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Taxonomy of Critical Listening for Sound Engineers

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 presents a taxonomy of learning outcomes in critical listening for sound engineers. Derived from the literature on auditory perception and broader classifications of perceptual processes, the taxonomy segregates critical listening processes to improve curriculum development and pedagogical practices in the field. Building on previous findings that begin to support this taxonomy, its effectiveness as an educational tool is qualitatively assessed using learning journals and focus groups with 51 audio engineering students. This evaluation leads to a refinement of the taxonomy which offers a more robust classification of listening processes.

1 Introduction

The term "critical listening" generally refers to the notion of listening with intent. In audio engineering, this intent revolves around the technical integrity of audio signals outside of musical meaning [1], often including the tools that can alter quality [2]. However, this definition overlooks the finer nuances in perceptual processes necessary for educators. Consequently, the design of learning and teaching experiences in audio engineering may benefit from a classification of critical listening processes. Thus, with an aim to provide a model that audio engineering educators can implement in their own practice, this paper presents and evaluates a taxonomy of critical listening for instructional and curriculum design.

2 Background

A taxonomy is a classification framework where categories lie along a continuum, which can benefit pedagogues [3]. A review of taxonomies related to perceptual-cognitive skills [4] concluded that Moore's five-level taxonomy of perception [5,6] presents the broadest view of perceptual abilities. After testing it in different contexts (e.g., [7, 8]), she suggests that her taxonomy may relate particularly well to auditory perception.

The first level of Moore's taxonomy, *sensation*, relates to the awareness of the informational aspect of stimulus energy [6]. Based on Forgus' hierarchical order of perceptual segregations [9], it is the detection of change in stimulus energy. Within auditory perception, Moore posits that this stimulus information can reveal the perceiver's detection thresholds, suggesting pitch, loudness, duration, and timbre differences as potential focus elements [8]. Insofar as this raw sound data is an inexhaustible concrete given, and that detection thresholds are subjective to the perceiver, this level bears similarities to Schaeffer's *perceiving* [10]. Likewise, Tuuri et al. offer *reflexive listening* as a pre-conscious type of listening which relates to perceptual thresholds [11]. To confirm perception within an educational context, detection thresholds only require binary communication to indicate whether a change in stimulus information is perceived or not.

The second level of Moore's taxonomy, *figure perception*, relates to the awareness of entity [6]. Based on Forgus' hierarchical order of perceptual segregations [9] and Guilford and Hoepfner's structure-of-intellect [12], it is the discrimination of figural unity as separate from the background. Perhaps one of the most widely used theories using this figure-ground perceptual organisation within the realm of sound is Bregman's *auditory scene analysis* [13]. Using gestalt psychology notions applied to the perception of sound, he argues that acoustic events can be grouped sequentially or spectrally based on the ecological validity of their affiliation through a process of parsing. Such process coincides well with Schaeffer's *hearing* as it is an abstract perceptual organisation by the perceiver [10]. Moore illustrates this level of her taxonomy by proposing that hearing a slight knock against an engine hum segregates two sonic entities: the hum and the knock [5]. This macro-level discrimination between sound sources could be further refined by separating each entity's dry signal from their reverberation components. These examples are, however, more relevant to the distinction between broad layers of sound, thus somewhat departing from Bregman's notion of auditory grouping as spectral or temporal fusion. To confirm perception within an educational context, communication for this level of the taxonomy is not limited to a specific method or medium, so long as it is indicative of the auditory object being focused on. For example, auditory groupings can be indicated through vocalised imitation, abstract visual graphing and subjective descriptions, or objective descriptions if the sound source is known.

The third level of Moore's taxonomy, *symbol perception*, relates to the identification of figures [6]. Based on Forgus' hierarchical order of perceptual segregations [9] and Guilford and Hoepfner's structure-of-intellect [12], it considers stimuli as denotative signs without consideration for meaning. Within the context of sound, this implied causality coincides with Schaeffer's *listening* as it is interested in the concrete aspects of the perceptual object [10]. Similarly, *causal listening* refers to a sound as an index of its cause [11, 14]. Within audio engineering, causal identification links to Smalley's *technological listening* [15]. Moore illustrates this level through clicking sounds denoting improperly adjusted engine valves [5]. Similarly, one could recognise a series of tones as belonging to a guitar for macro-level identification. The guitar's timbral attributes could also indicate the use of a plectrum or an off-axis microphone as a finer resolution of this level. These examples make use of objective causal facts about the sound entirely inferred from itself. Therefore, to describe this causal reference within an educational context, an objective language for sound is necessary.

The fourth level of Moore's taxonomy, *perception of meaning*, relates to the significance associated with symbols [6]. Based on Forgus' hierarchical order of perceptual segregations [9] and Guilford and Hoepfner's structure-of-intellect [12], it is both the interpretive ability of the perceiver as well as the mental manipulation of the identified symbol. Within auditory perception, the interpretation of sound as an appraisal of quality without reference to meaning bears a resemblance to *reduced listening* [10, 11, 14, 16]. However, if an abstract meaning is associated to the perceptual object, Schaeffer's *comprehending* is a more pertinent fit [10]. Similarly, *semantic listening* considers associated meaning for sounds [11, 14, 16]. Beyond significance associations, Moore hints at the pivotal role of language by suggesting that this taxonomic level relates to an ability to understand verbal imagery, metaphors, and other figures of speech [6]. This process requires an understanding of words as signifiers of concepts, governed by the perceiver's embodied, cultural, and social experience. Because metaphors are often qualifiers of acoustic attributes (e.g., [17]), they offer some information on the appropriateness of a sound for a given situation. Moore proposes the examples of appraising rhythm, harmony, intensity, and phrasing within the field of music perception, which support this assumption [8]. She also posits that a mechanic listening to a car engine may advise alternative options for a specific defective engine sound [5]. Later, she suggests that such appraisal may stem from mental manipulation of the stimulus information [6]. Following on from this claim, she mentions that a mechanic should be able to imagine the sound that a malfunctioning part would produce [7]. From an educational standpoint, it may be fitting to separate this level into its interpretation and imagination components. In doing so, Guilford and Hoepfner's *semantic* category, interested in meaning and verbal thinking, is separated from Forgus' *manipulation* task, itself turning into problem-solving. Such separation then places the imagination process at the edge between perception and action, as is often suggested within the context of auditory imagery (e.g., [18]), therefore bearing ties to Corey's *isomorphic mapping* [2] and Macedo's *technical ear training* [16]. To confirm perception within an educational context, subjective language, through the often-used medium of the metaphor, is the primary communication for this interpretation of sound as it offers a description of what the perceptual object sounds like. However, when delving into the appropriateness of sound and the suggestion of better suited alternatives through mental manipulation, both objective and subjective language are necessary to describe problem-solving processes.

The fifth level of Moore's taxonomy, *perceptive performance*, relates to the reactive integration of all previous taxonomic levels in an intuitive manner [6]. Based on Guilford and Hoepfner's structure-of-intellect [12], it highlights the perceiver's behaviour in relation to the incoming stimulus and external factors. Although there is no new perceptual area of focus at this level, Moore proposes that the reactive and accurate response of the perceiver may provide grounds for creative achievement. The strong emphasis on the response to stimulus provided in her description of the level, coupled with the provided examples for music studies such as performance and composition [8], ties back to Gibson's ecological perception [19]. In effect, the perceiver's action is a response to stimulus information scanning and is constantly adjusting to the produced output. Within an educational context, confirmation of attainment for this taxonomic level is undertaken through successful action related to practical tasks.

Drawing from Forgus [9] and Hebb [20], Moore concludes that the first two levels of her taxonomy may belong to a more primitive (or naïve) part of the perceptual system; while the last three levels may be further subjected to conscious control [6]. She posits that her taxonomy, and perceptual processes more broadly, relate to sensory input. However, she insists that confirmatory output is similarly organised [6]. This notion is supported by the parallelism between the verbal (descriptive) and nonverbal (depictive) systems in multimedia learning theories such as Schnotz' *Integrated model of text and picture comprehension* [21] and Paivio's *Dual coding theory* [22]. Relating back to Schaeffer's seminal writing in the field [10], the communication circuit is also an integral part of his four modes of ordinary listening.

3 Preliminary taxonomy

Table 1 is a revised version of Moore's taxonomy. It separates her *perception of meaning* into discrete levels and provides labels more relevant to critical listening. The first level is labelled "detection", a term used by Moore in her explanation of this level [6]. Although psychological literature may refer to this process as discrimination along just-noticeable differences, detection seems a better fit due to the perceptual thresholds implied. The second level is labelled "discrimination" in relation to figure-ground perceptual organisation and auditory stream segregation/integration. Moore also uses this term in her explanation of this level [6]. The third level is labelled "identification" as it involves background knowledge to recognise sounds. Moore uses this term in her explanation of this level [6]. The fourth level, labelled "interpretation", also requires background knowledge although from the subjective perspective of attaching significance to sounds. Moore refers to an interpretive ability in her explanation of this level [6]. The fifth level is labelled "imagination" in reference to mental manipulation of sound. The sixth level is labelled "integration" as it refers to the unification of all perceptual information and skills to produce a desired outcome.

Table 1 also presents the type of communication used to confirm perception, with objective (verbal) communication referring to words that describe the technical/physical attributes of sound, and subjective (verbal) communication referring to onomatopoeias, analogies, and metaphors. Finally, although presented as one-dimensional separations of perceptual processes, all levels could provide macro to micro-degrees of perceptual precision as a sub-scale for assessing critical listening skills.

Perceptual Process	Confirmatory Communication
1. Detection ...of perceptual thresholds (e.g., pitch/loudness/duration/timbre differentiation)	Binary
2. Discrimination ...of auditory streams (e.g., sequential/spectral grouping, figure-ground organisation)	Indicative (visual, verbal)
3. Identification ...of causal references (e.g., technical/physical attributes recognition)	Objective (verbal)
4. Interpretation ...of sound quality (e.g., metaphorical associations, verbal thinking, conceptual attributes appraisal)	Subjective (verbal)
5. Imagination ...of prospective sound quality (e.g., isomorphic mapping, mental manipulation, critical thinking, problem solving)	Objective & Subjective (verbal)
6. Integration ...of ecological information (e.g., reactive global approach, complex decision-making, creativity)	Action

Table 1. Preliminary taxonomy of critical listening.

Although the bottom-up hierarchical organisation of these critical listening processes implies gradual complexity for the perceiver, this proposed taxonomy does not suggest an increased difficulty in learning and development. It is merely intended as a categorisation for educational settings. Furthermore, as suggested by Schaeffer, in practice the perceiver uses all listening modes simultaneously [10]. Moylan describes an analogous ecological perspective by likening a sound engineer's listening process to that of a scanner that quickly switches between levels of detail, perspective, and types of information [1]. This approach effectively relies on practising both bottom-up and top-down processes in parallel.

4 Preliminary evaluation

To begin validating this preliminary taxonomy of critical listening, 10 educators in composition/sound design, music production, and audio engineering were interviewed in a previous study [23], where they were asked to define the term "critical listening". Each participant answered by providing one or more of four processes undertaken during critical listening, which directly map to the taxonomy:

• Identify sounds through perceptual ability
→ Discrimination
• Deconstruct sounds into production components
→ Identification
• Critique technical/aesthetic sonic characteristics
→ Interpretation
• Imagine possible sound improvement actions
→ Imagination

The second question used to confirm the taxonomy's validity revolved around the notion of mental representations. The taxonomy of critical listening, which differentiates between the interpretation and imagination of sound, deviates from Moore's taxonomy of perception which combines all mental representations under the same "perception of meaning" label. In this regard, six participants offered one of two definitions of mental representations that warrant the suggested segregation of processes:

• Modal transduction between sound and other senses
→ Interpretation
• Imagining sounds and/or sound transformations
→ Imagination

This preliminary evaluation of the taxonomy of critical listening paved the way for its broader assessment with student.

5 Method

This study involved undergraduate audio engineering students at SAE Creative Media Institute (Brisbane, Australia) enrolled in their third trimester of study, undertaking the module AUD210: Studio 1. This module was chosen because of the highly flexible studio teaching model at SAE Australia (see [24]), and three of its five discipline-specific learning outcomes (LO) directly relate to critical listening:

• LO2: Replicate production techniques to achieve specified outcomes within audio productions.
• LO3: Develop critical listening skills by evaluating various sound recordings using accepted frameworks.
• LO4: Use various synthesis techniques to create specified sounds.

A pilot and three iterations of the full study were undertaken for this research, spanning across a 1.5-year (4 trimesters) timeframe between June 2020 and September 2021. The participant (P) sample size (n=51) represents the majority of students enrolled in the module used for this study (69 in total), and over a full year's worth of student intakes which reduces potential issues with specific student cohorts.

This study used data from the learning journals (LJ) of 46 students, and 7 focus groups (FG) involving 42 students, each participating in a single focus group. The learning journals, mandated for all students at SAE Australia (see [24]), provided insights into the students' educational experience without additional burden for participating. The focus groups clarified and extended the learning journal data in a forum resembling the students' usual classroom discussions.

Given the student/teacher relationship between the participants and the researcher, the methodology was designed with great attention to protect participants from harm. Accordingly, a high-risk ethics clearance was obtained. The researcher used an arms-length recruitment process to ensure that students did not feel coerced into participating. At the beginning of each trimester, the student council emailed invitations to participate to all eligible students, including information sheets noting that participation was entirely voluntary. Clarification on the purpose and topic of the research, including a clear distancing between the research and any current or future student assessment, was provided in class in response to queries. The researcher reminded students that he would not be responsible for awarding grades for this module, instead acting as a subject matter expert invited to deliver content. Students agreeing to have their learning journals used for research purposes were sent the consent form. At the conclusion of each trimester, students were reminded of the time and date of focus groups that they could attend if they wished to do so. Consent forms for focus groups were filled out at the beginning of each session.

Both learning journals and focus groups were analysed concurrently using the same methods. Following a constructivist grounded theory approach (i.e., emphasising co-constructed interpretations to produce and refine theoretical concepts grounded in the participants' perspectives and experiences), the data was coded using predetermined and emerging codes. Because this research was part of a larger study, two main predetermined themes were used: students' classroom experiences and out-of-class learning activities. Within the first theme, predetermined codes followed lesson topics: taxonomy of critical listening, recording, mixing, and synthesis. Within the second theme, predetermined codes related to two aspects of instruction: technical ear training and resources developed specifically for this research. Both themes also featured emerging codes developed using one-sentence summaries to group similar insights into clusters related to specific aspects of teaching and learning.

Motivation theories served as the foundation for evaluation. Eccles's expectancy-value theory was the principal means of judging effectiveness (expectancy of future success) and relevance (value attached to an activity) through motivation [25]. Attribution theory [26], related to the perceived reasons for success and failure, also guided this process to ensure relevance to the research. Finally, within the results section of this paper, the illustrating quotes are representative of larger trends of similar perspectives.

6 Materials

As an introduction to critical listening, the taxonomy was used to prime students to think more deeply about their sense of hearing as it relates to audio engineering and music production. An initial class presented the various taxonomic levels and the types of exercises that could be undertaken to develop each level.

The taxonomy was also more subtly employed in teaching. Some activities focused on developing detection skills by incrementally lowering differences between sounds under investigation. Others focused on developing identification and interpretation through a communicative teaching approach whereby students were asked to subjectively verbalise perception when presented with new technical concepts (see [27]).

Using insights from the literature on critical listening (see [28]), several lessons were developed for this study. A workshop comparing hardware to their software counterpart aimed at developing detection thresholds and required students to verbalise the differences they were hearing. A synthesis workshop focused on the identification and interpretation of synthesizer elements, largely through the objective and subjective verbalisation of perception. A single-microphone recording workshop required students to record an acoustic ensemble with a single microphone and describe the tonal qualities of each microphone and position used. This workshop principally aimed at developing identification and interpretation skills. A multi-microphones recording workshop offered an extension of this class as it required the same critical listening practice applied to a more extensive project, thereby focusing on the integration of critical listening skills. A mixing workshop required students to mix the same stems with various restrictions on time and equipment. One mix was restricted to two minutes in-the-box, another fully done on a mixing console, and the last done in one hour in-the-box. Although there was a large emphasis on imagination at the beginning of the class for the two-minute mix, this mixing workshop principally aimed at training students to integrate their critical listening skills.

Song analyses were also used as part of this research. Uncovered in a previous study as being the most common type of assessment used in study modules that focus on critical listening [29], this activity allowed students to develop their critical listening in a self-paced manner, focusing on visual graphing (discrimination), discussing objective technical properties of sound (identification), linking those to subjective terms (interpretation), and finally suggesting improvement methods (imagination).

7 Results

The introductory class which presented the taxonomy and relevant exercises for each level received two opposing views from students during focus groups. Some saw this session as a good introduction to the topic to "set up the tone" for the rest of their studies (P1, FG), further clarifying that it "encouraged me to start [practising critical listening skills]" (P13, FG). However, students generally did not seem to value the session enough to remember the taxonomy itself by the end of the study module, stating that "it definitely wasn't a specific point of interest" (P9, FG).

Because these were the only views provided that specifically addressed the taxonomy, analysing the language used by students revealed more information regarding the different critical listening elements which may have been emphasised in development throughout the trimester. For example, concerning the first level of the taxonomy, detection, students see this aspect of critical listening as one of the more important goals because "a good engineer needs good ears to hear even the most microscopic difference in tone" (P19, LJ). One student further commented that "the subtle differences of getting almost to that point of moving a dB or so, I now understand it's super important" (P41, FG).

Regarding the second level of the taxonomy, discrimination, the data revolved around listing sound sources, albeit applied to different topics: musical instrument and environmental sounds. For example, one student mentioned that they are "now able to more accurate [sic] pick out and identify sounds in environments" (P26, LJ), while another stated that classes "really helped me to notice new sounds within mixes and alert me as to what to look out for" (P35, LJ). Having been provided with visual graphing tools for song analysis, some students commented that this practice "helps you visualize where everything was panned and the depth of field" (P29, FG).

Most learning journal entries related to the third level of the taxonomy, identification, as students often describe their production processes within project updates. Similarly, focus group comments related to this level were generally more frequent than others. At this taxonomic level, students expressed how their ability to technically pick sounds apart such as "identify[ing] problem frequencies" had developed (P7, LJ). With sound analysis being a large part of student practice, some students also commented that they were now "constantly being critical" of what they listen to and "thinking about how it potentially could have been achieved" (P12, FG).

In relation to the fourth level of the taxonomy, interpretation, the data emphasised communication and being able to describe what something sounds like. For example, one student stated that "associating a word with a frequency range enables communication with other sound engineers and efficiency in finding where the frequency is" (P15, LJ). Another mentioned that they now know "this is the word we use to describe it [a specific sound], and these are the technical factors that make it sound like that" (P22, FG). As perhaps the most praised example of this topic, students commented on the synthesis class which heavily emphasized the use of subjective descriptors to develop a common lexicon for the sounds of each subtractive synthesizer element. One student mentioned that it was good "to describe what we were hearing because obviously, we've got two different classes [student cohorts] and I'm sure the other class came up with different descriptions of the same sound" (P14, FG).

Few comments were made regarding the imagination level of the taxonomy. Although it was included in lessons in the way of prompting questions regarding sound improvement methods for each topic at hand (e.g., microphone placement, mixing techniques), only two students commented on this strategy as being beneficial for critical listening development, with one describing the imagination of sound processing as being helpful in "visualizing" the mix (P37, LJ). It should be noted, however, that consistent feedback sessions both in class and asynchronously through chat groups revealed consistent involvement with this aspect of critical listening.

Finally, no comments were made specifically regarding how the taxonomy may have helped with independent practical skills implementation (and therefore its highest level, integration). However, students broadly suggested that critical listening training helped them become more purposeful in their endeavours and "not just blindly messing around" when working on sound (P32, FG).

8 Discussion

The benefits of presenting the taxonomy to students remain inconclusive. Although it may be useful as an introductory topic for study modules that explicitly require students to delve into critical listening as a subject matter itself, the data indicates that students do not place value on the taxonomy itself. As such, it may be more useful as a curriculum design tool than a teaching subject. This view stems both from the student perspectives offered during the focus groups as well as the general lack of reflection on this topic in their learning journals. It should be noted that there are some limitations in confirming this perspective. First, students undertaking this study module (finishing their first year of undergraduate study) may not yet have enough context to accurately judge its importance for their future careers. Second, the open-ended approach to critical listening development inherent to the study module used for this study may have affected the results. In effect, the freedom afforded by the educational model employed at SAE in Australia where students choose which topic they want to reflect on in their learning journals may have led them to place less emphasis on this topic depending on its perceived value (see [24]). Although this may be a useful insight in itself, further empirical research is necessary to truly explore the use of this taxonomy as a direct teaching tool.

The language used by students does, however, fit within the different taxonomic levels, thus further validating the taxonomy. Moreover, it helps uncover which aspects of critical listening students seem to value and aim to develop. For example, they view the detection of increasingly smaller differences in sounds as one of the more important aspects of their skills to develop as they equate hearing increasingly smaller differences in sound to a more refined ear. This aspect of listening reduces the number of perceptual variables and could, therefore, primarily aim to develop attention vigilance as the listener is highly focused [30]. As such, undertaking this type of training early on is warranted as attention vigilance is necessary in all critical listening training (i.e., one must remain focused on auditory stimuli under investigation during critical listening training). This perspective was supported in a previous study with one type of technical ear training exercise said to help with perceptual abilities in another, thus principally aiming to refine attention regulation and vigilance [23]. This notion may also explain the bottom-up training sequence suggested in the literature, initially focusing on decreasing just-noticeable differences [30, 31], and increasing complexity rather than subtlety for more advanced listeners [32]. This view suggests that detection training limited to binary options (i.e., whether a perceptual difference exists or not) should be undertaken earlier than identification that uses a higher number of variables (i.e., what the perceptual difference is). Likewise developing listening skills from relative to absolute perception is recommended [33]. In this instance, detection of differences is always considered in relation to the original stimulus, compared to identification which requires an absolute point of reference for causality.

As a process analogous to that of parsing in language listening and Bregman's auditory scene analysis, the discrimination level of the taxonomy was not heavily emphasized as an essential aspect of critical listening in student data. However, it did manifest as the listing of sound sources (thereby overlapping with the identification level of the taxonomy) and the visual graphing of sonic elements. As this skill is said to be acquired early in life [34] and a more primitive mode of listening [6], it may not be viewed by students as requiring much attention from a training perspective. The lesser emphasis on this aspect of critical listening may also be explained by the arguably small number of training activities that focus on this skill (e.g., [35, 36] for environmental sounds and [37] for mindfulness practice). Another practice suggested by the literature on music production analysis is the visual graphing of sonic elements [1, 23]. Students confirmed this activity as beneficial. Regarding the resolution at which discrimination skills can be developed, both student data and the literature seem to focus on the macro-level discrimination of sound sources. Reinforcing the bottom-up development of skills, it could be argued that finer detection skills may benefit the discrimination of micro-level aspects of sound sources (e.g., separating reverberation from dry sound). This is the idea underpinning Tsabary's model of aural atoms and synergetic structures [30].

Stemming from its prevalence in the literature and student data, the identification level of the taxonomy is arguably the principal critical listening process to be developed. Most textbooks (e.g., [38]), technical ear training (e.g., [39]), and video tutorials (e.g., [40]) primarily relate to this level as they aim to develop the identification of causality by exploring sound engineering tools. Previous research presents a matching view as most recommended readings for critical listening study modules are technical textbooks [29]. Similarly, students principally refer to this level of the taxonomy by describing techniques used in their work. This is the element that they strive to develop as they view it as directly impacting their productions. Furthermore, the data indicate that conducting sound analysis from an engineer's perspective and identifying technical processes led students to change their everyday listening practice. It should also be noted that there are some mentions of the benefits of this aspect of critical listening to the development of an objective language for sound.

Student data only refers to subjective communication for the interpretation level of the taxonomy, a topic which is often suggested as a developmental point in the literature (e.g., [1, 33]). The data shows no connection to mental representations beyond the cross-modal mappings used in metaphors that make up a subjective language of sound. From a curriculum planning perspective, this aspect of interpretation may need further exploration to develop critical listening skills beyond expanding one's vocabulary and into the realm of context-based appraisal. In this regard, a limitation of this study is that the participants belonged to a sound engineering rather than a music production degree, which may have affected their views regarding the importance placed on context for interpreting sound quality. Still, the communicative approach to teaching critical listening which extensively used subjective language emphasises this level of the taxonomy and was highly praised by students to better understand technical concepts (see [27]). In other words, this interpretation is viewed as an alternative way to describe sounds in comparison to the identification of causality. As such, it may be appropriate to join these two levels of the taxonomy together as they can be thought as being "two sides of the same coin". In this case, both identification and interpretation may be more meaningfully grouped under the label "description".

The imagination level of the taxonomy takes two forms in the literature and data collected. First, some literature suggests that guided imagery exercises could benefit skills development (e.g., [1, 23, 36]). Although some students positively commented on this type of activity, guided imagery was not employed at length. This strategy, therefore, remains a point for further research. The second element related to this taxonomic level relates to feedback. After an extensive implementation both within and outside of class, student data suggests that this is a helpful strategy, in line with previous research [23]. However, the data does not explicitly refer to critical listening development but to learn from others.

Finally, student data suggests that the application of skills within activities such as synthesis and mixing have improved over the trimester, thereby addressing the integration level of the taxonomy. In this case, it is believed that students may not be clear or vocal about the processes by which their critical listening skills may influence the quality of their practice. Instead, the data shows that students become more purposeful in their audio engineering endeavours, an idea that links back to this highest level of the taxonomy and the goal of critical listening according to the literature [23, 39].

For instructors, segregating critical listening elements enables educational experiences that target specific learning outcomes. Based on the findings from this study, Table 2 presents a revised taxonomy of critical listening for sound engineers, where the identification and interpretation levels are grouped as parallel descriptions for sound. Interpretation, in this case, varies depending on the context for critical listening. From a sound engineering perspective, interpretation relates to the embodied appraisal of sound akin to Schaeffer's *reduced listening*. However, adding the consideration of context (such as musical affect), the meaning of sound in the sense of Schaeffer's *comprehending* mode of listening becomes more apparent. This revision better fits the definition of a taxonomy as it is ordered by cognitive complexity, where the earlier levels use principally perception and gradually involve higher cognitive functions such as critical thinking. As with the preliminary taxonomy of critical listening presented in Table 1, all levels offer macro to micro-degrees of precision, which may provide a sub-scale for assessment purposes. To illustrate this point, Table 3 presents a rudimentary grading rubric featuring a two-level sub-scaling between low and high grades for each level, illustrating the idea of macro and micro-level skills. It should also be noted that the linear weighting of each level could be amended depending on context.

<table>
<tr><th colspan="2">Perceptual Process</th><th>Confirmatory Communication</th></tr>
<tr><td colspan="2">1. Detection ...of perceptual thresholds
(e.g., macro to micro degrees of differences in pitch, loudness, duration, timbre)</td><td>Binary</td></tr>
<tr><td colspan="2">2. Discrimination ...of auditory streams
(e.g., macro to micro-level sequential/spectral grouping)</td><td>Indicative
(visual, verbal)</td></tr>
<tr><td rowspan="2">3. Description
...of sound attributes
(concrete & abstract)</td><td>3.1. Identification ...of causal references
(e.g., macro to micro-level technical/physical attributes)</td><td>Objective
(verbal)</td></tr>
<tr><td>3.2. Interpretation ...of sound as embodied associations
(e.g., personal to context-based metaphorical attributes)</td><td>Subjective
(verbal)</td></tr>
<tr><td colspan="2">4. Imagination ...of prospective sound quality
(e.g., isomorphic mapping, mental manipulation, critical thinking, problem solving)</td><td>Objective & Subjective
(verbal)</td></tr>
<tr><td colspan="2">5. Integration ...of ecological information
(e.g., reactive global approach, complex decision-making, creativity)</td><td>Action</td></tr>
</table>

Table 2. Taxonomy of critical listening for sound engineers.

Criteria	Low Grade	High Grade
Detection (10%)	Ability to detect macro differences in pitch (e.g., 1 semitone), loudness (e.g., 10dB), duration (e.g., 100 milliseconds), and timbre (e.g., different instruments) against silent background.	Ability to detect micro differences in pitch (e.g., 0.1 semitone), loudness (e.g., 1dB), duration (e.g., 10 milliseconds), and timbre (e.g., same instrument) against noisy background.
Discrimination (15%)	Ability to discriminate macro auditory structures (e.g., a voice recording) among few simultaneous auditory groups.	Ability to discriminate micro auditory structures (e.g., the reverberation component of a voice recording) among many simultaneous auditory groups.
Description (20%)	Ability to identify macro technical/physical attributes (e.g., recognising a voice recording). --- Ability to interpret/appraise sound quality using subjective qualifiers with personal bias (e.g., describe the sound of a voice recording).	Ability to identify micro technical/physical attributes (e.g., recognising the reverberation time on a voice recording). --- Ability to interpret/appraise sound quality within a specified context (e.g., appraise the sound of a voice recording for a specific musical genre).
Imagination (25%)	Ability to imagine simple sound improvements (e.g., propose one way to improve the clarity of a voice recording).	Ability to imagine complex sound improvements (e.g., propose multiple ways to improve the clarity of a voice recording).
Integration (30%)	Ability to integrate critical listening skills to produce a work-in-progress product (e.g., produce a rough mix).	Ability to creatively integrate critical listening skills to produce a product that matches a reference (e.g., produce an industry-standard mix).

Table 3. Example grading rubric for critical listening assessment.

9 Conclusion

This paper has presented and evaluated a taxonomy of critical listening for sound engineers. Adapted from Moore's taxonomy of perception and linked back to the literature on auditory perception, this segregation of listening processes can be particularly helpful to educators. It allows for the development of curriculum and training that target specific aspects of critical listening, with reliable evaluation methods through the communicative outputs associated with each level. Furthermore, it offers a clear description of critical listening elements for a bottom-up skills development sequence as suggested in the literature and data. Finally, it is hoped that this taxonomy can provide the basis for further research in audio engineering education.

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