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Original Contributions - Originalbeiträge

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Listening to Sound-based music: Defining a perceptual grammar based on morphodynamic theory

Introduction

The vast world of contemporary and experimental music today encompasses a variety of musical genres, some of which remain challenging to access as objects of study. Research on this music is often carried out by a small group of specialists, in contrast to more widely spread genres and musical contexts. However, contemporary, experimental, and avant-garde music has had a significant impact well beyond its boundaries (P. Griffiths, 2010; Solomos, 2019) extending its influence to a vast range of new musical contexts, ranging from film and video game soundtracks to the sound design of physical environments, traversing the world of advertising to various popular music genres, from rap to electronic dance. This music, given its specific sonic characteristics, is a direct source of today's musical culture in terms of multisensory experiences and virtual and augmented listening (C. Cox & Warner, 2017; Dyson, 2009).

If we consider the field of studies on music perception, there exists a spectrum of expertise formed by both analytical studies exploring the listening of sound qualities and timbre (Giordano & McAdams, 2010; Grey, 1977) and works connected to various fields such philosophy, semiotics, and the psychology of music (Kivy, 1991; Scruton, 1997). Such range of research commonly considers Western classical repertoire, popular and world music. Only a small number of works focus on contemporary music genres and experimental and avant-garde scenes (Deil et al., 2022; Glover et al., 2018; Mencke et al., 2019; Ockelford & Sergeant, 2012; Viel, 2019), and this gap is somewhat paradoxical considering that contemporary art music itself raises various questions centered on listening and more broadly on perception (Grisey, 1987; Oliveros, 2005; Landy, 2007).

Throughout the 20th century, certain currents within contemporary art music have progressively shown a more explicit interest on the intrinsic properties of sound and its perception. From the mid-twentieth century onwards, several trends such as non-teleological and acousmatic perspectives, the fusion of electronic, acoustic, and concrete sounds, and the extensive use of sound spectra, have emerged and become fundamental principles in a wide array of sonic practices (Solomos, 2019; Wanke, 2021). Many genres within this music panorama thrive on exploring highly extended temporal forms and frequency ranges, auditory stimuli at the limits of our perception, and unconventional listening contexts (via multichannel, multimodal, or even in darkness). This trend has manifested in various musical movements over the past century and can be referred to as "the emancipation of sound within 20th-century music practices" (Solomos 2019).

When examining works by artists like James Tenney, Annea Lookwood, Georg Friedrich Haas, Ryoji Ikeda, Mika Vainio, Eliane Radigue, or Jürg Frey, we encounter works that extend beyond the definite form of a musical or sound object; they lack clear edges or boundaries, making them potentially indistinguishable from environmental sounds or presenting acoustic challenges in perception. A vast range of sonic practices is indeed rooted in essential sonic forms that prioritize an immediate and phenomenological appreciation, rather than conveying narrative or representational messages. Certain academics have labeled this diverse collection as belonging to the sphere of sonic arts (Moore 2016) or to sound-based music (Landy 2007). What seems interesting to me is that despite originating from various musical backgrounds, these artistic manifestations share essential traits and, as I have posited, possess distinct perceptual possibilities (Wanke 2021).

This is the reason why traditional approaches commonly used to study the perceptual and cognitive mechanisms involved in music listening (Huron, 2006; Juslin & Sloboda, 2013; Lerdahl & Jackendoff, 1983; Snyder, 2001) often appear to be ineffective when applied to contemporary art music. While some traditional theories choose to overlook less conventional musical forms (Huron, 2006, p. 351), others describe them as something that disrupts common perceptual patterns (Snyder, 2001) or by not adhering to proposed principles, even question the validity of such music (Lerdahl, 1992). Due to its specific characteristics, listening to sound-based music can elicit a different kind of response, as it confronts the listener with a broader range of sounds and developments than the more limited set of conventional musical sounds (Deliège, 1989; Imberty, 2005).

What is the perceptual-cognitive response to a musical piece lacks tonal constructions, traditional narrative structures, or linear temporality but instead contains a combination of noises, real-world sounds, both acoustic and electronic, all within non-linear developments? How does contemporary music relate to our mnemonic abilities and expectations? Why do we often feel a sense of disorientation, becoming engaged in an immersive experience when listening to this music? Why is the listening experience of this music often associated with visual and tactile sensory qualities and described in terms of masses of sound, surfaces, lines, and even geometric forms?

These are precisely the questions from which this paper begins, focusing on a set of musical genres that includes post-spectralism, minimalism, electroacoustic music, glitch-electronica, genres such as dubstep and minimal techno belonging to the so-called intelligent dance music (IDM), as well as artistic forms belonging to sound art. This diverse selection of music practices concerns a precise perspective on sound, which I defined "ecstatic-materialist" (2021), that reveals explicit attention to the intrinsic properties of sound rather than any functional and representational construction. Central to these genres is the creation (and the listener's experience) of sound textures and masses, rather than a dialectical relationship between tones (melodies). In this music, there is a clear shift from sound considered as an element of music with a given *function*, to sound made structurally autonomous to the point of being defined (and appreciated) not based on its use but through its nature (Bonnet, 2012, p. 130).

Building on this perspective, this contribution presents an original view of sound-based music and its modes of listening, and it argues that the experience of this music has a particular connection to our experiential world, involves a form of embodied cognition,[1] and could be efficiently described through a morphodynamic cognitive model.

Recently, studies in the field of embodied cognition (A. Cox, 2016; Leman, 2008; Reybrouck, 2020, Kozak, 2020) which focus on the perception of contemporary and experimental music, draw from phenomenological accounts and Gestalt principles within the cognitive sciences, philosophy of art, and ecological theories (Clarke, 2005; Gibson, 1979; Solomos, 2023). Researchers advance new perspectives on sound that go beyond Schaefferian "reduced listening" (i.e. the possibility of sounds to be perceived "in itself"), preferring the idea of sound as having an inherent value – somehow borrowing the notion of *affordance* from Gibson's account (1979) of visual perception – (Kozak, 2020; Krueger, 2014; Menin & Schiavio, 2012), or incorporating into sound a poietic and aesthetic level that refers to the world beyond and external to the musical work (Landy, 2007).

Considering that the appreciation of contemporary and experimental music genres remains tied to familiarity, educational level, economic policies, and marketing (Bourdieu, 1979; Grebosz-Haring & Weichbold, 2020; Menger, 2014), I have proposed that part of this music is particularly suited to be studied starting from a perceptual level (Wanke, 2019; 2021). The sonic characteristics of sound-based music appear to be based on essential principles and to correspond to primitive perceptual mechanisms, such primal segregation (Bregman, 1990), the formation of auditory Gestalten (Koelsch & Siebel, 2005; Santarcangelo & Wanke, 2020) and working memory (Schulze & Koelsch, 2012; Joseph, 2015). This striking

[1] Embodied cognition is a cognitive theory suggesting that aspects of cognition (ideas, thoughts, concepts, and categories) are determined not only by brain processing but also by the characteristics and movements of the human body in its environment.

correspondence let us to envisage how the listening experience of sound-based music essentially involves processing sound patterns within a spectrotemporal domain, and that this processing primarily occurs through an implicit cognitive pathway. A pathway, as we will see, made possible by the characteristics of this music that remain intact, passing from substrata to substrata, from the acoustic external world to mental images, forming the basis of an embodied cognition.

If this is true, we are facing a new understanding of contemporary and experimental music practices which, on one hand, opens up to effective strategies for accessing a music that is still largely considered an isolated and elitist form of expression, and capable, on the other hand, of shedding lights on the appreciation of a wide range of today's sonic experiences (e.g., multisensory installations, ambisonic listening, sound virtualizations).

The perceptual grammar

Given that sound-based music cannot be studied and fully understood through traditional musicological approaches, the next step is to construct new tools to examine its characteristics. While there is already a well-established field of research aimed at developing analytical tools for individual genres (Emmerson & Landy, 2016; Roy, 2003), it must be recognized that the idea of a method suitable for exploring, from a broader perspective, how the musical genres we are discussing act at the perceptual level has not yet matured. While the notion that contemporary music today as a plural and interconnected field of various musical genres is already established, recent publications (Lundy et al., 2022) continue to gather essays focused on sectoral aesthetic perspectives applied to specific genres (*musique concrète*, DJ styles, minimalist music), sometimes compared to each other. I developed a different approach, which allows the study of various genres in which the unifying element is the same idea of sound (Wanke, 2021).

In a previous analysis of pieces from various contemporary and experimental music genres (Wanke, 2021; Wanke & Santarcangelo, 2021), I coined the term "perceptual grammar" and utilized it to describe the auditory experience of a set of acoustic stimuli which are in common to different styles and contexts of today's sound-based music, ranging from lengthy written orchestral compositions (e.g., *in vain* (2001) by Georg Friedrich Haas) to short tracks of semi-improvised electronics (Pan Sonic's *Kesto* (2004)). It is a cognitive grammar that consists of sound patterns used in various combinations, encompassing (i) structural features:

- the extended spectral exploration (including noises, inharmonic spectra, and infrasounds);
- the use of microtonality (or more generally of the psychoacoustic effects generated by the interaction between neighbouring frequencies);

- the presence of continuous frequency movements (*glissandi*), and sound masses (sustained tone-based aggregates, drones);

and (ii) progressive features:

- metric frames (rhythmic and periodic figures);
- sonic contrasts (both dynamic and timbric).

Moreover, the sound patterns belonging to the perceptual grammar incorporate particular (iii) effects due to:

- hypnotic, immersive, cumulative reiterations; and
- auditory challenges at macro/micro sound scales, such as distortions, illusory effects, psychoacoustic phenomena;

and (iv) arrangements which are non-functional, non-teleological, sculptural and with an extended temporality.

The perceptual grammar presents interdependences and hierarchies and accounts for essential qualitative and quantitative discontinuities within the spectrotemporal domain. It embodies the principles of Gestalt and encompasses a series of essential dichotomies (identity/difference, movement/stasis), spatial organisations (ascending/descending, figure/background), scalar and kinaesthetic dimensions (tension, linearity, amplitude, and projection) (Sheets-Johnstone, 1999; Tenney, 2015; Van de Cruys & Wagemans, 2011). When listening to sound-based music we are faced with sound patterns, as emergent auditory units, that present themselves within spectrotemporal boundaries and do not incorporate crucial information regarding external spatialization, sound origin (Kubovy & Van Valkenburg, 2001; Santarcangelo & Wanke, 2020), but rather refer to the so-called intrinsic properties of sound, *i.e.* a portion of the acoustic stimulus in which sound expresses its internal content, imaginable as the place where it possesses its concrete objectivity and material nature (Wanke, 2021). Defined as "sound-matter" (Wanke, 2021; Bériachvili, 2010), it is the domain of the tangible qualities of sound, its extension, density, and grain. In this portion of the sonic experience, listeners have a reduced ability to identify the cause and spatial location of the sound stimulus and must instead focus on the intrinsic sonic characteristics. In short, the sound originally produced by an instrument, under specific listening conditions, detaches itself as becoming something independent from the object or external cause that generated it.[2]

[2] I have discussed (2021, pp. 83-84) how certain contexts of musical consumption –such as the experience of listening in complete darkness, the use of sound manipulation to mask the recognition of the source, and the importance of being fully aware of sound production methods– allow the listener to focus on the intrinsic properties of sound without being distracted by our inherent tendency to seek a cause for the auditory stimulus (cf. Eitan et al., 2012; Ross, 2010).

The essential characteristic of the perceptual grammar that unites these sound patterns is their abstract nature: the movements and shapes evoked by the sounds do not recall elements of their production but rather suggest primary features of our experiential world, such as figure/ground arrangements, descending and ascending movements, broken and continuous trajectories, overlaps, and so on.

When we listen to an entangled descending *glissando* played in the *String Quartet n.2* by Georg Friedrich Haas, we clearly recognize the sound coming from the string instruments and we are able to appreciate the profile of the sound patterns depicted within the sound-matter. We express and articulate our experience not only in terms of concrete external elements (i.e. the string instruments), which continue to be common parameters, but also by referring to geometries and forms: planes, lines, layers, contrasts, and degrees of density, that belong to the immanent emergence of sound patterns (Wanke, 2019). This happens because the perceptual grammar is more akin to experiential patterns of our being in the physical world – concepts such as trajectory, block, near-far, full-empty, ascent, descent, overlap (Johnson, 1987, pp. 45–47, 126) – than to any kind of representational dialectic language, and because, more generally, the formal characteristics of sounds are at the centre of the aesthetics of sound-music.

Perceptual and Cognitive Domains

There is an on going debate in the cognitive sciences on the dilemma of whether the formation of our consciousness is exclusively based on brain function (Seth, 2021; Dennett, 2017; Churchland, 2013) or rather on the integration of processes involving a periphery-centre synergy and our bodily interaction with the external world (Damasio, 2010; Varela et al., 1991; Noë, 2004). The latter perspective has been extensively developed in recent studies on musical perception and embodied cognition (Kozak, 2020; Leman, 2008) and I have discussed on other occasions how sound-based music has a unique potential in relation to both the initial stages of perception and higher-level cognition. Due to its specific characteristics, this music (i) corresponds to the mechanisms of our primary segregation, (ii) promotes specific modes of listening, and (iii), by reflecting experiential patterns of our being in the world, has a significant influence on higher-level cognition (Santarcangelo & Wanke, 2020; Wanke, 2021).

Firstly, at the perceptual level, the sound patterns of sound-based music coincide with the functioning of working memory and processes of segregation, grouping (formation of perceptual Gestalts), storage, and prediction (Di Bona & Santarcangelo, 2018; Koelsch & Siebel, 2005; Wanke & Santarcangelo, 2021). Considering that early perceptual stages involve (potential) auditory objects and do not process acoustic features separately (Joseph et al., 2015), the sound patterns correspond to these fundamental perceptual units in the form of coherent configurations where acoustic components are segregated within a spectrotemporal domain (intensity, frequency, time). Furthermore, given that the "what" and "where" of an acoustic stimulus are processed separately (Alain et al., 2001; Di Bona & Santarcangelo, 2018, p. 64), the debate on the role of sonic causality – namely, the degree of identification by the listener of the actions and materials that caused the sound – comes to the forefront (Caramiaux et al., 2014). Some researchers (Frey et al., 2009; Godøy, 2021) propose new insights to Schaefferian notions of "sound object" (*objet sonore*) and "reduced listening" (*écoute réduite*) (Schaeffer, 1966) to find a synthesis between natural and aesthetic mechanisms of perception.[3] In this regard, one should note that sound-based music does not use recognizable noises or everyday sounds that call straightforwardly for the sonic causality. Thus to invoke the need of a "reduced listening" – an active focus on the intrinsic sonic qualities and a disregard to sound causality – when we experience this kind of music is superfluous: it is the music itself and its configurations that promote attention to the sound rather than its production.

Secondly, it is worth considering that pieces by composers such as Giacinto Scelsi, Iannis Xenakis, Eliane Radigue, Alvin Lucier, and Jakob Kierkegaard challenge our listening (Snyder, 2001; Wanke & Santarcangelo, 2021). They do so by using sounds from a wide range of frequencies, often without clear boundaries and defined durations. The mentioned authors exploit the principles of psychoacoustics, use sonic materials that can confuse us, blend different sounds into a coherent perceptual chain (*i.e.* families of sounds that are morphologically similar), challenging our temporal expectations to the extent that it encourages a "vertical" and immersive listening experience (Kozak, 2020; Kramer, 1988; Wanke, 2021).

Thirdly, certain studies suggest that the mental representations evoked by music may be originated from a set of frequency/time constructs (Di Salle et al., 2003; Godøy & Jørgensen, 2001; T. D. Griffiths & Warren, 2004). The appreciation of sound-based music can escape, in the first instance, high-level conceptual associations while leading to the formation of corresponding mental representations directly related to the morphodynamic of stimuli (Godøy, 2010). If we consider, for instance, a descending *glissando*, a sequence of distorted pulsations at low frequencies, or a microtonal transition, these sound patterns do not connect to anything in the world but instead consist of sound patterns that unfold within an acoustic (first) and perceptual (second) domain and lend themselves, as we will see, to be processed at a higher cognitive level through an implicit pathway.

Researchers from various disciplines continue to debate the nature of the transitions connecting unconscious neural processing to cognitive phenomenological

[3] For a detailed description of the concepts of auditory object, sonic object, or sound object, refer to (Hjortkjær, 2015) and (Rocchesso & Fontana, 2003).

experiences. Some have proposed connections between synchronized activations of cortical areas in the brain (dynamic and causal) and the emergence of object identities and activities in the mind (mental representations) (Damasio, 2010; DeLanda, 2022; Fingelkurts et al., 2010). When discussing the specificities of sound-based music, I hypothesized the presence of an internal-external bridge that allows thinking of the existence of a domain where sound geometries from the physical-acoustic world are somehow reproduced internally (Wanke, 2021). I focused particularly on how we, as listeners, mentally represent the frequency dimension of sound. It is known that the conceptualization of audible frequencies as a vertical axis is not innate (A. Cox, 2016; Eitan & Granot, 2006), while there is a common consensus in mentally visualizing the separation between frequencies as a kind of extension, a dimensional compass (Fingelkurts et al., 2010; Gallistel, 1990).[4] What we call a high note is not literally high in our world, but the anatomy and functioning of our auditory system show a path in which tonotopic organization (*i.e.* the physical discrimination of frequencies) is established in the cochlea and maintained throughout the pathway of our auditory system up to the cortex included (T. D. Griffiths & Warren, 2004; Shamma, 2001).

The relationship between these two levels (cochlea and cortex) has been proposed in the form of a functional isomorphism rather than a physical one (Fingelkurts et al., 2010): an internal neural process that corresponds to the response to an external stimulus of a circle does not involve neurons arranged in a circular shape. The relationship is, therefore, functional rather than of the first order: sensory and neurological systems achieve the same process in different ways. If brain activity is isomorphically related to the spectrotemporal features of the acoustic stimulus, it seems plausible that subsequent cognitive steps at a higher level keep track of these features (DeLanda, 2022). It is reasonable to think, for instance, that listening to a *glissando* – a continuous movement within the boundaries of frequency, time, and intensity – can generate a *functionally* coherent set of perceptual responses capable of preserving the constituent elements of the *glissando* itself, such as wholeness, continuity, directionality, movement, and progressive change. This sort of "memory" which would pass from substrata to substrata has been conceived in different ways. Lakoff and Johnson speak of "orientational metaphors" in the case of language (1980; 2008, p. 14), and Godøy proposes the paradigm of form in the discussion of musical cognition (1997).[5] To account for the mental images evoked by sound-based music, I find it more appropriate, however, to rely on the notion proposed by Mark Johnson of *image schema* (1987). The advan-

[4] In other musical cultures, for example, the dimension of frequencies is described and expressed along a "sharpness/heaviness" or "small/large" axis (A. Cox, 2016; Eitan & Granot, 2006; Zbikowski, 2008, 2017).

[5] Godøy's theory, in particular, envisions an epistemological foundation for this paradigm, consisting of the idea that "musical objects [could be seen] as a retentional image in memory" (1997, p. 99).

tage of using the notion of image schema lies in its characteristics: "[a]n image schema is a recurring, dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience" (Johnson, 1987, p. xiv). Based on an intrinsic spatial structure and a kinaesthetic character, image schemas can be used to connect our perception to the external world within a framework of embodied cognition and is an efficient description of our cognitive response to the sound patterns of sound-based music.

Image schemas account for our experiential interactions with the world (Figure 1), they essentially belong to four classes: those schemas describing trajectories along 2D-extents (PATH, CYCLE, SURFACE), 2D- or 3D-entities (OBJECT, CONNECTION, MASS-COUNT, WHOLE-PART), interactions (SOURCE-PATH-GOAL, MERGING, SPLITTING, TOWARDS AWAY/FROM), and forces (COMPULSION, ENABLEMENT, COUNTERFORCE, IMPACT). All classes are subjected to a variety of quantitative (SCALE) and qualitative discontinuities (STRAIGHT, CURVE, STEADY, INTERMITTENT) and frequently overlap (e.g., the image schema defining entities encompass, to a large extent, a description of interactions). Image schemas are often experienced together, one superimposed on the other in an experiential Gestalt structure. During these co-experienced Gestalt groupings, the combinations of image schemas co-occur in our experience in spatial and force-dynamic combinations (*e.g.* MASS-COUNT, COLLECTION, MERGING, OBJECT, and their relation to a NEAR-FAR perspective (Cienki, 1999).

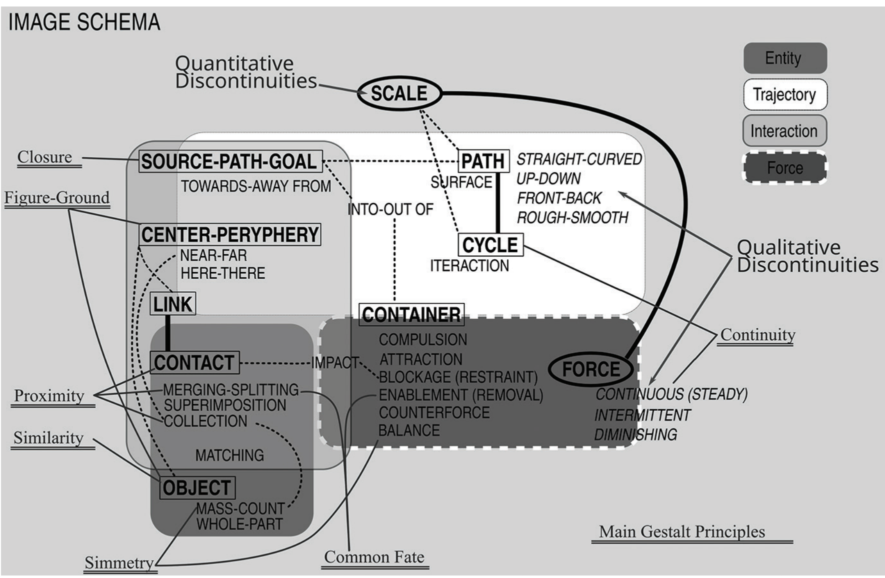

Fig. 1. Schematic Representation of classes of image schemas and their correspondences with main Gestalt principles.

We will see how image schemas work as structuring tools for incoming sound patterns of sound-based music, thus opening up to the formation of embodied mental images.

The morphodynamic theory applied to sound-based music

Looking at the aesthetic experience of sounds allows us to focus on how we interact with and interpret acoustic stimuli outside the everyday context (noises, everyday sounds) and any evolutionary theory: a melody (or a *glissando*) is nothing more than a concatenated (or continuous) series of acoustic stimuli unfolding within a perceptual domain independent of the external world and its phenomenological information (cause, directionality, position, external movement, etc.).

The experience of the "world of sounds", to use an expression by Roger Scruton (1997), involves cognitive processes similar to those used for abstract concepts such as mathematics and geometry. However, the cognitive domain in which a melody emerges is not that of abstract logic, as in formal languages (formal logic, formal semantics, categorical grammars, etc.), but is closely tied to the sensory level and the external physical world.

Several studies have observed that musical structures, belonging to this sort of virtual space, are appreciated in terms of movement and forces (Brower, 1997, 2000; Larson, 2012; Larson & VanHandel, 2005; Lerdahl, 2001). It is crucial, however, to make an important distinction based on the difference between sequences of notes and continuous changes of frequencies. Most of these studies discuss music in general terms without distinguishing between equal temperament and microtonal systems, or more generally between music based on notes and music based on sound. Generally, these works conclude that the "movement" of musical notes (at a stable frequency) leads to a certain perceived effect. Snyder defines the sensation of movement evoked by a sequence of notes as an illusion (2001), while Johnson discusses the experience of musical movement "as real as temporal motion" (2008, p. 255). Traditional melodies are musical patterns within a multidimensional space of frequency, time, and intensity. But, while time is a continuous dimension, frequency movements are formally "quantized" into notes. Zuckerkandl clarifies that

> motion is the process that conveys the thing from here to there, in a continuous and never suspended traversal of the interval. If it stops anywhere, the motion is instantly abolished. But in a melody we have nothing but this, nothing but stops, a stringing together of static tones, and, between tone and tone, no connection, no transition, no filling up of intervals, nothing. It is the exact opposite of motion (1969, p. 83).

The difference between a descending sequence of notes and a *glissando* is evident here. If there is a sense of movement when listening to a sequence of notes, this is amplified to the point of being considered real in the case of sonic movements in the frequency continuum. The sonic patterns of sound-based music – such as *glissandi*, binaural beats, and microtonal transitions – consist of continuous movements in the spectrotemporal domain and are experienced as real movements.

Works by composers such as Justė Janulytė, Giovanni Verrando, György Ligeti, Kaija Saariaho or performers like Mika Vainio, Oren Ambarchi, and groups like Emptyset and Boards of Canada explore sonic characteristics as aesthetic elements. Unlike more traditional musical genres, here we find ourselves dealing with music made up of sonic patterns whose nature is fundamental to the aesthetic aspect. Its formal level is neither symbolic nor functional but rather topological and geometric.

The morphodynamic theory proposes a connectionist model of cognition in which the structures and patterns of the external physical world are made explicit through their morphodynamics. This theory identifies a series of abstract invariants in the geometry of perceptual scenes that can be reformulated as constituent structures. Initiated by René Thom in the 1960s, morphodynamic theory drew immediately on mathematical models and dynamic systems, applying them to linguistics, phonetics, semiotics, and categorical and visual perception (Hampe, 2008; Kosslyn et al., 2007; Laeng, 2013; Lakoff & Johnson, 1980; Marr, 1982; Petitot, 2011, Gärdenfors, 2000).

The traditional symbolic paradigm asserts that mental representations originate as internal formal structures: within this account, it is the cognitive system that assigns meaning to its internal symbols. Mental representations would be symbolic insofar as they refer to internal mechanisms of thought, and following this formalist position, mental representations cannot be directly ascribed to principles governing the physical world. Conceived in a physicalist sense, the latter must be considered *a priori*, devoid of relevant meaning for the cognitive system. Referring to traditional cognitive theories, Petitot talks about an "ontological gap" that separates the symbolic level from the physical one (2011, p. 51). The morphodynamic model instead is a connectionist model because it seeks to address this gap (Smolensky, 1988). A morphodynamic level, in fact, (i) has a physical origin: morphological information is preserved through transduction (Marr, 1982), (ii) is geometric-topological, and (iii) is not symbolic, nor logical, although it continues to be formal. In cognitive sciences, the morphodynamic model operates at a pre-symbolic cognitive level by connecting the external physical level to the symbolic one (Petitot, 2011). Abstract structures of meaning are, from the morphodynamic perspective, natural structures that can no longer be seen as symbolic elements connected by formal relations. They are emerging natural Gestalten, perceptual organizations, self-organized, and dynamically regulated.

The morphodynamic theory can, therefore, be used in the auditory domain, but especially in the musical context once music is understood as a series of organized sound forms. This use is even more effective when considering sound-based music. Applied to the cognitive mechanisms that are at the core of the auditory experience of sound-based music, morphodynamic theory, precisely because it highlights the connection between sound patterns and evoked mental images, comes into play in helping us understand how sound patterns may correspond to the experience of veritable geometries in motion. In case of auditory perception and particularly musical cognition, some important works already hypothesize that musical structures can evoke mental images in the form of geometries and forms (Godøy, 1997; Reybrouck, 2013).

As mentioned above, sound-based music presents itself to us through its perceptual grammar that consists of organized configurations of sounds built on the principles of Gestalt and kinaesthetic models. Listeners experience the patterns of the perceptual grammar as emerging forms with the potential to unfold, expand, and collapse within a perceptual domain (Wanke, 2019). The validity of morphodynamic assumptions depends here on the fact that the qualitative and quantitative discontinuities of sound patterns are preserved and transmitted up to higher cognitive levels. If musical episodes containing abrupt oppositions of sound masses or transient appearances of fragile overtones or repeated descending *glissandi* evoke mental images like solid blocks, empty or full, oscillating lines, or inclined profiles, it is because information is preserved.

Now it is clear that the connectionist proposal can find correspondences in some non-representational theories of cognitive sciences, such as ecological psychology (Gibson, 1979) and enactivism (Varela et al., 1991). Both of these theories reject the idea of cognition based on computational operations of internal mental representations and instead propose that cognition is realized towards an interaction with the external world, seen from time to time as a system of references useful for meaning (Gibson) or as a context in which to act (Varela). Applied to music, these two positions have given rise to two visions: on the one hand, some studies suggest the possibility that sounds offer an *affordance*, an inherent value within a subject-object framework (Kozak, 2020; Krueger, 2014; Menin & Schiavio, 2012; Reybrouck, 2012; Windsor & de Bézenac, 2012); on the other hand, enactivism in musical practices emerges as an embodied cognition inherent of the relationship between the individual and collective environments (Leman, 2008; Reybrouck, 2020; Van der Schyff et al., 2022). The morphodynamic model which accounts for the experience of the sound patterns of sound-based music fits between these two visions: it is deeply rooted in a specific type of sound and its characteristics (i.e., perceptual grammar) that, as we will see, activate a kind of *virtual* affordance, and it asserts that such sound allows for embodied cognition.

From image schemas to embodied responses through virtual affordances

Over the past few years, I have conducted empirical research using listening questionnaires to examine the cognitive potential of sound-based music (2022; 2019; Wanke et al., 2018). An important result emerging from these studies is that our listening experience of the sound-based shows a very specific connection to the external world.

It's worth summarize three key aspects that characterize this music. First, the discussed sound patterns are appreciated aesthetically and presented to listeners as music rather than generic acoustic stimuli. This context tends to limit factual listening; participants in my studies, or more generally, the audience of sound-based music, might have questioned whether the perceived sounds originated from environmental noises, but they were fully aware of grasping parts of a musical piece. In this case, the "ecological" response that an individual might give in relation to a continuous sound increasing in intensity, typically interpreted as the approach of a sound source, is overlooked.

The second aspect concerns the perceptual grammar of this music, which directly points to a non-functional level. Sound-based music pieces possess a limited dialectic between musical elements that appear more as parts of a global sonic idea rather than distinct figures articulated in mutual relation (Wanke, 2021). This is a characteristic feature of minimalism, spectralism, and part of electroacoustic, electronic, and avant-garde music, exemplified by figures like La Monte Young, James Tenney, Eliane Radigue, Annea Lookwood, Alvin Lucier, Maryanne Amacher, or Pan Sonic. Therefore, we can say that these authors create music based on the presentation of sound elements, minimizing their articulation, characterized not by a narrative relationship between notes or melodies, but by a grammar governing the sonic material at play. This aspect reduces possible stylistic appreciation and recognition while favouring the phenomenological one.

Thirdly, after seeing how the nature of perceptual grammar directs the listener directly toward the broader experiential world, we can affirm that the movements, forces, and tensions that this music displays are the same ones encountered in our daily experience of the world (referring to daily experiences like slipping, falling, touching, scraping).

The combination of these three aspects leads to the consideration that, compared to other auditory stimuli, the sound configurations of sound-based music are unique, and their aesthetics plays a key role. If aesthetics, understood broadly, concerns how we create and experience values and meanings, then the aesthetics of sound-based music is given by an auditory experience constituted by meaningful sound patterns. Perceptual grammar consists of a set of hierarchies and internal dependencies between sound patterns that account for intentionality in the form of forces (constraint, block, attraction) occurring along trajectories (starting point, path, destination, evolution) drawn over time. Thus, forces, understood as trajectories and time, are essential factors of movement. These are, to some extent, paradigmatic aspects of all music, but – due to the three aspects listed above – they play a central role in the case of sound-based music.

But why do a repeated sequence of descending *glissandi* or extreme contrasts between strong sound masses evoke a sense of falling (or descent) or a mental image of massive stone blocks? Following the reasoning developed so far, one can answer that cognitive associations are nothing but the realization of forces (trajectories and time) expressed by sound patterns. The sense of falling would be the result of our experiential response to a *glissando*. In this view, the sound patterns of sound-based music match Johnsonian image schema as they evoke our persistent associations, those arising from recurring experiential patterns. Thus, we can speak of embodied cognitive responses to the extent that they arise from our physical experience in the world.

The morphodynamic analogy is due to the fact that incoming sound patterns and experiential image schemas share essential forces and tensions of our existence in the physical world (Figure 2). Embodied concepts like "CONTINUOUS PATH" or "SURFACE" (*i.e.* trajectory image schemas) are present in the perceptual grammar as a continuous change of frequencies or a sustained distorted sound; image schemas accounting for spatial definitions (FIGURE/GROUND, WHOLE/PART, MASS/COUNT, SUPERIMPOSITION), movements (NEAR/FAR, COMPULSION, BLOCKAGE, ENABLEMENT) and temporal recurring patterns (e.g. CYCLE), can be found in the organised auditory objects as a result of primal and schema-driven segregation (Bregman 1990). This convergence of experienced sound patterns "here/now" and image schemas, as "invariant" patterns, lead to the mental images whose level of embodiment largely depend on our experiential cognition of the external world: a distorted drone may recall a 2D-shape (i.e. plane) or an action of scraping a surface, a descending *glissando* may elicit an abstract declining line or an embodied sense of falling. There is a link, an affordance, which ties in sonic characteristics with experiential knowledge.

Studies that apply Gibson's theory of visual perception (1979) to the auditory level suggest, in fact, the possibility that sounds offer affordances. It may seem inappropriate to invoke the concept of affordance – a notion of ecological perception – in the case of contemporary and experimental music, which is often listened to in contexts far from ecological. As observed earlier, if a concert

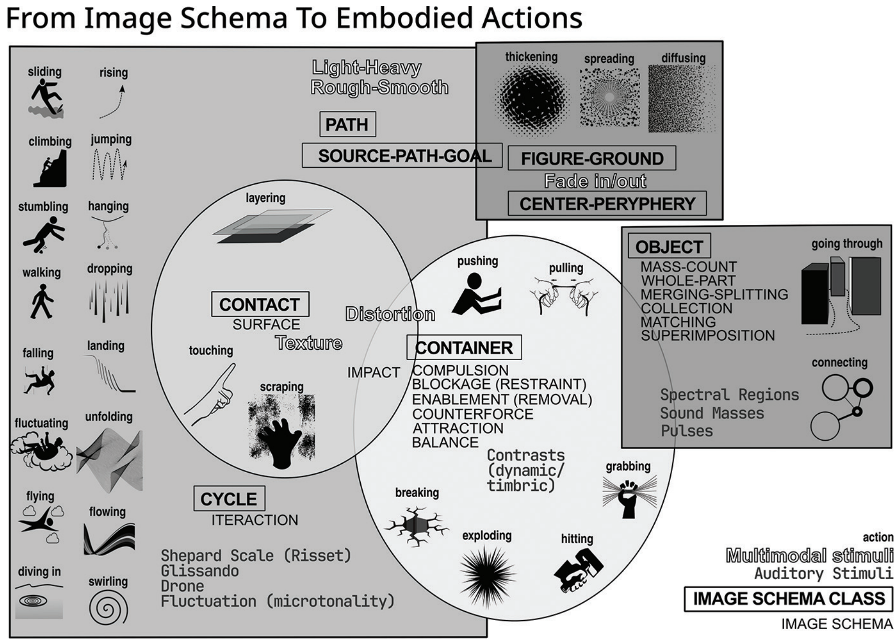

Fig. 2. Representation of the parallel among classes of image schemas, stimuli of different modalities and embodied responses.

listener hears a sound increasing in volume, they certainly don't interpret it as a sound source approaching. That kind of ecological response is bypassed (or ignored). It should be noted that in the case of contemporary music, especially in electroacoustic contexts, the notion of affordance has often been related to the presence of sounds and noises from everyday life (or synthesized sounds simulating environmental sound events), investigating how they appear to us and what images and sensations they convey. The use of sounds (real or synthesized) intended to create imaginary realities is a typical practice of acousmatic music, and in this sense, "[t]he acousmatic piece affords 'interpretation' because its affordances must be manufactured, to a large extent, by the interpretative activity of the listener" (Windsor, 2000, p. 22). A piece like *De Natura Sonorum* (1978) by Bernard Parmegiani presents the listener with articulated sequences of sounds, each of which has a possible affordance: a kind of identity, a "role", given by the functional relationship with other sounds. In this case, affordances have the potential to suggest real environments within a subject-object framework (listener-sound), providing information about causality (real or recreated) and behaviour (real approach or simulation). In this situation, they would give rise to adaptive behaviour.

In this paper, I reconsider the idea of affordance that plays a role at an implicit level and avoid any hermeneutic approach. The sound patterns escape causal and contextual interpretation and unfold in the "world of sounds"; they do not explicitly refer to instrumentation (e.g. the string technique of *pizzicato*, *col legno battuto*), or compositional perspectives. Instead, they convey forces and tensions through sound. What kind of affordance is conveyed by a sequence of strong distorted electronic pulsations or a continuous descending *glissando*? These are virtual affordances (Barsalou, 1999; Zbikowski, 2002, 2010): sound-based music is based on primitive structures, pervasive patterns that replicate the forces we know from our experience of the external world.

We are not external observers/listeners of a sound event from which we extract information about origin, position, production, and contextual factors, but we are active bodies interacting with the auditory stimulus, experiencing a sense of falling, slipping, and descent; we are subjects undergoing forces acting on us; we are organisms sensing our own movement through solid obstacles. This is why a series of distorted sound pulsations evokes an action (a desire to break and shatter?) rather than a recognition of something that produced these pulsations. The proposed affordance here does not concern any information about the sound source but rather the action that the subject is called to embody. This experience integrates somatic information received from our body: these are assimilated into the experiential knowledge of our actions in the world. The brain continually monitors the body, resorting to the correlation between sensory and proprioceptive information,[6] and finding correspondences between these stimuli (Delanda, 2022).

But how can simply listening to a *glissando* lead to this sensation of falling? The reasons why the phenomenological properties of a *glissando* can evoke post-experiential bodily sensations are quite diverse. This type of auditory→bodily transmission can have many causes such as statistical, linguistic (Johnson & Larson, 2003; Zbikowski, 2008), or cultural learning (Dolscheid et al., 2013), factors dependent on stimulus selection, or innate tendencies (Wagner & Dobkins, 2011).[7] The sense of falling can be generated by the similarity of the acoustic environment experienced in real-life falling scenarios, such as the auditory and bodily stimulus experienced during an airplane landing (the sound of the airplane engine is a descending *glissando*). More generally, these sensations come from the identification of recurring patterns formed through the previous natural selection of lived events. In particular, it can be said that some statistical regularities in the world lead to the existence of preferred postures in body dynamics (DeLanda, 2022, p. 48; Gärdenfors, 2000).

[6] Proprioception is " a form of internal perception required to keep the brain informed about the body's current posture, limb configuration, and state of movement" (DeLanda, 2022, p. 48).
[7] For a review please refer to (Leech-Wilkinson & Prior, 2017; Spence, 2011).

The essence of our experience is defined "by the nature of our bodies and brains, the kinds of environments we inhabit, our social interactions, and the values and purposes we have. The patterns of our ongoing interactions [...] define the contours of our world and make it possible for us to make sense of, reason about, and act reliably within this world" (Johnson, 2008, p. 136). The sound patterns of sound-based music activate precisely "these basic structures of sensorimotor experience by which we encounter a world that we can understand and act within" (ibid. 2008, p. 136).

A final example

Among the materials to discuss, based on the results of many analysed responses, I'll mention at least one example.

In the listening of a short musical excerpt taken from the *String Quartet No. 2* (1998) by Georg Friedrich Haas, participants, presented with two abstract drawings of lines and shapes, were asked to choose the one they deemed more fitting for the musical excerpt and to comment on their listening experience.[8] Beyond the specificity of individual responses, a notable series of comments stood out for coherence, revealing a very precise experiential idea related to the concept of *viscosity*: "...something dripping from the ceiling"; "... something that slowly comes out from a static source"; "Sensation of something rough"; "highly viscous substance oozing…".

In the presented musical excerpt (see Figure 3, embedded spectrograms), the four instruments play continuous notes and create a sonic flow (consisting of four lines, starting from the fundamental note and their respective natural harmonics). Each instrument moves in parallel but not simultaneously, gradually transitioning to the next harmonic series. Introducing a new fundamental note, the cello anticipates the new harmonic series while the viola and violin lines remain stuck in the previous series. The idea of viscosity, expressed by participants with different sensitivities, emerges from the sound pattern: a flow of sound with various harmonic series that change gradually. The listening experience is characterized by an association that comes from the everyday experience of the external world, specifically the knowledge of the consistency and behaviour of a viscous substance.

The association between a sequence of sustained tones and a dripping viscous substance has a "cross-modal" character: listeners recognize in the music (auditory mode) the same abstract pattern they found during a visual (or tactile) experience of such a substance. The "viscosity schema" thus emerges as

8 The request to associate music and drawing also aimed to encourage participants to focus their attention on sound characteristics rather than other stylistic or organological aspects.

a common (and shared) experiential pattern. The ability to correlate patterns from one perceptual domain with features of another perceptual modality is a fundamental component of everyone's intuitive understanding of our world through bodily interactions (Johnson, 2008, pp. 42–43). It seems that the idea of viscosity, expressed by participants in different ways, suddenly emerges: none of the listeners alludes to an explicit parallelism between the melodic line and the idea of viscosity, nor is there any mention of the cello's attack (otherwise recognizable) ready to introduce the new harmonic series, dragging the viola and violins with it. On the contrary, everyone refers to a specific association ("...something dripping from the ceiling") as if it were unconsciously originated from the just-heard sound patterns. This experience suggests that the very nature of this association we have examined is implicit: there is no reference to music in terms of comparisons and similarities with something, but an intuition, a perception, an immediate image is evoked, and some more distinctly, others with different nuances, account for it only through essential characteristics ("...something slowly coming out of a static source"). The cross-modal association occurs unconsciously where image schema typically operates (Johnson, 2008).

This music has the potential to minimize semantic interpretation (style, genres, instrumentation) and factual listening (production, contexts) and connect us to the real world at a deeper level than the phenomenology of sounds from the real world and everyday noises which instantly refer to their means and sources of production (Caramiaux et al., 2014; Gaver, 1993). This does not mean, of course, that sound-based music precludes every concrete conceptual association: it is natural for listeners to use higher cognitive schemas, past experiences and knowledge to process any incoming information; the difference – compared to other musical repertoires – is that this music can naturally activate implicit cognitive responses as well.

Conclusions

The uncommon, provocative, complex features of some musical genres in today's experimental music challenge scholars and researchers to propose new theories to explain the perception of these new forms of music, still largely considered a niche phenomenon. However, it is evident that within mass musical contexts, it is increasingly common to find concerts and innovative performances ready to break our canons and expectations. Therefore, the growing interest in better understanding the aesthetic nature and perceptual potential of these experiences can foster openness towards contemporary and experimental music. Indeed, sound-based music could represent the perfect candidate for studying the psycho-aesthetic response to sound.

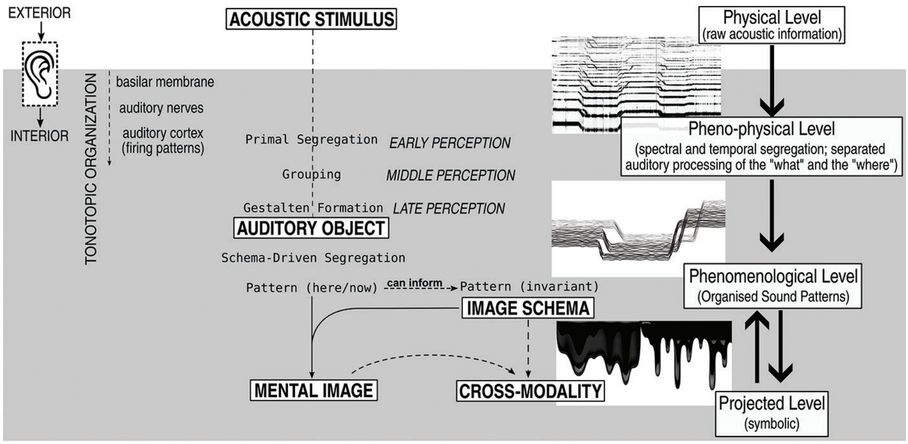

Fig. 3. Proposed scheme of auditory perception of sound-based music coupled with Petitot's description of perceptual levels in the morphodynamical account (2011).

In my research, I advance the idea that certain musical genres within today's sound-based music have the potential to engage us through unconscious cognitive pathways capable of generating associations at a higher cognitive level. The massive electronic interventions of artists like Pan Sonic or Emptyset, or the intertwined lines present in compositions by Haas, Scelsi, Saariaho, or Tenney, are sound patterns. Listening to them activates the basilar membrane of our cochlea, generating information that preserves its tonotopic organization up to specific regions of the auditory cortex (Figure 3). Petitot explains the passage from the external micro-physical level – in our case, a level of raw acoustic information – to the pheno-physical level where macro-structures emerge:

> When a system possesses many levels of organization, the higher "macro" level is causally reducible to the lower ones, yet at the same time its structures can be largely independent from the underlying "micro" dynamics. It benefits from a certain objective autonomy (2011, p. 50).

This raw information of the micro-physical level is segregated and grouped through a series of low-level perceptual processes (Bregman, 1990) along a path that leads to the macro-structures of the pheno-physical level. At this stage, we independently process spatial and non-spatial properties of acoustic stimuli (Alain et al., 2001) and these neurophysiological streams account separately for the identification of sonic content (pitch, spectral and temporal issues) and its external spatial location (based on interaural time and phase differences).

Following Petitot's account, the pheno-physical level precedes and informs the phenomenological level, which, in the case of sound-based music, is the domain inhabited by sound patterns. These are, as mentioned above, *patterns (here/now)*, which can contribute, during concepts formation, to refine established *patterns (invariant)*. These latter are the core of experiential image schemas, which serve to give coherence to sound patterns and support the formation of mental images (Figure 3).

At a phenomenological level, the sound patterns are "organised" following the Gestalt and kinaesthetic principles of the perceptual grammar (front/back, up/down…) in such a way that also depends on the higher symbolic level (projected level). At the projected level, everyone makes different associations based on their cultural values and practices, music-historical conventions, and prior experiences. The "viscosity pattern" discussed earlier evokes a cross-modal association. Therefore, in this morphodynamic model, the phenomenological level of sound-based music is the locus of cross-modal patterns and is able to prompt cross-modal associations.

What sets this interaction apart from processes at play in listening to more traditional music genres is that sound-based music deliberately seeks this territory because it is rooted in a certain idea of sound: where sound itself (and not notes, melodies, or functional constructions) forms a perceptual grammar made up of emerging Gestalten and kinesthetic patterns.

So, the experience of this music is not a representation of the sound world around us but involves a connection with the world. This is why the morphodynamic model lends itself well to describe this embodied connection. Listening to sound-based music does not consist of an experience of a mere random sequence of acoustic signals but a human-created sound construction, which brings forth meaning through essential (preferred) cognitive patterns. We are not subject-observers, but we are called to confront an aesthetic experience of senses. The sonic involvement found today in the vast panorama of experimental music can thus be at the centre of a new aesthetic perspective regarding sound appreciation, capable of flourishing numerous insights in the artistic, social, and scientific fields.

Summary

In this contribution, I discuss the perceptual potential of certain genres of experimental and contemporary music, commonly grouped under the label "sound-based music". The sonic patterns typical of this music are mostly associated, during listening, with visual and tactile sensory qualities and can evoke mental representations as shapes in motion. These are the result of physical-acoustic energies organized according to a perceptual grammar whose organization follows a series of Gestalt and kinaesthetic principles. The paper explores the nature of the relationship between sound patterns of sound-based music and their mental images. Based on morphodynamic theory, it is proposed the emergence of cognitive image schemas, which are at the centre of this relationship. The image schemas

depict the forces and tensions of our experience of the world (e.g., figure-background, near-far, superimposition, compulsion, blockage), as being the cognitive and experiential response to the incoming sound patterns. The sense of this music activates precisely the basic structures of sensorimotor experience by which we encounter a world that we can understand and act within, leading to a rich series of high-level associations and responses.
Keywords: Sound-based Music; Embodied Cognition; Auditory Gestalt; Sound Aesthetics

Zusammenfassung

In diesem Beitrag erörtere ich das Wahrnehmungspotenzial bestimmter Genres der experimentellen und zeitgenössischen Musik, die gemeinhin unter dem Begriff „klangbasierte Musik" zusammengefasst werden. Die für diese Musik typischen Klangmuster werden beim Hören meist mit visuellen und taktilen Sinnesqualitäten assoziiert und können mentale Repräsentationen als Formen in Bewegung hervorrufen. Sie sind das Ergebnis physikalisch-akustischer Energien, die nach einer Wahrnehmungsgrammatik organisiert sind, deren Organisation einer Reihe von Gestalt- und kinästhetischen Prinzipien folgt. Der Beitrag untersucht die Art der Beziehung zwischen den Klangmustern klangbasierter Musik und ihren mentalen Bildern. Auf der Grundlage der morphodynamischen Theorie wird die Entstehung von kognitiven Bildschemata vorgeschlagen, die im Zentrum dieser Beziehung stehen. Die Bildschemata stellen die Kräfte und Spannungen unserer Welterfahrung (z.B. Figur-Hintergrund, Nähe-Ferne, Überlagerung, Zwang, Blockade) als kognitive und erfahrungsmäßige Antwort auf die eingehenden Klangmuster dar. Der Sinn dieser Musik aktiviert genau die grundlegenden Strukturen der sensomotorischen Erfahrung, durch die wir einer Welt begegnen, die wir verstehen und in der wir handeln können, was zu einer reichen Reihe von Assoziationen und Reaktionen auf hoher Ebene führt.
Schlüsselwörter: Klangbasierte Musik; verkörperte Kognition; auditive Gestalt; Klangästhetik

References

Alain, C., Arnott, S. R., Hevenor, S., Graham, S., & Grady, C. L. (2001). "What" and "where" in the human auditory system. *Proceedings of the National Academy of Sciences*, *98*(21), 12301. https://doi.org/10.1073/pnas.211209098

Barsalou, L. W. (1999). Perceptual Symbol Systems. *Behavioral and Brain Sciences*, *22*(4), 577–660.

Bériachvili, G. (2010). *L'Espace Musical: Concept et Phénomène à travers l'Avant-Garde des Années 1950-60 (Stockhausen, Xenakis, Ligeti...)*. Université de Rouen.

Bonnet, F. J. (2012). *Les mots et les sons: Un archipel sonore*. Éditions de l'éclat.

Bourdieu, P. (1979). *La distinction. Critique sociale du jugement*. Les Éditions de Minuit.

Bregman, A. S. (1990). *Auditory scene analysis: The perceptual organization of sound*. MIT Press.

Brower, C. (1997). Pathway, Blockage, and Containment in Density 21.5. *Theory and Practice*, *22*, 35–54.

Brower, C. (2000). A Cognitive Theory Of Musical Meaning. *Journal of Music Theory*, *44*, 323–379.

Caramiaux, B., Bevilacqua, F., Bianco, T., Schnell, N., Houix, O., & Susini, P. (2014). The Role of Sound Source Perception in Gestural Sound Description. *ACM Transactions on Applied Perception*, *11*(1), 1–19. http://dx.doi.org/10.1145/2536811

Churchland, P. M. (2013). *Matter and Consciousness*. MIT Press.

Cienki, A. (1999). *Some Properties and Groupings of Image Schemas*. In M. H. Verspoor, K. D. Lee & E. Sweetser (Eds.), *Lexical and Syntactical constructions and the construction of meaning* (pp. 3–16). John Benjamins Publishing Company.

Clarke, E. (2005). *Ways of Listening: An Ecological Approach to the Perception of Musical Meaning*. Oxford University Press.

Cox, A. (2016). *Music and Embodied Cognition. Listening, Moving, Feeling, and Thiking*. Indiana University Press.

Cox, C., & Warner, D. (2017). *Audio Culture, Revised Edition: Readings in Modern Music* (Vol. 1). Bloomsbury Publishing.

Damasio, A. (2010). *Self Comes to Mind: Constructing the Conscious Brain*. Knopf Doubleday Publishing Group.

Davies, S. (1994). *Musical Meaning and Expression*. Cornell University Press.

Deil, J., Markert, N., Normand, P., Kammen, P., Küssner, M. B., & Taruffi, L. (2022). Mind-wandering during contemporary live music: An exploratory study. *Musicae Scientiae*, 10298649221103210. https://doi.org/10.1177/10298649221103210

DeLanda, M. (2022). *Materialist Phenomenology. A philosophy of Perception*. Bloomsbury.

Deliège, I. (1989). *Approche perceptive de formes musicales contemporaines*. In S. McAdams & I. Deliège (Eds.), *La musique et le science cognitives* (pp. 305–326). P. Mardaga.

Dennett, D. C. (2017). *Consciousness Explained*. Hachette UK.

Di Bona, E., & Santarcangelo, V. (2018). *Il suono. L'esperienza uditiva e i suoi oggetti*. Raffaello Cortina Editore.

Di Salle, F., Esposito, F., Scarabino, T., Formisano, E., Marciano, E., Saulino, C., Cirillo, S., Elefante, R., Scheffler, K., & Seifritz, E. (2003). FMRI of the auditory system: Understanding the neural basis of auditory gestalt. *Magnetic Resonance Imaging*, *21*(10), 1213–1224. https://doi.org/10.1016/j.mri.2003.08.023

Dolscheid, S., Shayan, S., Majid, A., & Casasanto, D. (2013). The Thickness of Musical Pitch: Psychophysical Evidence for Linguistic Relativity. *Psychological Science*, *24*(5), 613–621. https://doi.org/10.1177/0956797612457374

Dyson, F. (2009). *Sounding New Media. Immersion and Embodyment in the Arts and Culture*. University of California Press.

Eitan, Z., & Granot, R. Y. (2006). How music moves: Musical parameters and listeners' images of motion. *Music Perception*, *23*(3), 221–247.

Emmerson, S., & Landy, L. (Eds.). (2016). *Expanding the Horizon of Electroacoustic Music Analysis*. Cambridge University Press.

Fingelkurts, A. A., Fingelkurts, A. A., & Neves, C. F. H. (2010). Natural world physical, brain operational, and mind phenomenal space-time. *Physics of Life Reviews*, *7*(2), 195–249. https://doi.org/10.1016/j.plrev.2010.04.001

Frey, A., Daquet, A., Poitrenaud, S., Tijus, C., Fremiot, M., Formosa, M., Prod'homme, L., Mandelbrojt, J., Timsit-Berthier, M., Bootz, P., Hautbois, X., & Besson, M. (2009). Pertinence cognitive des unités sémiotiques temporelles. *Musicae Scientiae*, *13*(2), 415–440.

Gallistel, C. R. (1990). *The organization of learning*. MIT Press.

Gärdenfors, P. (2000). *Conceptual Spaces. The Geometry of Thought*. MIT Press.

Gaver, W. W. (1993). What in the world do we hear? An ecological approach to auditory event perception. *Ecological Psychology*, *5*(1), 1–29.

Gibson, J. J. (1979). *The Ecological Approach To Visual Perception*. Houghton Mifflin.

Giordano, B. L., & McAdams, S. (2010). Sound Source Mechanics and Musical Timbre Perception: Evidence From Previous Studies. *Music Perception: An Interdisciplinary Journal*, *28*(2), 155–168. https://doi.org/10.1525/mp.2010.28.2.155

Glover, R., Gottschalk, J., & Harrison, B. (2018). *Being Time. Case Studies in Musical Temporality*. Bloomsbury.

Godøy, R. I. (1997). Knowledge in Music Theory by Shapes of Musical Objects and Sound-Producing Actions. In M. Leman (Ed.), *Music, Gestalt, and Computing. Studies in Cognitive and Systematic Musicology* (Springer-Verlag, pp. 89–102).

Godøy, R. I. (2010). Gestural Affordances of Musical Sound. In R. I. Godøy & M. Leman (Eds.), *Musical Gestures: Sound, Movement, and Meaning* (pp. 103–125). Routledge.

Godøy, R. I. (2021). Perceiving Sound Objects in the Musique Concrète. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.672949

Godøy, R. I., & Jørgensen, H. (Eds.). (2001). *Musical Imagery*. Taylor & Francis.

Grebosz-Haring, K., & Weichbold, M. (2020). Contemporary art music and its audiences: Age, gender, and social class profile. *Musicae Scientiae*, *24*(1), 60–77. https://doi.org/10.1177/1029864918774082

Grey, J. M. (1977). Multidimensional perceptual scaling of musical timbres. *The Journal of the Acoustical Society of America*, *61*(5), 1270–1277. http://dx.doi.org/10.1121/1.381428

Griffiths, P. (2010). *Modern Music And After* (3rd ed.). Oxford University Press.
Griffiths, T. D., & Warren, J. D. (2004). What is an auditory object? *Nature Reviews Neuroscience*, *5*(11), 887–892. https://doi.org/10.1038/nrn1538
Grisey, G. (1987). Tempus ex machina: A composer's reflections on musical time. *Contemporary Music Review*, *2*(1), 239–275.
Hampe, B. (2008). *From Perception to Meaning: Image Schemas in Cognitive Linguistics*. Walter de Gruyter.
Hjortkjær, J. (2015). Sound objects – Auditory objects – Musical objects. *Dansk Musikforskning Online*, *SPECIAL EDITION*, 47–56.
Huron, D. B. (2006). *Sweet Anticipation: Music and the Psychology of Expectation*. MIT Press.
Imberty, M. (2005). *La musique creuse le temps. De Wagner à Boulez: Musique, psychologie, psychanalyse*. L'Harmattan.
Johnson, M. (1987). *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason*. University of Chicago Press.
Johnson, M. (2008). *The Meaning of the Body: Aesthetics of Human Understanding*. University of Chicago Press.
Johnson, M., & Larson, S. (2003). "Something in the way she moves"—Metaphors of musical motion. *Metaphor and Symbol*, *18*, 63–84.
Joseph, S., Kumar, S., Husain, M., & Griffiths, T. D. (2015). Auditory working memory for objects vs. Features. *Frontiers in Neuroscience*, *9*, 13. https://doi.org/10.3389/fnins.2015.00013
Juslin, P. N., & Sloboda, J. A. (2013). Music and Emotion. In D. Deutsch (Ed.), *The Psychology of Music (Third Edition)* (3rd ed., pp. 583–645). Academic Press.
Kivy, P. (1991). *Music Alone: Philosophical Reflections on the Purely Musical Experience*. Cornell University Press.
Koelsch, S., & Siebel, W. A. (2005). Towards a neural basis of music perception. *TRENDS in Cognitive Sciences*, *9*(12), 578–584.
Kosslyn, S. M., Shephard, J. M., & Thompson, W. L. (2007). Spatial Processing during Mental Imagery: A Neurofunctional Theory. In F. Mast & L. Jäncke (Eds.), *Spatial Processing in Navigation, Imagery and Perception* (pp. 1–15). Springer US. https://doi.org/10.1007/978-0-387-71978-8_1
Kozak, M. (2020). *Enacting Musical Time. The Bodily Experience of New Music*. Oxford University Press.
Kramer, J. D. (1988). *The time of music: New meanings, new temporalities, new listening strategies*. Schirmer/ Mosel Verlag GmbH.
Krueger, J. (2014). *Affordances and the musically extended mind* (Vol. 1).
Kubovy, M., & Van Valkenburg, D. (2001). Auditory and visual objects. *Cognition*, *80*, 97–126.
Laeng, B. (2013). Representation of Spatial Relations. In K. N. Ochsner & S. Kosslyn (Eds.), *The Oxford Handbook of Cognitive Neuroscience, Volume 1: Core Topics* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199988693.013.0003
Lakoff, G., & Johnson, M. (1980). *Metaphors We Live By*. University of Chicago Press.
Lakoff, G., & Johnson, M. (2008). *Philosophy In The Flesh* (Vol. 1).
Landy, L. (2007). *Understanding the Art of Sound Organization*. MIT Press.
Larson, S. (2012). *Musical Forces. Motion, Metaphor, and Meaning in Music*. Indiana University Press.
Larson, S., & VanHandel, L. (2005). Measuring Musical Forces. *Music Perception*, *23*(2), 119–136. https://doi.org/10.1525/mp.2005.23.2.119
Leech-Wilkinson, D., & Prior, H. M. (Eds.). (2017). *Music and Shape*. Oxford University Press.
Leman, M. (2008). *Embodied Music Cognition and Mediation Technology*. MIT Press.
Lerdahl, F. (1992). Cognitive Constraints on Compositional Systems. *Contemporary Music Review*, *6*(2), 97–121.
Lerdahl, F. (2001). *Tonal Pitch Space*. Oxford University Press.
Lerdahl, F., & Jackendoff, R. (1983). *A Generative Theory of Tonal Music*. MIT Press.
Lundy, T., James, C., & Reybrouck, M. (2022). Editorial: Neuroscience and new music: Assessing behavioral and cerebral aspects of its perception, cognition, induction, and entrainment. *Frontiers in Psychology*, *13*. https://www.frontiersin.org/articles/10.3389/fpsyg.2022.979570
Marr, D. (1982). *Vision*. MIT Press.
Mencke, I., Omigie, D., Wald-Fuhrmann, M., & Brattico, E. (2019). Atonal Music: Can Uncertainty Lead to Pleasure? *Frontiers in Neuroscience*, *12*, 979. https://doi.org/10.3389/fnins.2018.00979
Menger, P.-M. (2014). *The Economics of Creativity. Art and Achievement under Uncertainty*. Harvard University Press.
Menin, D., & Schiavio, A. (2012). Rethinking Musical Affordances. *AVANT*, *III*(2), 202–215.

Moore, A. (2016). *Sonic Art: An Introduction to Electroacoustic Music Composition*. Routledge.

Noë, A. (2004). *Action in Perception*. MIT Press.

Ockelford, A., & Sergeant, D. (2012). Musical expectancy in atonal contexts: Musicians' perception of "antistructure". *Psychology of Music*, *41*(2), 139–174. https://doi.org/10.1177/0305735612442582

Oliveros, P. (2005). *Deep Listening: A Composer's Sound Practice*. Iuniverse.

Petitot, J. (2011). *Cognitive Morphodynamics. Dynamical Morphological Models of Constituency in Perception and Syntax*. Peter Lang AG.

Reybrouck, M. (2012). Musical Sense-Making and the Concept of Affordance: An Ecosemiotic and Experiential Approach. *Biosemiotics*, *5*(3), 391–409.

Reybrouck, M. (2013). Musical universals and the axiom of psychobiological equivalence. In J.-L. Leroy (Ed.), *Topicality of Musical Universals / Actualité des Universaux musicaux* (pp. 31–44). Editions des Archives Contemporaines.

Reybrouck, M. (2020). *Musical Sense-Making: Enaction, Experience, and Computation*. Taylor & Francis.

Ridley, A. (2004). *The Philosophy of Music: Theme and Variations*. Edinburgh University Press.

Rocchesso, D., & Fontana, F. (Eds.). (2003). *The Sounding Object*. GNU Free Documentation License.

Roy, S. (2003). *L'Analyse des Musiques Électroacoustiques: Modèles et Propositions*. L'Harmattan.

Santarcangelo, V., & Wanke, R. (2020). The Early Stage of Perception of Contemporary Art Music: A matter of time. *Organised Sound*, *25*(2), 130–141. https://doi.org/10.1017/S1355771820000047

Schaeffer, P. (1966). *Traité des Objets Musicaux*. Seuil.

Scruton, R. (1997). *The Aesthetics of Music*. Oxford University Press.

Schulze, K., & Koelsch, S. (2012). Working memory for speech and music. *Annals of the New York Academy of Sciences*, 1252, 229–236.

Shamma, S. (2001). On the role of space and time in auditory processing. *TRENDS in Cognitive Sciences*, *5*(8), 340–348.

Sheets-Johnstone, M. (1999). *The Primacy of Movement*. John Benjamins.

Smolensky, P. (1988). On the proper treatment of connectionism. *Behavioral and Brain Sciences*, *11*, 1–74. https://doi.org/10.1017/S0140525X00052432

Snyder, B. (2001). *Music and Memory*. MIT Press.

Solomos, M. (2019). *From Music to Sound: The Emergence of Sound in 20th- and 21st-Century Music*. Routledge, Taylor & Francis.

Solomos, M. (2023). *Exploring the Ecologies of Music and Sound: Environmental, Mental and Social Ecologies in Music, Sound Art and Artivisms*. Routledge, Taylor & Francis. https://www.routledge.com/Exploring-the-Ecologies-of-Music-and-Sound-Environmental-Mental-and-Social/Solomos/p/book/9781032184234

Spence, C. (2011). *Crossmodal correspondences: A tutorial review* (Vol. 1).

Tenney, J. (2015). *From Scratch: Writings in Music Theory* (Vol. 1).

Van de Cruys, S., & Wagemans, J. (2011). Gestalts as predictions—Some reflections and an application to art. *Gestalt Theory*, *33*(3–4), 325–344.

Van der Schyff, D., Schiavio, A., & Elliott, D. J. (2022). *Musical Bodies, Musical Minds*. MIT Press.

Varela, F. J., Thompson, E., & Rosch, E. (1991). *The Embodied Mind*. MIT Press.

Viel, M. (2019). *Listening Patterns. From Music to Perception and Cognition*.Lap Lambert Academic Publishing.

Voegelin, S. (2014). *Sonic Possible Worlds. Hearing the Continuum of Sound*. Bloomsbury.

Wagner, K., & Dobkins, K. R. (2011). Synaesthetic Associations Decrease During Infancy. *Psychological Science*, *22*(8), 1067–1072. https://doi.org/10.1177/0956797611416250

Wanke, R. (2019). A unified approach to perceiving sound in current experimental music genres. *Filigrane. Musique, Esthétique, Sciences, Société.*, *23*. https://revues.mshparisnord.fr/filigrane/index.php?id=879

Wanke, R. (2021). *Sound in the Ecstatic-Materialist Perspective on Experimental Music*. Routledge, Taylor & Francis.

Wanke, R. (2022). Listening Survey – figshare. DOI: 10.6084/m9.figshare.21590658.v3

Wanke, R., Camci, A., Noble, J. D. K., & Lembke, S.-A. (2018). Symposium: What do we hear in contemporary and experimental music? New answers to an old question. *ICMPC15/ESCO10*. International Conference on Music Perception and Cognition, Graz (AU), Montreal (CA).

Wanke, R., & Santarcangelo, V. (2021). Memory as the Aspatial Domain for the Perception of Certain Genres of Contemporary Art Music. *Music & Science*, *4*, 1–18. https://doi.org/10.1177/2059204321997658

Windsor, L. W. (2000). Through and around the acousmatic: The interpretation of electroacoustic sounds. In S. Emmerson (Ed.), *Music, Electronic Media and Culture* (pp. 7–35). Ashgate.

Windsor, L. W., & de Bézenac, C. (2012). Music and affordances. *Musicae Scientiae*, *16*(1), 102–120.
Zbikowski, L. M. (2002). *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (Vol. 1). Oxford University Press.
Zbikowski, L. M. (2008). Metaphor and music. In *The Cambridge Handbook of Metaphor and Thought* (pp. 502–524). Cambridge University Press.
Zbikowski, L. M. (2010). *Foundations of Musical Grammar* (Vol. 1). Oxford University Press.
Zbikowski, L. M. (2017). Music, Analogy and Metaphor. In *The Routledge COmpanion to Music Cognition* (pp. 501–512). Routledge.
Zuckerkandl, V. (1969). *Sound and Symbol: Music and the External World*. Princeton University Press.

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