical	'Brightness': frequency height/spectral centroid	Smalley: vertical implications of *characteristic motions* (push-drag via rise, throw/fling and fly) in relation to ground/initial state Lakoff and Johnson (1999, 48) *verticality schema*	Pitch/frequency height (verticality schema); ground/weight=stable versus height/lightness=unstable
Z/depth	Presence or absence of attack transients	Though Smalley does not account for attack transients in terms of acoustic or material properties, he notes the '[d]irectionality implied in spectral change' (Smalley 1997, 114) and advances a broader *spectral density* as spatial perspective concept (*ibid.*: 121) Lakoff and Johnson (1999, 35) *centre-periphery schema* (taken here to be centre as individuated point, periphery as diffuse/background sound)	Presence (foregrounded salience) to diffusions; see Patton (2007), and Emmerson's (2007) *local/field* concept (applied here in context of individuated sounding action, not in performative/diffusion context)

Table 2: comparing the formalist timbre-space (Grey 1977; Grey and Gordon, 1978) with Smalley's (1997) spectromorphology, image schema theory (Lakoff and Johnson 1999) and Johnson's (2007) qualitative dimensions of movement, resulting in an embodied timbre-space (Graham *et al.* 2017; Roddy and Bridges 2018)

2.2 Ecological Timbre Space, and Space-time, in Smalley's Spectromorphology

Considering Smalley's spectromorphology from ecological-embodied perspectives, we can theorise a number of forming principles related to the perceived salience and coherence of groups of timbres:

(1) **The gesture-concept and framing:** Dimensions of motion within timbre-space-time are integrated by concepts and framing derived from physical gestures (perspective consistent with embodied cognition; gestural forms connect individual sound objects, groups of sound objects/streams, or broader sonic ecologies); the gesture-concept as a key underpinning conceptual structure which allows for the application of the other principles); examples could include pitch-frequency gestures and spectral height versus 'groundedness' (verticality image schema); grouping by proximity and similarity (see point 2, below)

(2) **Perceptual-ecological grouping/segregation relating to correlation**: Similarities or differences between generalisable schema of sound-gestures (the articulation envelopes of particular phases, i.e. contours of attack phases, types of attack transients, or overall energy-motion profiles of spectromorphologies) contributing to the grouping of sound events (perspective consistent with ecological perspectives; ecological framing based on similarity or slow change in properties of sounds, including gesture types, materials, etc.)

(3) **Temporal dimensions and extension of gestures:** relative dynamism or inertia of sound gesture/envelope leads to or implies coupling with spectromorphologies of related dynamism/temporality (energy-motion profiles: motion-launching/contour energy/inflection)

(4) **Spatial presence and individuation versus diffusion/blending/'backgrounding':** related to 2, above, transients or broadband noise spectra contribute to a sense of locative presence in contrast to the tendency of sustained sinusoidal or harmonic materials to diffuse; 3 and 4 may be cross-coupled, resulting in cases of spatiotemporal individuation or diffusion

Analysing the concepts above, we note the operation of the following embodied and ecological perspectives:

(1) Embodied cognition: mapping, image schemata, conceptual blending: gestures act to define/map and connect spaces

(2) Ecological: 'bottom-up' perceptual grouping based on primitive similarity/difference heuristics–see (Bregman 1990; 1993)–auditory grouping and stream segregation acting to define/map and connect spaces

(3) Embodiment, energy and time: temporality as experienced and moderated through gesture: see Smalley's (1997) *energy-motion contours*

(4) Embodiment, space and presence: spatiality as experienced and moderated through foregrounded gesture versus encapsulating/surrounding environment

More broadly, (3) and (4) can be derived from (1) and (2); the temporality (as 'apparent causality') is conceived through individual and composite gestures, with these gestures experienced as being delineated from or blended within an encapsulating spatial territory and environment (see Emmerson's (2007) *local/field* space frames). Connecting with Godøy's (2006) embodied triad of (1) *gesture sensations*, (2) *sound tracing* and (3) *multimodal gesture-images*, we have a dimensionality of (y) the multimodal-conceptual space of

frequency correlated with embodied verticality, (x) discrete versus continuous temporal unfolding (with potential multimodal connections via correlating patterns), and (z) gesture sensations and sound tracing related to transient noise and, hence, materiality (audible interaction of materials and gesture). Godøy's (*ibid.*) exposition makes significant use of a continuity/discontinuity model of perceptual framing of gestures, after Shaeffer (1966) and Husserl (1964). More significant, however, is the manner in which Godøy (2006) relates gestural form and materiality to integrating "meso-gestural objects". Like Smalley, the question of integration (via a perceptually or conceptually similar gestural model) is central to the consideration. Crucially, in terms of an extension, Godøy's account makes additional use of material concerns, including transients. This conceptualisation of timbre-space-time thus serves an integrating (ecological) impulse through the consideration of ecological factors including both material and physical gesture components (and couplings). The use of a single dominant metaphor of gesture affords us the opportunity to consider how the forms of related conceptual metaphors may help to explain various aspects of timbral structure within music. Considering individuated, discrete timbres first, we can frame a temporal dimension based on similarity or difference in terms of partials' temporal correlation, and hence envelope characteristics: simultaneity and strong correlation (dynamism) versus graduated entry and weaker correlation (inertia). As noted above, this type of space (Graham and Bridges 2015; Roddy and Bridges 2018) provides a set of embodied narratives for the earlier Grey (1977) cognitive studies of timbre, employing the discourse of Smalley's spectromorphology (with sounds considered as *energy-motion profiles*) and *qualitative dimensions of movement* from Johnson (2007).

Furthermore, as embodied spatial conceptions of timbre intersect with sources of varying degrees of temporal extension and recognisable materiality, the connection between any timbre-space and electroacoustic music's gestural language may take on the complexities of *conceptual blending* (Fauconnier and Turner 2002), in which spatially-based conceptual metaphors create emergent structures through the interaction of their combined dimensionality and the associations of their individual spatial dynamics; see (Kendall 2010; 2016). Considering how the formalised spatiality of timbre-space can be combined with an embodied-conceptual spatiality of sonic relationships may allow us to develop structural perspectives which balance the utility of a focussed ecological formalism on the one hand (i.e. attempting to find unifying frameworks to explain lower-level features), with this music's riches of novel configurations and diverse styles, on the other.

3. Gesture, Conceptual Blending and Timbre Space-time in Electroacoustic Music Theory

Spectromorphology (Smalley 1997), with its gestural surrogacy, foregrounds one particular conceptual metaphor; that of sound as gestures or *energy-motion profiles* across dimensions of time, frequency, amplitude, and, indeed space; see also (Smalley 2007). Considered as a conceptual metaphor with spatial properties, we can interrogate this use of gesture via Fauconnier and Turner's (1998; 2002) *conceptual blending*. As discussed above, this takes as its point of departure the idea that conceptual metaphors might be a combination of spaces with various relatable properties, leading to the creation of a *blended space* derived through mappings which integrate various features of its *input* spaces (see figure 2, below). To take a simpler example, we might have the generic space of an organism, 'filtered' through the conceptual spaces describing (1) human and (2) robot, leading to the conceptual blend of the cyborg.
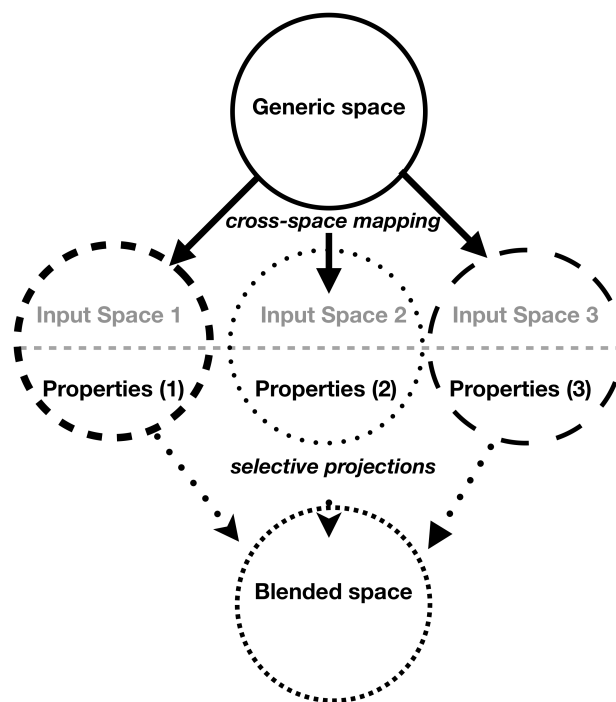

Figure 2: con*ceptual blending*: relationship of input spaces to blended space via selective projections, after Fauconnier and Turner (1998; 2002)

The use of conceptual blending to explain aspects of electroacoustic music's functioning is not new; see Kendall (2014) on conceptual blending and affect in composition. However, due to its utility in enumerating the properties of various component spaces (dimensions) and considering their relationships in integration, it may be particularly instructive for electroacoustic music to apply conceptual bending to spectromorphology and timbre.
The present approach (see figures 3 and 4, below) follows on from the parallels between Johnson (2007) and Smalley (1997) identified in Graham and Bridges (2014; 2015) and Roddy and Bridges (2016; 2018), and from the application of these *qualitative dimensions of movement* (Johnson 2007) to spectromorphological gestures via *tension/rootedness* (inertia or overcoming inertia), *linearity/coherence/correlation* of path, and *projection* (as rapid changes

of state, discontinuity and rupture). These attributes comprise a localised gestural-sonic space, the individuated, intrinsic spectromorphological gesture. We may also consider these as the structural factors behind Grey's (1977) timbre-space (Graham and Bridges, 2015; 2017; Melvin and Bridges, 2021) via dimensions for tension/rootedness (y=frequency-height/verticality), linearity/rate of change of path (x=synchronicity of start time of partials), and projection (z=presence/absence of transient detail via energetic change in system state producing attack transients).
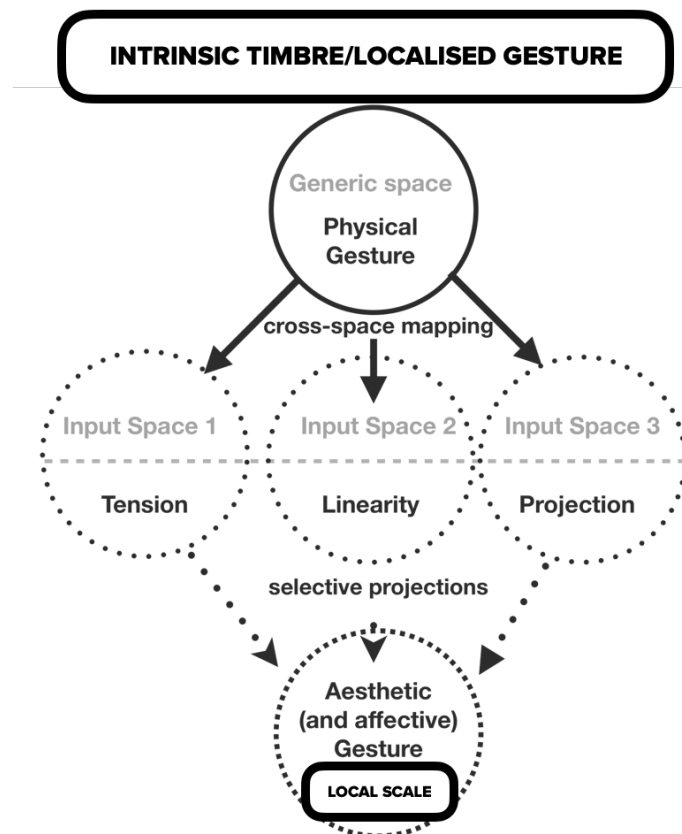

Figure 3: Timbre as an intrinsic/localised gesture: Johnson's (2007) qualitative dimensions of movement, in parallel with Smalley's spectromorphology, as a conceptual blend; see (Fauconnier and Turner, 2002)

We can extend this conceptual blend beyond the localised timescale of individuated timbre to the integration of multiple timbral gestures by means of analogous metaphorical dimensions (see figure 4, below). The tension/rootedness of an individuated source has already been discussed in terms of positioning in frequency space. The implied *verticality* of this space clearly provides one of the means by which we associate sound gestures in terms of 'brightness/dullness' or resonant spectral centre, and also in terms of pitch/frequency height position (cf. auditory streaming by pitch/frequency proximity). The degree of linearity or rapid rate of change may be reconsidered as *correlation* between sounding gestures.
The final embodied dimension of this model may be less obvious. Considering the degree to which some sound materials are perceived as diffuse, and difficult to localise, and which others are clearly individuated and foregrounded (a model focused upon in Emmerson's *local/field space-frame* typology), this model takes *presence* (with all of its associations with liveness), as the final dimension of an extrinsic timbre-space mapping. Whilst such a rubric

contains multiple potential associations and is clearly a concept which is more figurative than acoustic, it does connect with the audible affordances of particular sound gestures through the individuated attack transient, and it also relates to broader ecological imperatives around assessing dynamic elements of an auditory scene.
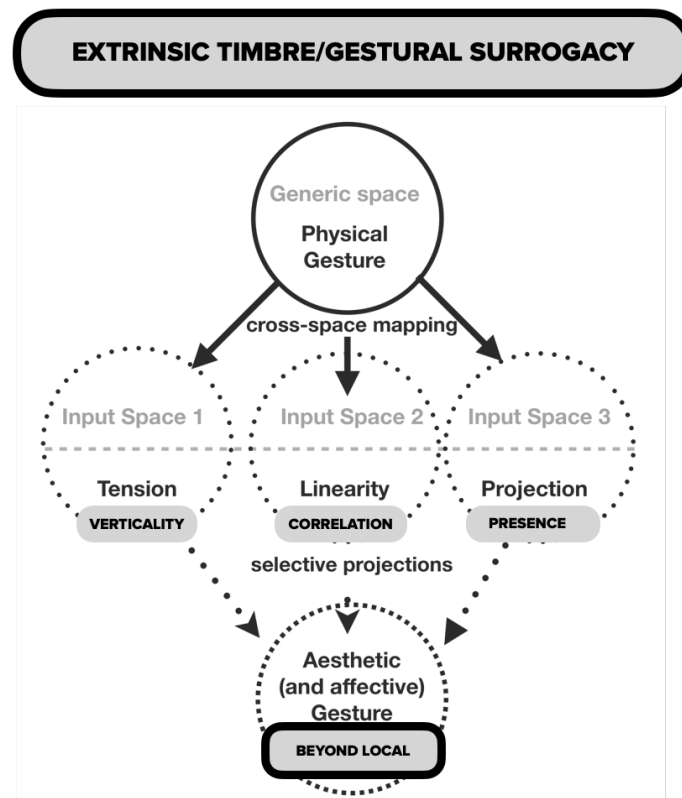

Figure 4: Timbre as an extrinsic global gesture/ecology of gestures: Johnson's (2007) qualitative dimensions of movement, in parallel with Smalley's spectromorphology, as a conceptual blend; see (Fauconnier and Turner, 2002))

More broadly, this renewed focus on transient detail as both signifier of presence in terms of both perceptible salience and liveness also raises the issue of another type of presence: that of materiality. As discussed above, the attack transient provides key detail regarding the distinctive signature materiality of a given excitation gesture. The dimensional riches of this particular category of features are beyond this paper's scope, but it is conceivable that some, e.g. linearity/rate of change of path (and, in frequency space, *spectral flux*) and projection (rapid changes in system state), may also describe sub-dimensions around which attack transients themselves could be organised. Timbre's material associations, sometimes overlooked for reasons which are consistent with the field's origins (Schaeffer 1966), may be the next frontier in our search for broader, creatively representative, models of timbral structure. Indeed, Schaeffer's (*ibid.*) technical, creative and conceptual revolution of the 'isolation' of sound objects has, through the development of the use of these objects as (wholly or partially) decontextualised sonic gestures, drawn attention to a more fundamental set of principles by which we might consider sonic organisation as grounded within principles derived from our (concrete) environments. The acousmatic veil could thus be seen as allowing us to see gestural similarities and differences and to frame our sense of causal structure as a result. The gesture-metaphor, transposed to differing dimensions of intrinsic/localised timbre

and extrinsic timbral ecologies may provide a productive means for considering compositional structure across textural and temporal, as well as conceptual domains.

4. Conclusion

This paper has considered electroacoustic music theory, and in particular Smalley's spectromorphology, from the perspective of ecological and embodied cognition. It has explored how our conception of timbral structure may operate at different levels of organisation, but also within analogous, indeed isomorphic, conceptual spaces, in broad alignment with more ecological perspectives (Ferrer 2011; Bregman 1993). This may provide the means by which we refine our understanding of the connection between timbral gestures at intrinsic and extrinsic temporal and structural levels, expanding upon Smalley's (1997) *gestural surrogacy*. Exploring dimensions of (1) *tension versus rootedness* (or instability versus stability) in a vertical schema, (2) *linearity/correlation*, and (3) *projection/presence* may allow us further insight into some of the most basic conceptual models by which we structure our disparate sound materials. In addition, through the plasticity of conceptual blending (Fauconnier and Turner 2002), we may consider how we may develop more extended associative sonic-conceptual metaphors: see Young (2007), Kendall (2014), and, on the soundtrack, Melvin and Bridges (2021). Analysing timbre via embodied concepts may allow us to more freely conceptualise the modulation between differing temporal frames, and between these and associative and figurative properties of the sound materials, through combinations (conceptual blends) of differing materiality and gestural presence. Spectromorphology's core metaphor of gesture can be seen as providing both intrinsic and extrinsic spaces delineating a vertical perspective of stability versus instability, a temporal-causal perspective of correlation versus chaos, and, as the theory is further advanced (Smalley 2007), in spatial and ecological senses of presence. By considering timbre, via gesture, as an extended conceptual metaphor (conceptual blend) we may be better able to build upon and adapt existing theories and models to the demands of new musics and sonic-mediatised experiences. To adapt the ideas of embodied cognition theorists (Clark and Chalmers 1998; Dove 2018), is the concept of timbral-gestural connections a kind of conceptual 'technology', a tool or interface? Rather than being considered as fixed models of sound structure, could models such as spectromorphology provide us with adaptive spaces, interfaces to be 'hacked', when considered via the lenses of embodied cognition and conceptual blending? If so, it may be an appropriate time for more explicit consideration of the findings of our field through concepts of embodiment, not in isolation, or in the sense of seeking singular comprehensive models, but rather in the sense of seeking organisational principles which may bring diverse models in to productive alignment. Indeed, it is perhaps doubly appropriate that we consider our models of sound structure as in some way modular in nature, given the recent resurgence of interest in modular synthesis in our field and related areas. This paper contends that by considering timbre as both localised/intrinsic and globalised/extrinsic frames with similar structural dynamics via the conceptual medium of gesture, we may be better able to investigate our field's established concerns (compositional forms, mapping, and categorisation of sound materials) alongside emerging challenges around materiality, multimodality and immersivity, and accessibility and more diverse sonic languages and experiences.

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