Meaning-making and Embodied Cognition in Sound Design Research

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Abstract
This chapter examines the historically prevalent models of cognition that have shaped research methods and techniques in some of the fields associated with sound design. It discusses the efficacy of disembodied models of cognition, which, in favour of reductive explanations, overlook how embodied and perceptual experience can shape and constrain cognitive function. The chapter is particularly concerned with sonic meaning-making—the process by which a listener interprets or assigns meaning to a sonic symbol—as this process is crucial to sound design research. It chronicles developments in psychoacoustics, computing, cognitive science, and music, and suggests that sound design research should adopt embodied models of cognition. Such models have more recently come to the fore in these fields, and offer more convincing accounts of meaning-making by addressing how our physical, perceptual, and sensorimotor dimensions shape and constrain cognition.

Keywords
Embodied Cognition, Meaning-making, Sound Design, Music, Cognitive Science.

1.1 Introduction

Sound design research is a young and growing field that combines methods and approaches from a broad range of areas. Although this multidisciplinarity is a strength, it also brings some challenges. Psychoacoustics, computing, cognitive science, and music are four areas core to sound design research. Throughout their development, each of these fields has had to reckon with the problem of meaning-making, the cognitive process by which people interpret and assign meaning to perceived and mental phenomena to various degrees. We distinguish, here, between two broad approaches to meaning-making; *embodied*: those which account for how physical, perceptual, and sensorimotor dimensions shape and constrain cognition; and *disembodied*: those which offer a purely mental description of cognition and do not involve the body.

In general terms, disembodied models of cognition suggest that meaning-making is a purely mental phenomenon that involves the rule-based computation of abstract symbols on a mental layer that is isolated from the physical/biological world (Putnam 1967). This approach has been criticised by thinkers like Searle (1980), Harnad (1990) and Dreyfus (1965) for its insufficient account of how abstract mental symbols are assigned their meaning. The key argument made by these thinkers is that a disembodied mind would not be capable of meaning-making: what Harnad terms the *symbol grounding problem*. Embodied models of cognition acknowledge how the physical, neural, and perceptual apparatus of the human body, shape and constrain cognition, and hold that mental symbols are grounded in bodily experiences (Lakoff and Johnson 1980). Meaning-making is critical to sound design, and the creation of meaningful sonic symbols is a key focus for the discipline. On each project, sound designers work to ensure that the sounds they create convey the appropriate meaning and can be properly interpreted by a listener. It is in this context that we believe care must be taken, then, to adopt models of cognition which can account for meaning-making and allow us to better understand how meaning-making functions in sound design research contexts. However, disembodied models of cognition have historically been prevalent in many of the fields related to sound design and a trend towards embodied models of cognition has only arisen in more recent times. The following sections of this chapter will examine how the disembodied models came to the fore within fields which have influenced sound design, and how they were eventually challenged by embodied models of cognition. Although disembodied approaches have often been superseded in these fields, we argue that sound design research may need to address assumptions inherited from these fields whilst they were at an earlier stage of development.

1.2 Disembodied Roots.

Dualism is the metaphysical belief that reality is composed of two parts, the mental and the physical. *Mind-body dualism*, chiefly associated with Descartes' (Descartes 1641) 'Cogito ergo Sum', is the further and related belief that each human being is composed of two unique and independent parts: a material, publicly observable human body of physical dimensions, and a privately experienced mind of thoughts, emotions and perceptions. This seemingly irreconcilable distinction is often termed the *mind-body problem*. It has persisted in one form or another in Western cultures, shaping historical and contemporary thought (Uttal 2004). Responses to Cartesian dualism have often involved the adoption of *essentialist* positions on the mind-body problem, reducing reality to either purely *materialist* or purely mental, or *idealist*, descriptions and therefore eliminating the role of the human body in constituting and mediating cognition. According to Samuel Todes (2001): "[t]he human body is the material subject of this world" (88). Todes' statement describes an integrated triadic relationship where body, world and subjectivity are mutually constitutive of one another. Removing one element renders the other two elements meaningless, as there can be no body without a world, and no subjectivity without a body, etc. This integrated relationship between body, subjectivity and world is a key factor in embodied models of cognition which differentiates them from disembodied models which tend to draw a hard distinction between mind and world (Varela *et al.* 1991; Lakoff & Johnson 1999).

Although associated with Descartes, some form of mind-body dualism has permeated Western culture since at least the work of Aristotle (Heinaman 1990) and some have presented evidence for roots that go back to the Paleolithic era (Uttal 2004). Damasio (1994) has been particularly critical of Cartesian dualism and Todes (2001, 23) argues in a similar vein that mind/body dualism precludes a cohesive understanding of how mind, body and world interrelate. Similar sentiments are echoed in Varela *et al.'s* (1991), foundational work on *embodied cognition* where mind-body dualism is implicated in the distinctions between materialism and idealism, as well as rationalism and empiricism, and further linked to the computational theory of mind discussed here below.

1.3 Psychophysics

We can begin to understand how dualism has influenced research methodologies in auditory perception by considering developments in the field of *psychophysics*. *Psychophysics* and *psychoacoustics* (the study of hearing in the via psychophysical methods) do not directly deal with meaning-making or describe how a listener assigns a meaning to some sonic symbol. Instead they quantify relationships between physical stimuli and their perceptual correlates. This field of study has enriched our understanding of human perception and led to innovation in the fields of auditory display and sound localisation (Walker and Nees 2011, Middlebrooks et al., 2000).

Psychophysics was pioneered by Gustav Fechner (1860), who built upon Ernst Weber's (1846) earlier observation that the just noticeable difference in a stimulus is proportional to the initial stimulus value to propose a logarithmic relationship between the intensity of a stimulus and its perceptual result. Stevens (1957) revived and updated the Fechner-Weber laws. Through a process of *magnitude estimation*, he had experimental participants estimate the intensity of a series of stimuli assigning value measurements they felt to be appropriate in the absence of any set scale. *Psychophysical scales* that govern the relationships between stimulus and response could be inferentially drawn by comparing results across large sets of repeated experiments. Stevens' power law was developed in this way, and proposed that subjective sensation is a function of the magnitude of the physical stimulus raised to a constant power, with the exponent specific to a given magnitude (e.g., the brightness of a light, loudness of a sound). C*ross-modal matching* (Stevens 1975) was the formalisation of the relationships between these psychophysical scales as experimental participants would match the perceived intensities of stimuli in one modality (e.g. loudness) with a second modality (e.g. brightness).

Morabito and Della Rocha (2010) point out that Fechner had originally gone to great lengths to address and overcome the problem of Cartesian dualism in his methodology. He attempted to build *a common system of quantification* that addressed the interconnection between mind and body, rather than focusing on the relation of mental phenomena as distinct from physical phenomena. Stevens departed from Fechner's approach, opting instead to quantify mental and physical phenomena as distinct. From a sound designer's point of view, Stevens’ approach is concerned with making sounds that are perceptually relevant and intelligible for a listener, and this is a critical factor for sound design. At the same time, we also need to keep in mind that we cannot assign a meaning to a sound using a framework like Stevens’: we only make the sound’s meaning clearer or less clear to the degree that we account for relevant psychoacoustic constraints. The *meaning* of the sound has to come from somewhere else.

Key criticisms of early psychoacoustics research focus on shortcomings in both the philosophy and research methods of the field. Presenting experimental subjects with unrealistically simplistic and isolated stimuli in laboratory contexts led to research results that did not stand-up in real-world contexts (Neuhoff, 2004). This, in turn, led researchers to *ecological* approaches to psychoacoustics, which aimed to study sounds in their natural listening environments where they are dynamic, complex, and heard concurrently. In the ecological approach to psychoacoustics, questions of meaning-making began to move back to the fore (Walker & Kramer, 2004).

2.1 Computer Science and Cognitive Science

As discussed previously, the concept of meaning-making is central to sound design as a crucial concern of the field is effectively conveying correct or intended information to a listener. *Cognitive science*, the interdisciplinary study of thought and mental phenomena, has contributed much to our current models of meaning-making. In the late 1940s, growing dissatisfaction with *behaviourist* approaches to psychology led scientists who were interested in the human mind to seek answers from elsewhere. They turned to new and exciting developments in the field of computer science for answers.

Cognitive science grew out of developments at the first Hixon Symposium on Cerebral Mechanisms and Behaviour in 1948, where John Von Neumann, and also Warren Mc Culloch and Walter Pitts, drew striking comparisons between the computer and brain and central nervous system, while psychologist Karl Lashley challenged the prevailing behaviorist attitudes and called for a new approach to studying the mind (Gardner 1985). In fact, there were a number of key developments in the early days of computer science that suggested computing processes were similar to human cognitive processes. One early example came in 1936 with the Universal

Turing Machine (Turing 1936), a hypothetical device that could simulate the logic of any algorithm using four simple rules. Also that year, the Church-Turing thesis lent formal definition to the concept of the algorithm (Church, 1936, Turing 1936). Shannon (1938) used Boolean logic to represent states in, and solve problems with, electromechanical relay switches, and suggested this approach could model cognitive processes. Similarly, while demonstrating how networks of neurons can be modelled with logic, McCulloch and Pitts (1943) concluded that that mental activity could be thus modelled and that these logical transformations could be run on a Universal Turing Machine. In 1945 Von Neumann introduced the concept of a 'stored program' that could be recalled from memory as required (Von Neumann 1945). This made it theoretically possible for a machine to program and reprogram itself, a concept that bore a striking analogy to human-like thought (Aspray 1990). Wiener (1948) introduced the field of cybernetics, arguing that machines which exhibited feedback could be described as striving towards goals because they modified their own behaviour to achieve an objective. Finally, Turing (1950) proposed the Turing test, which stated that if a user could not distinguish the responses of a machine from those of a human, then that machine could be said to be capable of thought. Breakthroughs in computer science during this period therefore seemed to be making the subjective and private cognitive processes ignored by behaviourists (psychologists concerned with behaviour rather than thinking) publicly observable and objectively verifiable.

The first generation of cognitive science was heavily influenced by these developments and adopted a computational model of the mind. In 1961, Philosopher and Mathematician Hillary Putnam (1967) proposed the *Classical Computationalist Theory of Mind* (CCTM). He argued that the human mind was an information processor and that thought was a form of computation. Mental content, thoughts and perceptions, were rendered as symbols, and thinking was conceived of as the rule-based processing of those symbols. We see this position developed in cognitive science by Jerry Fodor (1975) and Newell and Simons (1976), and by the 1980s, the CCTM was the prevailing model of cognition (Lakoff and Johnson 1999, Chapter 6).

Alongside these developments, the role of the computer was evolving. In 1945 Vannevar Bush, who was instrumental in the Manhattan Project, wrote *As We May Think* (Bush 1945). In it, he presented a radical reimagining of the role of the computer in society, laying the groundwork for a range of innovations including personal computing, hypertext and the Internet (Zachary 1999). This would, in time, usher in a new era of computing, driven by Englbart's introduction of hypertext and the mouse (Baecker 2008), Licklider's envisioned forerunner of the Internet, the ARPANET (Lukasik 2010), and Sutherland's (1964) *Sketchpad*, a prototype of the graphical user interface with 3D modelling and a 'light pen' controller. The mainstreaming of these developments began in the 1980s, with the advent of personal computing and the wealth of new computing technologies being developed and adopted, attention was increasingly paid to the development of new modes of interaction.

The *home computing boom* saw the widespread consumer adoption of computing hardware and this led to the birth of *human-computer interaction* (HCI) a field of research focused on understanding how users interact with computers in order to develop better systems for interaction. In 1983, the publication of *The Psychology of Human-computer Interaction* (Card, Newell and Moran, 1983) helped to define the research agenda for the field. However, as Hürtienne (2009) notes, at the forefront of this movement was Allen Newell, who had played a pivotal role along with Herbert Simon in developing the CCTM, and now looked to HCI to further support and find an application for this theory. Card, Moran and Newell (1983) introduced the *Model Human Processor*, representing the user as a biological machine of integrated perceptual, motor and cognitive systems. This model was used to estimate how long a user might take to perform specific cognitive tasks by accounting for the perceptual and cognitive constraints, including measures of visual and auditory capacity alongside perceptual and conceptual 'processor cycle' times. As such, these early HCI researchers paid little attention to aspects of cognition that were not encompassed in the CCTM effectively designing the user out of the system by developing technologies that were designed solely for the users' 'rational' information processing faculties, and so limited in their usability (Bannon and Bødker 1989).

The failure of these approaches to result in more usable and useful systems eventually led to a broader *embodied turn* in HCI as researchers adopted a user-centric approach (Bannon 1995). These approaches acknowledged the role of the human body in meaning-making and placed empirical testing of real users above the theoretical projections from generalised models (Dourish 2004). By the mid-late 2000s, HCI researchers were beginning to consider how embodied cognition principles could be used to guide the design of more meaningful user interactions (Imaz & Benyon 2007; Hurtienne & Blessing 2007).

2.2 Computer Music

The early development of *computer music* was driven by the advances in computer science noted above. As a result, early experiments in computer music inherited disembodied modes of interaction. In 1957, Max Mathews, working at Bell Labs, developed the first significant music software platform, the aptly named MUSIC (Doornbusch 2017); though only capable of generating monophonic melodies (its successor MUSIC-II, could manage four-part polyphony (*ibid.*)), and programming with this software was laborious and computationally expensive work. Still, by the release of MUSIC-V, a system of dedicated subroutines called *unit-generators* made the compositional process manageable and more user-friendly (*ibid.*). Computer music was becoming a viable creative project and a core group of early enthusiasts of Mathew's work carried the MUSIC-N family of languages to more than a dozen academic research centres, eventually contributing significantly to the development of computer music as a formal research field. In spite of their influence and portability, MUSIC-N-type languages had their drawbacks too. With the use of orchestra (.orc) files to define synthesis routines and score files (.sco), to define musical patterns, they continued the tradition in Western art music of overlooking the contribution made to a musical work by the embodied human performer. Wishart (1996) reasons that as Western art music evolved the focus of composers shifted from creating and organising musical performances to creating and organising written scores. This reduced the rich multidimensional musical spectra to just three primary dimensions: pitch, duration and timbre, a small subset of the many possible dimensions of sonic experience. Worrall (2010, 2013) argues that this reductive approach to music is informed by the CCTM and that modern music technologies are built around this same disembodied framework. This is compounded by the fact that, until recent releases of Csound, MUSIC-N-type languages did not run in realtime and so could not support interactivity in live performance.

Another early development at Bell Labs, which ran counter to the initial disembodied turn of computer music, was the GROOVE—Generated Real Time Operations On Voltage-controlled Equipment—system (Mathews and Moore 1970.) GROOVE was the first interactive computercontrolled analog synthesiser to run in real-time. While relatively simplistic by modern standards it was foundational in the context of musical interaction where it opened the question of how a designer can best map physical gestures to sound in a computer music context. It represented a first step towards integrating physical gestures into computer music production, contrasting with the initially disembodied mode of MUSIC-N.

Nonetheless, the original MUSIC-N model remained influential, proliferating on the commercially accessible personal computing platforms of the 1980s via Barry Vercoe's introduction of Csound, an extended version of Mathew's MUSIC-11 (Vercoe 1986) that would work on any PC capable of running C. Other computer music languages and platforms were developed, including the visual, patching-based Max/MSP and Pure Data (Puckette 1996) and other, more purely synthesis-focused platforms, such as Native Instruments' Reaktor. The text-based, but object-oriented, SuperCollider and ChucK, would follow in 1996 and 2002 respectively. Many of these technologies have been adopted for sound synthesis and music generation tasks in a number of fields beyond their original domain, which may draw attention to their implicit conceptual underpinnings. For example, in the field of *auditory display*, tools originating from MUSIC-N have been adapted for the task of sonification (Hermann *et al.* 2011) although, as discussed above, they have been criticised, along with popular DAW–based approaches, for failing to account for embodied aspects of sound during sonification design (Worrall 2010; 2013). Nonetheless, much recent research and commentary (Paine 2009; Fyans and Gurevich 2011) within the field of computer music has been devoted to questions of embodied cognition, gesture and interactivity in live performance.

2.3 Western Music Theory

Sound design has historically been mediated by technology, with the capture, reproduction and editing of sounds encompassing a variety of technologies whose working methods have found their way into later technologies; for example, the use of tape recording as a metaphor in DAWs. Similarly, our conceptualisation of music frequently carries the conceptual baggage of previous generations of practices, from the Pythagorean monochord to the pipe organ, and from both of these to the MIDI standard's use of *twelve–tone equal temperament*: the equal division of the octave to obtain consistent intonation when transposing, obtained at the expense of adherence to integer harmonic ratios (Keislar 1987).

The formalisation of musical notes is said to have originated in the West with Pythagorean thought, birthing the integer ratio–based Pythagorean tuning system (Sethares 2005; Barbour 1953, 1). This represents an early attempt to relate the physical and the perceptual attributes of music, though it also introduced the distinction that a particular mathematically-based formalisation was the most important. The Pythagorean scale, built upon transpositions of a perfect fifth in 3/2 ratio, produced major thirds based on powers of three or less (*3-limit*) with the form 81/64; a construct which occurs in a very distant position within the harmonic series, and does not usually occur within perceptual experience of harmonic timbres: Parncutt and Hair (2018) have described Pythagorean tuning as being based on "ratios of psychologically implausible large numbers." A simpler form of the major third (which occurs within the harmonic series), the 5/4 ratio, was ruled out by Pythagoreanism because it introduced a new prime (five) as a component multiple within the scale definition. In contrast, later theorists, Didymus in the first century B.C.E. and Claudius Ptolemy in the second century C.E. discussed the use of the 5/4 major third, based on a *5-limit* (ratios expressed as powers of 5 or less) approach, aligning with those found in the earlier parts of the harmonic series (Benson 2006, 160). Thus, one of the foundations of Western music theory prioritises one of many alternative formalisms at the expense of perceptual experience: the Pythagorean preference for stopping at the early prime three was an apparently arbitrary preference for this particular formalism at the expense of simpler ratios and tuning which was closer to that of the early harmonic series (Bridges 2012, 41-3).

In his 1618 *Compendium on Music,* Descartes reaffirmed the distinction between perceptual experience and formalism, even as he attempted to make sense of musical experience using mathematical quantification. "[I]n the *Compendium* he attempted to demystify the power of music and substitute for it a geometry of sensation [...] By considering the object as an entity separate from its perception on the basis of its measurable mathematical and physical properties, Descartes automatically excluded the qualitative element from perception?" (Augst 1965, 122).

This account further suggested that *mental* and *emotional* elements of music were basically unworthy of analysis, with a conception of musical responses as based on simple reflexes (*ibid.* 130-32). Though not as influential as his other work, his musical ideas have nonetheless been influential, finding parallels in the work of theorists including Mersenne and Rameau (Jorgensen 2012). More broadly influential has been Kant's *transcendental idealism*, which holds that we experience the appearances of things rather than the things in themselves and so concepts like space, time and causality are mental constructs we use to organise our experience of these representations. This has been criticised for disregarding the relationship between the physical body and world by reducing bodily experience to a purely imaginary process (Todes 2001, 95). It retains, maybe even intensifies, the Cartesian mind/body distinction with a model of the human isolated from the real objective world.

Schopenhauer (1883) built upon Kant's ideas by pointing out that the human body is the only object a subject can be aware of both externally through subjective perceptions (*representation*), and internally, through the experience of embodiment (*will*). Because purely instrumental music was apparently not mediated by imitations of the phenomenal world, in the way that painting and sculpture are, he thought of it as a direct expression of *will*, one that could allow the listener to overcome the everyday suffering that typified existence (Schopenhauer 1883). In a way, Schopenhauer reaffirmed the importance of bodily experiences in his philosophy of music but the old Cartesian model still prevailed with private bodily experience (will) locked away *inside* a world of mental phenomena (representation), and music offered as a temporary reprieve from this unbearable situation.

Schopenhauer's thought had a profound effect on Wagner (Darcy 1994), and, later, Schoenberg (1941). Schopenhauer's view of music as an expression of objective reality was shared by Wagner (Wagner 1879) who counted his first reading of *The World as Will and Representation* as the most important event of his life and the inspiration for *Tristan and Isolde* (Wagner 1992). In fact Wagner's 'Tristan Chord', a chord based on the augmented fourth, sixth and ninth, in an influential view, is seen as challenging the established modes of functional (i.e. syntactical) tonal harmony (Kurth 1920), although there is now debate on the degree of its novelty (Taruskin 2008). Wagner's readiness to employ chromatic constructs may disrupt the idealism of functional harmony, 'grounding' it within the confines of motifs (*leitmotiv*) which serve thematic concerns. However, his 1849 essay *The Artwork of The Future*, he described his compositional philosophy in terms that closely foreshadowed Schoenberg's future work (Stein 1960); in fact, Schoenberg asserts (1941) that there was a formal logic shared between both Wagner's approach and his own, drawing parallels between the *leitmotiv* and the basic 12-tone set (series) as reifying an integrating compositional structure (even if later commentators, notably Taruskin (2008), have expressed some scepticism around this particular parallel).

Even as both composers attempted to forge their own novel musical languages, Wagner and Schoenberg can be seen (at least rhetorically) as striving for an assumed universal and logically-structured aesthetic. Wagner's tendency towards *universalism* eschews Western music's previous prioritisation of abstract or 'absolute' music's focus on functional harmony, replacing it with a new, totalising form of the *Gesamtkunstwerk* (complete artwork) incorporating music, drama and associated forms, whilst maintaining some claims to Western music's formalistic ambitions through permutational and narrative-driven modifications of various *leitmotif*. Perhaps more significantly, Schoenberg's universalism saw him famously claim that his new *serialist* approach would replace the common practice of Western tonality to the extent that, in this teleological progression of musical technique and aesthetics, he would guarantee that "the supremacy of German music is ensured for the next hundred years" (Schoenberg, quoted in Taruskin 2008, 316). We argue that this musical universalism, later criticised by Meyer (1956), was a symptom of Cartesian dualism inherited from Schopenhauer (and, indeed, via the broader intellectual heritage of Western music), whereby there is an assumed fundamental, objective structure inherent within a musical language which is then asserted through particular works and musical experiences. Furthermore, these universal structures, such as Schoenberg's series, can be seen as acting as the sole relevant source of structure, to the exclusion of personal embodied experience.

Webern and Boulez, of the Darmstadt School, inherited and extended Schoenberg's approach in pursuit of a 'democratic' serial music (Grant 2005) that while providing a counterbalance to traditional hierarchical structures in Western music, still poses problems for the perception and cognition of musical structures (McAdams 1989; Lerdahl 1992). Lerdahl (*ibid.*) initially focuses on the more complex case of *integral serialism* (the application of serial approaches to structures other than pitch) of Boulez's (1954) postwar *Le Marteau sans Maître*, whilst McAdams addresses serialism in its classical, pitch-based mode, but both conclude that serialism provides additional challenges to a listener when parsing music. In their assessment, it is almost as if what Lerdahl (1992 115) terms the 'cognitive opacity' of serialism renders significant aspects of the musical structure into a less accessible formalist domain (even if he concedes this is not necessarily a criticism of it as a compositional tool). Serialism is therefore, in the final analysis, considered by Lerdahl to be a useful tool for structuring creative work, but is not considered a satisfactory explanation for the perception and cognition of this structure; the meaning, again, must be derived from elsewhere. Although these musical developments were not uncontested (and the twentieth century provides many counter-examples, including experimentalism, stochastic approaches to composition, open form, and minimalism), serialism was particularly influential in many educational institutions for music composition (Gann 1998), setting a dualistic tone and framing for many of the musical developments preceding the latter part of the twentieth century.

2.4 *Elektronische Musik* and *Musique Concrète*

By the late 1950s two very distinct schools of electronic music had established themselves; the French *musique concrète* school and the German *Elektronische Musik*. Where *musique concrète* adopted an almost idealistic viewpoint inherited from Husserl (Kane 2007), *Elektronische Music* was motivated by a materialist understanding of the world borrowed from the field of acoustics (Eimert 1957; Dunn 1992). The early work of *musique concrète* pioneer Pierre Schaeffer set a positivist tone that would define the work of both schools and exerts a powerful influence on research in electronic music and sound production to this day (Dunn 1992). It is worth noting that Godøy (2006) later points out that Schaeffer's original framework of typological and morphological categories for sounds are embodied to the degree that they are all built around sound–producing physical gestures. However, in Schaeffer's own lifetime, at least some of his methods and approaches were considered to be positivistic, and even reductive of the role of the body in music.

Inspired by the positivistic methods pioneered in Webern's approach to serialism **(**Gloag 2012, 40), the Elektronische Musik movement grew out of the electronic music studio of Cologne's Nordwestdeutscher Rundfunk (NWDR) which opened its doors in 1953. Originally helmed by Herbert Eimert, it distinguished itself from Schaeffer's *musique concrète* early on with its focus on "synthesis from first principles", with Eimert declaring that electronic music should be synthesised from the bottom-up using electronically generated signals only (Eimert 1957). The culture that grew up around *Elektronische Musik* was defined by positivist approaches that concealed the role of the human body in determining aspects of the mind. Eimert and Meyer-Eppler elevated the rational in their approach to music, idolising the mathematical, statistical and formal to the point of eliminating the human subject from music altogether (Pace 2009). Eimert (1957) advocated for the parameters of pitch, amplitude and duration as objectively inherent to the note itself and dismissed the "living flesh and blood" of the musical note which unfettered would eventually lead to "the abrupt images and naked sensations of Expressionism". He compounded this positivistic attitude by reducing the role of the human body in both performance and composition to that of a machine which was better replaced by tape technology. Eimert believed this new music was purely objective and maintained that the sine tone was the fundamental unit of music perception, seeing it as the logical continuation of Webern's tripartite serialism through electronic means, and Meyer-Eppler, a physicist who advocated stochastic approaches to composition rooted in computer science and information theory, had similar views (Meyer-Eppler 1949). It would be some time before we see this position softened somewhat in Karlheinz Stockhausen's (1956) *Gesange der Jungliche* , which combined the methods of *Elektronische Musik* with the *musique concrète* techniques Stockhausen picked up during his time with Pierre Schaeffer.

By the early 1940's Pierre Schaefer's *musique concrète* introduced new compositional approaches specific to the medium of recorded sound. They were heavily influenced by Husserl's *phenomenology*, which broke with the Cartesian tradition to cast the body as the lived centre of an experience defined by our capacities for physical movement and sensory perception. His *epoché* or phenomenological bracketing recommended suspending judgement about objects of perception to better understand the objects themselves. Schaeffer (1966), in his *Traité des objets musicaux*, adapted this idea in his 'reduced listening' which encouraged "listening to the sound for its own sake as a sound object by removing its real or supposed source and the meaning it may convey" (Landy 2007). Such sounds, theoretically decoupled from their sources, Schaefer termed *object sonore* (sound objects). Schaefer intended *objet sonore* to be pure sonic substances, free of reference to any meaning beyond their own perceptual appearance, that could be easily manipulated and assembled in musical structures should they prove to be suitable *objet musicaux* (Teruggi 2007, Worrall 2013). It was with these *objet musicaux* that one could compose a new kind of music fit for the newly emerging medium of recorded sound.

For Husserl, the body is an intermediary phenomenon that bridges the Cartesian gap, providing the locus of reality for the disembodied transcendental ego that owns it (Carman 1999); however, although he gives the body a greater role in his philosophy than his predecessors, he is still bound by the old Cartesian framework. This shortcoming would later be criticised by Heidegger (1982) and Merleau-Ponty (Carman 1999). Through the *objet sonore* and his reduced listening, Schaeffer transferred Husserl's Cartesian dualism into the philosophy of electronic music, in many senses reducing the role of the body in composition, listening and performance (Kane 2007). He does this by focusing on the *objet sonore*, an isolated phenomenal object, stripped of its bodily mediated meaningful context and conceptualised instead as a substance of pure sonic potential. Schaeffer would go on to expand his Musique Concréte program with Pierre Henry through the *Groupe de Recherche de Musique Concrète* (GRMC) at the French Radio Institution. According to researcher Hugues Vinet and composer François Bayle the foundational techniques that Schaeffer developed for working with sound have become standards that define audio recording/manipulation technologies and techniques employed in studios around the world to this day (Teruggi 2007). The sound editing models associated with these technologies are here seen as essentially atomistic, decontextualised, and non-ecological. R. Murray Schafer (1993) would later cast these developments in a negative light describing recorded sound decoupled from its original source as 'schizophonic', favouring a phenomenologically-driven and ecologically grounded approach to, and understanding of, sound, that was at odds with the initial conception of *musique concrète*. Later commentators would point out that positivistic attitudes adopted during this period laid the groundwork for the removal of the human body from live performance of electronic and computer music (Fyans & Gurevich 2011, Paine 2009, Worrall 2013).

3. Conclusion

As established early on, disembodied frameworks of cognition do not explain how listeners interpret or assign meaning to a given sound. Without an understanding of this meaning-making process, the efficacy of sound design research may be limited. Each of the fields explored here experienced a transformation as their methods and theories matured and shifted to account for broader embodied and ecological contexts. In computer science, the second wave of HCI shifted its focus "from human factors to human actors" (Bannon 1995), while roboticists and AI researchers were similarly embracing embodied cognition principles in their work (Steels & Brooks 1995). The second generation of cognitive science focused on embodied cognition and how embodiment shapes cognitive functions like meaning-making (Lakoff & Johnson 1999). Ecological psychoacoustics (Neuhoff 2004) left the lab to examine hearing in real-world environments. Musicologists extended their frameworks to account for embodied models of meaning-making in *musique concrète* (Godøy 2006), *Elektronische Musik* (Chagas 2008), and computer music (Fyans & Gurevich 2011, Paine 2009, Worrall 2013). It is in the interest of sound design research to learn from the advances made in these fields by applying the theories and techniques that have been developed to address meaning-making through embodied cognition.

The meanings which we are concerned with in sound design are created at the intersection between multiple modes of perception and interaction. Embodied frameworks can explain meaning-making in multiple domains of vision and interaction as well as sound, making them uniquely useful to sound design as the practice is often paired with some visual (e.g. film) or interactive (e.g. video games or AR/VR) element. Understanding how these different modes can be related is another, more pragmatic, imperative behind the adoption of frameworks from embodied cognition. At a more fundamental level, this placing of embodied 'presence', part of Todes' triad, at the centre of sound design relationships also calls on us to consider again where potentially embodied correlates may lie within structures which we may previously have regarded as formal. Placing the body, whether as a conceptual framework, or as a physical entity with agency, at the centre of the act of designing sound, should help us to map the terrain of meaningful sound design much more quickly and efficiently.

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