Audio Engineering Society

Convention Paper 10299

Presented at the 147th Convention
2019 October 16–19, New York, USA

Mental Representations in Critical Listening Education: A Preliminary Survey.

Stephane Elmosnino[1]

[1] *University of Technology Sydney, 15 Broadway, Ultimo, NSW2007, Australia*

Correspondence should be addressed to Stephane Elmosnino (contact@se.audio)

ABSTRACT

This paper reports on a survey of critical listening training offered at tertiary education providers in the USA, UK, Australia, and Canada. The purpose of the investigation is to explore the concept of mental representations in educational contexts, as instructional materials do not always consider this aspect despite a rich research terrain in the field. The analysis shows a wide diversity of instructional methods used, seemingly influenced by course subject matter and institution business model. It also reveals a need to accurately define the concept of critical listening, depending on the context of its use. This study provides the background to a proposed evaluation of the effectiveness of mental representation models applied to new instructional designs.

1 Introduction

Audio engineering education programs have seen tremendous growth since the 1940s when some of the earliest tonmeister courses began. These offerings have now become commonplace in tertiary education provision, yet their curriculum varies significantly in terms of content. The elements of study to be included in such programs have been discussed several times over the years [e.g. 1-2], and critical listening is a topic that consistently appears. This consistent inclusion is no accident: Critical listening is an essential skill that relates to numerous aspects of an audio engineer's routine. Some courses view critical listening, which is sometimes merely seen as a vehicle for critical thinking, as their focal point. For example, the "Timbre Solfege" course established in 1974 at the Fryderyk Chopin University of Music in Warsaw has grown from being a one-off semester offering to a two-year endeavour for students in the field. A revised version of this course has even been delivered to professional workers in the automotive industry, indicating that critical listening skills are necessary beyond the creative industries [3].

Macedo states that the development of critical listening skills is an essential part of music technology education [4], although this statement holds for any other field requiring a critical assessment of sounds [5]. Nevertheless, the question remains: how and to what extent should critical listening be included in education programs? This question can be a subject of contention, particularly when different faculties deliver the subject within the same institution. Garfrerick states that curricula in music technology education should be moving targets due to rapid changes in technology [6]. However, critical listening is unchanging; therefore, a case could be argued for a "one-size-fits-all" approach to this topic. But how do educators know that their methods are appropriate? Scholars have written about the lack of pedagogical research within the tertiary education sector [e.g. 7], as insights in this field are generally provided by studies promoting the use of technical ear training (TET) programs [e.g. 8] or descriptions of the ways in which specific institutions deliver study modules [e.g. 5].

The information presented in these reports can be useful in giving a sense of educational best practices in the field. For example, Tappan describes the use of communication, organisation, leadership, and analysis/evaluation as the basis for teaching audio production [9]. Although the processes of communication and analysis/evaluation are only vaguely documented, Tappan hints at critical listening development for his students through the use of production analyses. A more fleshed-out framework for music analysis is put forward by Jones [10]. As timbre variations can play a significant role in the commercial success of contemporary songs, Jones's motivation for teaching critical listening resides in composition skills development for her students. Jones uses a primarily visual method for analysing songs, supplemented with the use of verbal descriptors of sounds.

While some research describes the use of more traditional methods of critical listening education [e.g. 11-12], these studies are among the few documented uses of established frameworks. Broader studies on pedagogical approaches and instructional design related to audio engineering are also present in the literature [e.g. 13-14], but these are infrequent. Overall, there is very little information available to guide curriculum developers when designing a course that features critical listening as a learning outcome.

Informed by Zagorski-Thomas' view on the use of theoretical research to inform pedagogy in the field of record production [15], this paper looks at how the concept of mental representations intersect with established methods of critical listening in the literature. From there, it aims to uncover how these ideas manifest in the current critical listening training of tertiary education programs.

2 Background

2.1 Mental Representations

Bregman argues that the "job" of perception is to derive representations of reality through sensory input [16]. This view is echoed by Kim when he proposes that perceiving and imagining both form part of the act of listening [17]. Since critical listening is primarily rooted in perception, it seems natural to include the study of mental representations alongside research in this field. However, it is necessary to first define mental representations in order to study their usefulness in critical listening training.

Johnson [18] and Lakoff [19] have proposed the concept of image schema in their seminal work in cognitive linguistics. They argue that image schemas are experiential gestalts directly related to sensory-motor experience. They are said to retain the original structure of the perceptual experience and operate across time, a view that continues to be supported by scholars. For example, Hubbard and Schaefer both suggest that auditory imagery preserves many structural and temporal properties of auditory stimuli [20-21]. McAdams and Bigand offer a similar glossary definition of the term "mental representation" as hypothetically representing some features of, or interactions between, a person and their environment [22]. However, they also differentiate this concept from that of "mental schema", considering it to be the process by which these representations occur. The difference between these two notions is significant, as critical listening within the field of audio engineering may refer to both the active control mechanism of listening as well as the resulting mental representation of sounds. Despite the links with ecological theories of perception, the concept of mental representations has been critiqued by followers of Gibson's ecological perspective [23]. Clarke, for example, raises the point that mental representations are purely conjectural and that since they only have a purpose when perceived, there may be an infinite number of layers of mental representations inside one's mind [24]. In other words, they suffer from the homunculus argument. Despite this, mental representations continue to lie behind many theories of critical listening.

Following McAdams and Bigand's definition of a mental schema as being the means by which mental representations occur, scholars have proposed different models by which sounds are processed. Viewed through the lens of musical aesthetics, Hargreaves proposes the "reciprocal-feedback model of music processing" [25]. His model consists of a three-way interaction between music, context, and listener; mental representations are at the centre of the

model, interacting with all three "stakeholders" and acting as the link between perception and the production of sounds. This model contains many similarities with Bayle's concept of musical perception, as proposed in "Image-of-sound, or i-sound: Metaphor/metaform" [26]. His trichotomy of the audible splits the process of perception between hearing and presentification; listening and identification; and comprehending and interpretation. Although Bayles subsequently further develops his concept into the realm of semiotics, the basic principles of the first two processes align well with what Hargreaves labels as the internal "response" to sounds (perception/imagination/production).

This sort of definition of sonic mental representations as being at the intersection between perception and production of sounds is presented under various labels throughout the literature. For example, Smalley puts forward the concept of "source-bonding" as being the natural tendency to relate sounds (intrinsic features) to their supposed sources and causes (extrinsic cause) [27]. Furthermore, through the concept of "gestural surrogacy", he suggests that this bonding can have varying degrees of metaphorical distance between sounds and their imagined cause. Smalley also extends these concepts to sounds in space under the "space-form" label: source-bonding dictates that the mental representation of a sound invariably include the representation of its space [28]. Finally, he makes an interesting point regarding the fact that source-bonding can be an entirely subjective construct since individuals imagine the source and cause of sounds according to their understanding of the world.

Building on this idea, Godøy suggests the term "motor-mimesis" as an explanation of how mental models stem from gesture [29]. This thought is the building block leading to his theory of "gestural-sonorous objects" [30]. This theory proposes sound-related gestures (more specifically sound-producing gestures in the case of timbre perception) as the basis for mental representations. He proposes that humans recode perceived sounds into gestural-sonorous images based on bodily constraints. This view is reinforced by Jensenius when he argues that action-sound couplings guide perception even for electronically created sounds [31].

Similarly, Wallmark, Iacoboni, Deblieck, and Kendall give a more refined model of mental representations of timbre following an extensive study combining behavioural, acoustical, and fMRI data [32]. Using an ecological, embodied interpretation of timbre, they conclude that their results could indicate a neurophysiological tendency to link timbral qualities with their associated actions. This finding is in line with Godøy's model of "gestural-sonorous objects" and Smalley's concept of "source-bonding". Furthermore, and due to the heavy emphasis on the metaphoric nature of timbre vocabulary, they conclude that their model supports Johnson and Lakoff's work in cognitive linguistics, leading to the concepts of image schemas.

Applying this definition of mental representations to timbre and audio engineering tools, Corey proposes "isomorphic mapping" as the process of linking timbre perception with the tools used to modify audio signals [33]. Through the use of technical content, practical exercises, and training software, he suggests that audio engineers should develop mental representations of sounds. This view relies on the memory of audio engineering tools and processes as the basis of language by which to describe sounds. Moylan advances a similar principle when suggesting that engineers should train their musical memory in order to improve the link between what is being perceived and their previous knowledge of sounds [34].

2.2 Critical Listening

Departing from discussions around the nature of mental representations, and delving into the deliberate act of critical listening, the current research offers diverse views on the mechanics of this skill. Drawing similarities from McAdams and Bigand's definition of mental schema [22], critical listening can initially be viewed as the process by which sounds are perceived, with one of the most widely used concepts being Bregman's "auditory scene analysis" [16]. Using gestalt psychology notions applied to the perception of sound, he argues that acoustic events can be grouped based on the

ecological validity of their affiliation through a process of parsing. The groupings can either be sequential or spectral and lead to auditory streams which can subsequently be analysed. This concept has been adapted to give rise to the many methods of computational auditory scene analysis [e.g. 35], and further developed into teaching frameworks such as Tsabary's notions of aural atoms and synergetic structures [36]. In short, Tsabary trains his students to break sounds down into the smallest possible parts (aural atoms), before reassembling those parts to recognise specific patterns (synergetic structures). The resulting sonic entity is usually called the "sound object", a term coined by Schaeffer [37]. While the sound object was initially referring to the sound itself, outside of the context of its cause or environment, different scholars have further broken down this sonic entity. For example, Moylan differentiates sounds for analysis as "sound events" and "sound objects", the former being perceived in time (the perception of sounds as they happen), and the latter out of time (the general idea or perceived quality of sounds) [34].

In order to reveal the sound object, audio engineers need to focus their attention and therefore alter their normal listening process. To that end, numerous ideas have been put forward over the years. Loosely based on the idea of phenomenological reduction, Schaeffer offers "reduced listening" as a way to reveal the sound object [37]. He then further proposes "four listening modes" as different perspectives by which to think about sounds, each belonging to the one part of the abstract/concrete and objective/subjective categories. As a concrete/objective mode, "listening" serves to identify the source or cause of a sound, effectively treating the sound as a sign of its source. This mode relates very well to the concept of mental representations presented earlier in this paper. The next mode, "perceiving", is said to be concrete/subjective and only serves as the passive hearing of sounds. "Hearing" is a closely related mode, as it allows for the selection of the perceived sonic elements of interest. This abstract/objective mode has procedural links to Bregman's auditory scene analysis. Finally, "comprehending" is an abstract/objective mode used to understand the meaning of a sound.

Schaeffer's seminal work has been revisited and further developed over the years. For example, Chion offers "three listening modes" [38]. The first, "causal listening" gathers information about the source and cause of sounds. Next, "semantic listening" helps decode the underlying message of sounds. Finally, "reduced listening" holds a similar meaning as Schaeffer's notion: it is listening to the sound quality without reference to its cause or meaning. Offering a binary view involving both music and audio engineering, Macedo suggests "six listening modes" [4]. The first four belong to the category of music listening. "Open listening" allows for any part immediately available to consciousness to be scrutinised (perceptual or semantic for example). "Syntactical listening" is concerned with musical elements such as melody and harmony. "Semantic listening" looks for signs that give significance to the piece (such as recognisable sounds that carry a specific meaning). Finally, "ontological listening" tries to understand the writer's worldview. The last two listening modes, "reduced listening" and "technical ear training" are relevant to audio engineers. While reduced listening carries the same definition as that presented by Schaeffer, Macedo makes the distinction of technical ear training as being specific to audio engineers, and interested in the elements of sound that could be modified through signal processing such as distortion and frequency content (similarly to Corey's "isomorphic mapping").

Within the realm of communication, critical listening also needs to be explored from the perspective of sound analysis. There are currently two broad means of communicating sound quality: through language or visuals. Schaeffer proposes a typo-morphological framework by which to classify and describe sounds [37]. Typology first classifies the sound using an appropriate language, and morphology is then used to describe it using both language and visuals. With a similar aim to devise a framework for sound analysis, Smalley advances the concept of spectromorphology: a system by which to describe the frequency content of sounds as they evolve [27]. This framework is solely based on language to describe sounds and is intended as an aid for the analysis of electroacoustic music. To the extent that it aims to provide a language for the sound of spaces, Smalley's concept of space-

form discussed earlier in this paper is also relevant to the topic of sound analysis [28]. More recently, Pedersen & Zacharov have conducted a series of studies in order to develop a common lexicon for the description of sounds [e.g. 39].

Predominantly based on the use of visuals as a mode of communication, scholars have devised different methods to represent sound quality. Intending to add a new methodology to the area of critical listening and acousmatic music notation, Cogan formulates a way to analyse music through the use of spectrograms and a sort of sound typology based on morphological oppositions in his "theory of oppositions" [40]. Pooling together a wide range of established concepts and viewed through a semiology of music, Roy then introduces the "grille fonctionelle" as a visual way to conceptualise and describe musical units when analysing electroacoustic music [41]. Moylan, thereafter, suggests the visual mapping of events, often focusing on macro-dynamics of songs as the primary basis of his framework [34].

In order to develop critical listening skills, there are numerous educational resources available for both students and professionals. For example, on the topic of raising awareness of environmental sounds, Oliveros' "Deep Listening: A Composer's Sound Practice" [42] and Schafer's "Ear Cleaning" [43] both offer exercises to train students in the practice of critical listening. Similarly aimed at critical listening practice but with a clear audio engineering focus, Everest's "Critical Listening Skills for Audio Professionals" [44] and Moulton's "Golden Ears" [45] are both books that provide audio exercises to develop students' skills. Software suites such as Szigetvári and Horváth's "Timbre Solfege" [46] also allow for the direct practice of critical listening. Finally, there are some textbooks that, through the use of a vast amount of audio examples, provide foundations for the development of critical listening skills [e.g. 47-48].

3 Findings

3.1 Method

This study presents a survey of 50 study modules that relate to critical listening as elucidated in their descriptions or learning outcomes. All of the modules are delivered in English with the exception of two from a French-speaking institution. The method used to select the relevant modules for analysis was primarily stratified sampling with some aspects of snowball sampling. Initially, 90 institutions were identified as delivering audio-related programs, of which 50 contained study modules that listed critical listening as a learning outcome. The data collection process involved a web search, direct requests, and referred requests and resulted in two different types of materials being collected: general information available to the public (with varying depth of content available) and more specific data obtained through email conversations, module guides, and lesson plans. From the initial pool of 50 relevant institutions, the information gathered and presented in this paper stems from 24 different providers from Australia (10), Canada (2), the United Kingdom (7), and the United States (5). Both private education providers (6) and public universities (18) are represented within the sample.

3.2 Results

Of the 50 modules examined, 27 have critical listening at the core of the weekly lessons. Critical listening is a secondary focus to the principal subject matter (such as audio engineering tools, composition techniques, or media studies) for the remaining 23 modules. Furthermore, within the group emphasising critical listening, 13 modules seem to use some of the established theories of mental representations presented in this paper (as depicted by their module descriptions, lessons content, and use of seminal books). For each of the three categories of content focus (labelled "theory" for theory-driven critical listening focus, "non-theory" for non-theory-driven critical listening focus, and "other" for modules not featuring critical listening as a focus), Tables 1–8 give a breakdown by country distribution, business type, faculty affiliation, degree type, subject matter distribution, assessment type, key text type, and key text mentions. Where decimal numbers appear in the tables, the same module may be delivered jointly by different faculties, used for the awarding of different degrees, and may cover different subject matters. In these cases, the module has only been counted once but distributed evenly within each category

representing it. While technical textbooks largely dominate recommended readings lists, Table 7 lists the number of key text type listed in each module to give a more accurate representation of each module type's resources focus.

	Theory	Non-theory	Other	Total
Australia	7	3	17	*27*
United Kingdom	0	9	4	*13*
United States	2	2	2	*6*
Canada	4	0	0	*4*

Table 1. Country distribution.

	Theory	Non-theory	Other	Total
Public	10	8	13	*31*
Private	3	6	10	*19*

Table 2. Business type.

	Theory	Non-theory	Other	Total
Arts	5	5.5	8	*18.5*
Music	6	4	6	*16*
Audio	2	3	9	*14*
Engineering	0	1.5	0	*1.5*

Table 3. Faculty affiliation.

	Theory	Non-theory	Other	Total
BA/Other	6	6	14	*26*
BMus	4	2.5	6.5	*13*
BSc	1	3.5	2.5	*7*
MA	2	2	0	*4*

Table 4. Degree type.

	Theory	Non-theory	Other	Total
Audio Engineering	6	10	16.6	*32.6*
Music Composition	6	4	4.6	*14.6*
Psychoacoustics	1	0	0.6	*1.6*
Media Studies	0	0	1	*1*

Table 5. Subject matter distribution.

	Theory	Non-theory	Other	Total
Process Reflection	6	5	9	*20*
Prac. Audio Project	3	2	20	*25*
Prac. Music Project	14	3	6	*23*
Recording Analysis	6	13	5	*24*
Written Exam	6	7	14	*27*
TET Exam	3	7	5	*15*

Table 6. Assessment type.

	Theory	Non-theory	Other	Total
Technical	6	8	12	*26*
Theoretical	8	2	3	*13*
Listening Exercises	2	2	2	*6*
Media Studies	1	4	1	*6*

Table 7. Key text type.

	Theory	Non-theory	Other	Total
Jason Corey [33]	4	2	2	*8*
William Moylan [34]	3	2	2	*7*
Michel Chion [38]	3	1	1	*5*
Denis Smalley [49]	2	0	0	*2*
Eldad Tsabary [36]	2	0	0	*2*
Albert Bregman [16]	1	0	0	*1*
Pierre Schaeffer [37]	1	0	0	*1*
Stéphane Roy [41]	1	0	0	*1*

Table 8. Key text mentions.

Overall, the concepts associated with mental representations are mentioned sparsely. Corey's "isomorphic mapping" is mentioned four times, while Smalley's concept of "space-form" is mentioned once through the topics of sound localisation and acoustic space listening. Some instructors do, however, provide activities which implicitly explore the notion of mental representation. For example, one given activity is the deconstruction of sounds through the recording of a door opening and closing, and subsequent event marking of the audio file.

The mechanics of listening is also a topic infrequently mentioned. Bregman's "auditory scene analysis" is mentioned three times, Chion's "three listening modes" appear three times, Schaeffer's "reduced listening" appears once, and there is one mention of "deep listening" as a class topic.

Two modules mention the requirements for their students to research and build conceptual frameworks for song analysis, while others mandate the use of established frameworks. For example, Moylan's "sound event/object" graphing appears twice, Roy's "grille fonctionelle" appears once, and there is one unreferenced mention of visualising sounds using spectrograms.

3.3 Analysis

From the data presented, two approximately equally-represented approaches to teaching critical listening have emerged. One approach teaches the "tools of the trade", such as recording techniques, mixing, and synthesis; and subsequently applies them to specific topics such as music projects, visual media composition, or mastering. The other approach sees critical listening as the focal point of the module and uses it as a lens through which professional practice is studied. While both methods presumably aim to develop students' critical listening skills, the latter approach includes implicit or explicit references to mental representations in half of the reviewed cases. This ratio suggests that curriculum designers may view this concept as a significant aspect of critical listening skills development.

Proportionally, public universities seem to deliver more theory-focused critical listening modules than private education providers. The sample suggests that public universities deliver 77% of all theory-focused modules compared to 57% of all other modules. While this difference can still be considered inconclusive due to the limited survey sample size, it could point to a difference in curriculum design focus. For example, some private education providers may be more concerned with the technical and practical application of skills required by an employability-driven curriculum design.

As depicted by a consistent proportional increase in faculty affiliation (+19%), degree type (+7%), subject matter (+23%), and most frequently used assessment type (+28%), the focus on established theories and mental representations in critical listening instruction appears to be more significant for the domain of music. This detail is further emphasised by a corresponding decrease for the non-music-related options in each category, with the exception of a marginal increase in the arts faculty (+2%) and the use of reflection as assessment (+1%), and a more pronounced increase in postgraduate degree (+10%) and psychoacoustics subject matter (+6%). Considering the higher category of Bloom's revised taxonomy as the ability to generate new and original products [50], this observation could indicate a link between the significance of mental representations within music instruction and higher-order thinking. The postgraduate degree increase also supports this idea further.

Corey's "Audio production and critical listening" [33] and Moylan's "Understanding and crafting the mix" [34] are the most-often prescribed textbooks related to the topic of critical listening and mental representations within the sampled modules. Their frequent inclusion could stem from the fact that, although they both touch upon the subject of mental representations, they are also technical enough to be used as textbooks for practice-oriented modules.

As suggested, between the varied instruction focus, assessment types, and use of resources, the term "critical listening" may be used differently by different education providers. Similar to how Boehm

indicates that the various uses of the term "music technology" in education can bring confusion to the topic [51], critical listening may need to be accurately defined within each educational context.

4 Conclusion

While this preliminary survey was limited in scope, common themes have emerged. With regards to the core instruction focus, and seemingly further emphasised by subject matter and business type, the different approaches to teaching critical listening confirm that the use of mental representations is not universally adopted. Furthermore, some texts related to the topic of mental representations appear more consistently than others. Finally, there is a need to accurately define the concept of critical listening, depending on the context of its use.

These preliminary findings offer an avenue for the development and use of critical listening instructional designs featuring mental representations. However, further work is needed to evaluate theories of mental representations for their effectiveness in critical listening training.

Acknowledgment

This research is supported by an Australian Government Research Training Program Scholarship.

References

[1] Sanders, D. H. (1993). *The professional preparation of the audio engineer: A survey of studio personnel and recommendations for school curricula design*. New York University.

[2] Bielmeier, D. (2018). Future educational goals for audio recording and production (ARP) programs: A decade of supporting research. In *AES 145th Convention*. New York: Journal of the Audio Engineering Society.

[3] Miśkiewicz, A., & Letowski, T. (2014). Timbre Solfege training in automotive industry. In *Forum Acousticum*. Krakow.

[4] Macedo, F. (2013). Teaching creative music technology in higher education: A phenomenological approach. *Journal of Music, Technology and Education*, *6*(2), 207–219.

[5] Miśkiewicz, A. (1992). Timbre Solfege: A course in technical listening for sound engineers. *Journal of the Audio Engineering Society, 40*(7/8), 621–625.

[6] Garfrerick, R. (2006). Music and entertainment industry curricula: A case for autonomy? *Journal of the Music and Entertainment Industry Educators Association*, *6*(1), 93–106.

[7] Walzer, D. A. (2015). Critical listening assessment in undergraduate music technology programmes. *Journal of Music, Technology and Education*, *8*(1), 41–53.

[8] Indelicato, M. J., Hochgraf, C., & Kim, S. (2014). How critical listening exercises complement technical courses to effectively provide audio education for engineering technology students. In *AES 137th Convention*. Los Angeles: Journal of the Audio Engineering Society.

[9] Tappan, T. (2011). A model for teaching master-level audio production: "COLA." *Journal of the Music and Entertainment Industry Educators Association*, *11*(1), 213–222.

[10] Jones, M. (2017). Practical production analysis: Helping students produce competitive songs. *Journal of the Music and Entertainment Industry Educators Association*, *17*(1), 59–78.

[11] Tsabary, E. (2009). Which aural skills are necessary for composing, performing and understanding electroacoustic music, and to what extent are they teachable by traditional aural training? *Organised Sound*, *14*(3), 299–309.

[12] Valiquet, P. (2017). Animating the object: Marcelle Deschênes and acousmatic education in Quebec. *Organised Sound*, *22*(3), 385–393.

[13] Elmosnino, S. (2018). *Instructional design considerations for the development of critical listening skills in audio engineers*. Queensland University of Technology.

[14] Reba, C. H. (2010). Sound quality education: Pedagogical issues, concepts and practices. In *AES 38th International Conference: Sound Quality Evaluation*. Piteå: Journal of the Audio Engineering Society.

[15] Zagorski-Thomas, S. (2016). How is theoretical research meeting the challenges of pedagogy in the field of record production? In A. King & E. Himonides (Eds.), *Music, Technology, and Education: Critical Perspectives* (pp. 67–84). New York: Routledge.

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

[17] Kim, S.J. (2010). Imaginal listening: A quaternary framework for listening to electroacoustic music and phenomena of sound-images. *Organised Sound*, *15*(1), 43–53.

[18] Johnson, M. (1987). *The body and the mind: The bodily basis of meaning, imagination, and reason*. Chicago and London: University of Chicago Press.

[19] Lakoff, G. (1987). *Women, fire, and dangerous things: What categories reveal about the mind*. Chicago and London: University of Chicago Press.

[20] Hubbard, T. L. (2010). Auditory imagery: Empirical findings. *Psychological Bulletin*, *136*(2), 302–329.

[21] Schaefer, R.S. (2014). Mental representations in musical processing and their role in action-perception loops. *Empirical Musicology Review*, *9*(3–4), 161–176.

[22] McAdams, S., & Bigand, E. (Eds) (1993). *Thinking in sound: The cognitive psychology of human audition*. Oxford: Oxford University Press.

[23] Gibson, J. J. (2015). *The ecological approach to visual perception* (Classic Ed). New York and London: Psychology Press.

[24] Clarke, E. F. (2005). *Ways of listening: An ecological approach to the perception of musical meaning*. New York: Oxford University Press.

[25] Hargreaves, D. J. (2012). Musical imagination: Perception and production, beauty and creativity. *Psychology of Music*, *40*(5), 539–557.

[26] Bayle, F. (1989). Image-of-sound, or i-sound: Metaphor/metaform. *Contemporary Music Review*, *4*(1), 165–170.

[27] Smalley, D. (1997). Spectromorphology: Explaining sound-shapes. *Organised Sound*, *2*(2), 107–126.

[28] Smalley, D. (2007). Space-form and the acousmatic image. *Organised Sound*, *12*(1), 35–58.

[29] Godøy, R. I. (2003). Motor-mimetic music cognition. *Leonardo*, *36*(4), 317–319.

[30] Godøy, R. I. (2006). Gestural-sonorous objects: Embodied extensions of Schaeffer's conceptual apparatus. *Organised Sound*, *11*(2), 149–157.

[31] Jensenius, A. R. (2013). An action–sound approach to teaching interactive music. *Organised Sound*, *18*(2), 178–189.

[32] Wallmark, Z., Iacoboni, M., Deblieck, C., & Kendall, R. A. (2018). Embodied listening and timbre: Perceptual, acoustical, and neural correlates. *Music Perception: An Interdisciplinary Journal*, *35*(3), 332–363.

[33] Corey, J. (2017). *Audio production and critical listening: Technical ear training* (2nd ed.). New York: Routledge.

[34] Moylan, W. D. (2015). *Understanding and crafting the mix: The art of recording* (3rd ed.). Burlington: Focal Press.

[35] Brown, G. J., & Cooke, M. (1994). Computational auditory scene analysis. *Computer Speech and Language*, *8*, 297–336.

[36] Tsabary, E. (2015). Aural atoms and structures: From electroacoustic ear training to analysis and back again. In *Electroacoustic Music Studies Network Conference: The Art of Electroacoustic Music*. Sheffield.

[37] Schaeffer, P. (1966). *Traité des objets musicaux*. Paris: Editions du Seuil.

[38] Chion, M. (1994). *Audio-vision: Sound on screen*. New York: Columbia University Press.

[39] Pedersen, T. H., & Zacharov, N. (2015). The development of a sound wheel for reproduced sound. In *AES 138th Convention*. Warsaw: Journal of the Audio Engineering Society.

[40] Cogan, R. (1984). *New images of musical sound*. Cambridge: Harvard University Press.

[41] Roy, S. (2003). *L'analyse des musiques électroacoustiques: Modeles et propositions*. L'harmattan.

[42] Oliveros, P. (2005). *Deep listening: A composers' sound practice*. Deep Listening Publications.

[43] Schafer, R. M. (1967). *Ear cleaning*. Toronto: Clark & Cruikshank.

[44] Everest, F. A. (2007). *Critical listening skills for audio professionals*. Boston: Thomson Course Technology.

[45] Moulton, D. (1995). *Golden ears*. Sherman Oaks: KIQ Productions Inc.

[46] Szigetvári, A., & Horváth, B. (2013). *Timbre solfege*.

[47] Elmosnino, S. (2018). *Audio production principles: Practical studio applications*. New York: Oxford University Press.

[48] Izhaki, R. (2018). *Mixing audio: Concepts, practices, and tools* (3rd ed.). New York and London: Routledge.

[49] Smalley, D. (1986). Spectro-morphology and structuring processes. In S. Emmerson (Ed.), *The language of electroacoustic music* (pp. 61–93). London: Palgrave Macmillan UK.

[50] Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory Into Practice*, *41*(4), 212–218.

[51] Boehm, C. (2006). The thing about the quotes: "Music Technology" degrees in Britain. In *International Computer Music Conference* (pp. 682–687). Michigan Publishing.