ARTEFACT, PARTICIPANT AND INTERACTION IN AUDITORY EXPERIENCES

Mariana Seiça, Licínio Roque, Pedro Martins and F. Amílcar Cardoso

University of Coimbra
Centre for Informatics and Systems of the University of Coimbra
Department of Informatics Engineering
`{marianac, lir, pjmm, amilcar}@dei.uc.pt`

ABSTRACT

The act of sound perception and its subjective dimensions, from physical to psychoacoustics, from semantic to affective, carry an inherent challenge for the conception and evaluation of every audio-based artefact. Starting from a previous framework of evaluation approaches, we seek to deconstruct the configuring elements of these processes, searching for theoretical foundations informing Sound Design and possible applications for Auditory Displays. This work is a first step into identifying a body of knowledge on the listener's experience, how the act of listening takes place and how the sequence of listening actions can evolve as forms of dialogue, creating dialogical spaces for making sense of auditory information. With this work, practitioners can gain new insights into how existing techniques for creating auditory artefacts can be configured and transformed into new, alternative approaches.

1. INTRODUCTION

Human audition, as "we begin to hear before we were born" [1], is one of the basic, instinctive senses with which we perceive and act with the surrounding world. Capable of identifying multiple sound forms and sources, our auditory system can reach complex levels of perception, from 1. natural sounds to human-made; 2. communicational, recognizing "voices and interpreting countless subtle levels of expression" [2] through language and temporal patterns; 3. or musical sounds organised in patterned structures. Besides, the "omnidirectionality of hearing" [1] and its constant presence, as the "sense of hearing cannot be closed off at will" [3], imposes an acoustic world that affects our perception, and from which we can benefit by exploring alternative forms of auditory communication. The subjectivity of sound characteristics and the intrinsic subjective nature of the "sensory impressions of an acoustic stimulus" [4] carries an impending challenge of every audio-based creation, either in the conceptualization and generation of the sonic output, but also in its evaluation and understanding how it is perceived.

Bringing this notion of auditory exploration to a computational perspective, audio-based research for presenting digital information to the user has grown since the 1980s. Bly [5] introduced this potential with multivariate data, acknowledging it only as a complementary medium to graphical output that could provide auditory cues of important data events, "easing the restriction of focused attention" [5] and increasing the dimensionality of graphics

variables. Combining the capacity of computational systems with sound forms creates a multitude of explorations, from computer-aided music or computational music, new interfaces for musical expression, co-creative musical environments and tools, musical e-learning systems, sound-based videogames, audio-centred systems for visually impaired people to sonification and data-based compositions, all of them forms in which sound is the main vehicle for the experience. For the last example, one key issue that has been raised regarding the widespread use of auditory displays for data communication [6] has been the evaluation stage, namely how it should be devised and what elements should be considered.

Starting from this challenge, Seiça et al.'s [7] conducted a literature review of evaluation methods and processes in two audio-focused conferences, Audio Mostly and the International Conference on Auditory Display (ICAD), which resulted in a contrasting difference of two opposite evaluation practises named by the authors: *user-centred* or *system-based*. Between these two extremes, the authors proposed a framework of evaluation approaches, founded on a spectrum of the user involvement in the evaluation process. The authors proposed a six-column framework that considers the user's role, the transformative capacity and linearity of auditory outputs and the exploration scope. The approaches were sequentially organised following a crescendo on the user's involvement, starting from: 1. a primary listening activity of a fixed sequence with the user's passive involvement ("Listening"); 2. an added control of the sequence's temporal dimension, with the user as an active agent with multiple exploration paths to reach a single output ("Active Listening"); 3. a space of predefined outputs, where the user is invited to explore the multiplicity of results through different pathways ("Search Listening"); 4. a space of mutable outputs dependent on the user's actions, who becomes the designer of the experience ("Listening while doing"); 5. an action-focused scenario where the act of listening becomes secondary ("Doing while listening"); 6. and an action-driven situation where sound is complementary and even expendable ("Doing").

A main axis of *intention-action* builds the foundational structure of the framework, with the authors arguing the user's intention to listen as the departing or driving force of the interaction, which gradually evolves to action-driven exchanges. This *intention-turns-to-action* baseline translates into multiple degrees of the user's search for meaning, depending on the ways each has available in the interaction space that is offered during the evaluation process. Depending on the position in the spectrum where the evaluation experience of a given auditory artefact is placed, the retrieved meaning(s) can be more or less consonant with the designer's intentions.

1.1. Evaluating Auditory Artefacts and Beyond

Regarding the Auditory Display (AD) community, the authors [7] reported a tendency to implement quantitative methods for evaluation, particularly listening tests. While this type of approach is necessary for measuring and comparing mapping choices and consequent data perception, as the authors describe, when we begin exploring scenarios designed for a wider user participation, new perspectives are necessary, which include "participatory workshops and active listening experiences" [8].

The contribution of Seiça et al.'s [7] framework, as an attempt to classify distinct evaluation approaches while dealing with auditory artefacts, shifts or enhances the focus to the user's action and contextualises how the interaction with the auditory artefact takes place, guided by this notion of evolving "intention to action in the production of meaning" [7]. This intention should help clarify what we should care about in each case, and how we could evaluate its effect.

However, we wonder: what is this intention? Beyond the relationship between the designer and the user's intention, where an artefact can be conceived to lead the user's view to the designer's, or the artefact designed to meet the user's preferences [9], what is the user's intention? The transformation across the spectrum of *intention for interpretation* to *action for interpretation* [7] dismisses the reason behind the action. Aren't our actions primarily guided by an *intention for action*? Intention for reaching a goal, an understanding or a state of affairs in the world, either for necessity or for enhancing perception of reality, is primarily present: we act with a purpose. That purpose may shift to a myriad of possibilities, and the space for action may change radically with each one. The six proposed approaches translate a generic classification of the spectrum of these action spaces. When dealing with auditory artefacts in their multiple generative forms, we may just be allowed to listen; or we may be able to act upon them. Intention then becomes a constant driving force in the entire realm of interaction options, illustrating an "intentionality towards the world" [10] for perceiving the auditory experience. We thus propose an alternative axis to Seiça et al.'s [7] framework (Fig. 1): it starts from the user's act of *listening* to the artefact for interpretation (left side of the intention-action axis), being progressively coupled with acts of *doing* through a set of actions that become the focus of the auditory experience, either its evaluation approach or the interaction itself.

LISTENING   DOING

INTENTION

"action-perception loops mediated by sound"
Serafin et al. (2011)

Figure 1: Listening - Doing Spectrum

Embracing action as a bodily form of interaction with the auditory object highlights the phenomenological notion of perception as an active process for meaning-making [10], through "action-perception loops mediated by sound" [8]. This expression, retrieved from Serafin et al.'s chapter on Sonic Interaction Design [8] becomes the design focus when we approach the right side of the spectrum, taking the synchronicity of gestures and sonic feedback centre stage in understanding and devising auditory artefacts. These auditory loops, despite being always present across the spectrum, require more complex sequences, and thus alternative and

novel forms of designing auditory artefacts that adopt the human as an actor. This circles back to the widening need for the AD community to explore novel forms of user participation in sonification scenarios. Hermann's proposal for closed-loop auditory interactions [11] already describes scenarios with higher levels of user involvement in three levels: basic *triggering* of a sound signal, *parameter adjustment* of mapping choices and the last and most complex *excitatory interaction*, which may support multiple human actions over the sonification system that responds to them. This embraces the notion of sequential auditory perception loops as Interactive Sonifications [12]; however, it stands tendentially within the purpose of data analysis and a somewhat rigid perspective of sound perception as function. Multiple studies have since been developed that seek alternative views and explorations within the field, grasping embodied metaphors and the role of aesthetics for sonification design [13, 14, 15, 16].

For this myriad of possible listening and action-focused scenarios, can the entire space of possibilities in dealing with an auditory artefact be mapped with the three dimensions proposed by [7]? On one side, we have the sequence linearity, which can be fixed, going from A to B as fixed starting and ending points, or variable, expanding the number of possible outputs and endings depending on how the user explores them. On the other, the relationship between the number of outputs and pathways: the user may be offered multiple pathways to reach one or multiple outputs, which may in turn be fixed or mutable according to the exploration pathway taken. For the role of the user, it may alternate between a passive or active listener, by exploring increasing degrees of control over the experience.

However, by retrieving the *user-centred / system-based* dichotomy, which of the three dimensions are under the responsibility of the user, the system, or both? How can we characterise them? And how can we define the interaction dynamics that emerge from the relation between them?

1.2. Aims and contribution

Deriving from the notion of the user as the driving force of auditory interaction, we seek here to deconstruct Seiça et al.'s proposed framework of evaluation approaches [7], in order to bring theoretical foundations that could support and broaden our understanding of the sonic interaction process. From this renewed understanding, we aim to gain a new perspective on what and how to conceive and evaluate auditory artefacts. Our main contribution is a deepened theoretical mapping of the dimensions at stake, aiming to sustain, transform and, hopefully, expand our ability to design and evaluate proposals for producing auditory experiences, applied within the sonification field.

We continue next with an overview of theoretical contributions from sound-related communities, proceeding with a reflection on how current models inform audio-centred perspectives on interaction with artefacts. From this, we address the triangular structure of the artefact, participant and interaction dimensions, alongside a collection of theoretical references uncommonly combined in auditory interaction. With this body-of-knowledge, we proceed with a theoretical reinterpretation of the six-approach framework for auditory artefacts, attempting new theoretical explanations on what and how to configure these approaches, illustrated with examples retrieved from the community.

2. THEORETICAL MODELS FROM SOUND COMMUNITIES

First, what can we consider as audio-based research? Murray Schafer, in his book *The Soundscape: The Tuning of the World* [3], introduced the term *soundscape* as the sonic environment that surrounds us, and that multiple areas of sonic studies, from psychoacoustics, sound recordings, electroacoustics, aural perception, to musical analysis (to name a few), deal "with aspects of the world soundscape" and are, consequently, a part of it. Continuing his work, Barry Truax focused on a human perspective of this soundscape, and the importance of how we, as individuals and a society, "understand the acoustic environment through listening" [2] as a key interface for communication. The sonic experience is highlighted as a major mediating factor between each member of a community and their environment, creating, influencing and shaping the relationships within it [2]. In every research regarding any kind of aspect of this universe of sound elements, either physical, psychoacoustic or communicational, it becomes of key importance to reflect upon the perspectives of the different communities concerned with understanding the sound medium, and how they categorise their practises.

A few examples of theoretical models regarding auditory artefacts arose in multiple sound-centred venues. From the collected examples in Seiça [7], Vogt [17] presented a quantitative approach to auditory display, using a multi-criteria decision aid (MDCA) method in a participatory workshop with experts to evaluate the design of eleven sonifications. The participants had to rate the sonifications through a weighted sum approach using nine parameters: aesthetics/amenity, intuitiveness, learning effort, clarity, potential, efficiency, contextability, complexity and technical effort. The goal was to understand their accuracy and efficiency in evaluating the design of a sonification. In 2013, Vogt, Goudarzi & Parncutt [18] conducted a series of user tests to retrieve how the learning curve of sonifications impacted the reported aesthetic appealing. O'Modhrain [19] proposed a framework for the evaluation of Digital Music Instruments (DMIs), acknowledging a "broader definition of the term evaluation than that typically used in HCI", due to the act of performing with them being such a mark of validity of their design. The perspectives of numerous stakeholders are the organizing pieces for the framework: the audience, the performer/composer, the designer and the manufacturer. For each perspective, the author described the kind of evaluation methods used to evaluate three major criteria: enjoyment, playability and robustness, as well as the achievement of specific design goals for the last two stakeholders. According to the author, only by acknowledging the role of each perspective can the overall design process be consistently evaluated.

Prechtl et al. [20] presented four methodological approaches to evaluate music for a video game, focusing on two main dimensions: the player's perspective, retrieving the level of player enjoyment and how does the music affect the player's gameplay, and the musical system's perspective, evaluating the aesthetics/musical style according to the game, and its function. Barbosa et al. [21] provided a literature review and analysis focused on the evaluation process, gathering common targets and stakeholders, goals of research, criteria and methods applied to draw a general portrait of evaluation trends. They pointed out three possible perspectives (from the audience, the performer or the designer), and multiple criteria whose importance varied according to the perspective. Some of these criteria included engagement, playability, expres-

siveness, effectiveness, control, precision, latency and intuitiveness. In 2017, Brown, Nash and Mitchell [22] also presented a literature review regarding three audio-based conferences to collect user-centred evaluation methods, with the goal of finding trends within music interaction research and future directions. Gathering the evaluation stakeholders (performer, audience, designer and composer), the UX dimensions, the tasks that the participants had to undertake and the respective methods, the authors found usability and aesthetics as the primary focus of evaluation.

The examples found for auditory displays tend to focus on the artefact spectrum, evaluating the system's performance and its design characteristics. Other examples broaden the spectrum of the different stakeholders at play, not only in the conceptualization scope of creating and devising the artefact, but also in their experimentation. The used criteria also acknowledged the perspective of the users, which parameters characterise their interaction with the artefact, and which evaluation methods could be more useful and insightful in analysing these parameters.

3. REFLECTION ON AUDIO-CENTRED PERSPECTIVES

In the majority of the examples given in the previous section, we find the common aspect of retrieving the perspectives from the numerous stakeholders involved, either from the author of a given auditory work, the one who performs or plays it, or the one who experiences it as a receiver or spectator of its use. Due to the systemic nature of auditory communication that interconnects "sound, the listener and the environment as a system of relationships" [2] through chained reactions, every intervention should not fall on the tendency for expert solutions, but explore instead ways for each individual to "bring about change and regain control" of their own perspective [2]. The sequence of these action chains and how they gradually develop are directly linked to the cultural environment of their performers [23], which reveal a direct and intimate bond between their behaviour; these chains are formed within relationships while forming their practitioners during the process. The perspectives of both the designer / author and the user can be combined, tfrom the initial intention that drove the creation process to the perceptual path followed by the user during the experience, balancing "multiple, perhaps conflicting interpretations and processes of interpretation in design and evaluation" [9].

This multi-perspective acknowledgment relates to the "complexity of multiuser activity" [24], where the focus is the *activity* in which a new artefact changes how the user experiences it, evolving not only the practise in the process, but also the human and the cultural community in which those practises take place [24, 23]. Activity theory is here brought, with its aim to expand our understanding of the *subject-object* relationship, while embracing Truax's mediating relationship of *listener-environment-sound*: the sound artefact becomes a mediator that the user acts through in a surrounding environment. We then have, on one side, the sound **artefact**, the **participant** who experiences it, and an **interaction** process through which meaning is retrieved. Sound design and evaluation is transformed from a predetermined, linear process to a dynamic, mediating relationship between the listener and the environment through sound [2], where the listener's involvement and control can vary substantially.

Different levels on how the participant can be involved and act upon the surrounding soundscape enable a space for multiple co-creation relationships with it. Mutual exchanges, weaving the meaning-making processes of its participants to auditory cues, can

be seen as practical dialogical spaces for the listener's intention to take place. Here, we retrieve Bardram's [25] proposal for three hierarchical levels of collaborative, dialogical activity inspired by Activity Theory: *co-ordinated*, as organised scenarios where its participants behave in expected, established routines of individual tasks; *co-operative*, representing situations where a common goal is the purpose of everyone's actions, demanding a balance and enhanced communication between them; and *co-constructive*, where foundational disruptions lead to the need for reconstructing the common motive of the activity, which requires a reconceptualization of the activity itself. Embracing this multiplicity of sonic contexts and sense-making processes through an interaction space of actions can give researchers new perspectives, not only on how to evaluate sonic experiences, but also on its design and exploration of alternative approaches.

4. A TRIANGULAR STRUCTURE FOR AUDITORY EXPERIENCES

Attempting to bring theoretical foundations to characterise Seiça's evaluation approaches [7], we will bring forth a theoretical basis to describe the roles of the Artefact, Participant and their Interaction process: we have the generated artefact, the participant who experiences it, and the interaction that characterises how the experience takes place. The bidirectionality of user-artefact grows to a triangular, multidirectional relationship between the three elements.
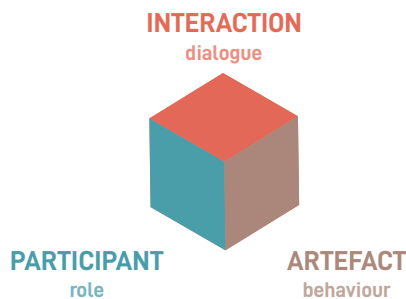

Figure 2: Artefact-Interaction-Participant Structure & Dimensions

The **artefact** is here taken as an object for the users to work on, with, and primarily through which they manifest a given intention, becoming a part of the sonic universe. Bødker and Klokmose [24] specified the notion of artefact as "crystallizations of activity", which embodies previous experiences with similar artefacts, and different ways of acting and perceiving the current one, shaping the experience itself during its existence. The *sequence* dimension [7], carrying the concept of linearity, can result from diverse ways the participant can interact with the sonic artefact, which depends on its use and the perceived frame of reference. The artefact can be understood either as a composition or as an instrument enabling the production of a sonic experience, whose orientation arises within itself and through the activity as an expression of the subject's intention [24];

The *outputs/pathways* dimension [7] carries characteristics of both the artefact, with the number of possible results deriving from its design, and the user, as the embodied role may influence the exploration paths that emerge during interaction. An encompassing concept of this relation can be the **behaviour** of the artefact, characterised as: 1. *passive* where it stands unresponsive to the envi-

ronment; 2. *reactive* as deterministically answering to each stimulus with an expected response; 3. *active* as an initiative-driven device who also follows a defined path of actions independent of external stimulus; and 4. *adaptable*, modifying and adjusting its responses according to changes in its surroundings.

Regarding the **participant** as the main agent of action, a "part of a dynamic system of information exchange" [2], the multitude of roles each can embody may be further deepened. Answering what these **roles** could be as functional entities with variable freedom exploring the contextual soundscape, we defined three kinds of embodied personas inspired by previous theoretical works [19, 21, 22]: 1. the *spectator* role, as a member of an audience exposed to an auditory artefact and actively listening to it, but with no direct action to control or change its course; 2. the *performer*, where sound becomes the conductor of the experience through the user's actions and exploration of the space of possibilities; and 3. the *composer*, a participant who becomes a member of a creation process, a creator of the auditory space itself, either in its design, composition and interaction layout.

The **interaction** process reveals the sonic experience in the realm of relationship between its participants, describing the mutual exchanges for meaning-making of the auditory surroundings. As a starting, non-dialogical scenario, we added the notion of *monologue*, describing scenarios where no external collaborative exchanges take place. We find two separated entities, with the subject/listener on one side and the sonic object on the other, whose auditory results are not influenced by the subject's interaction; the subject is as-if-passive, the object is deaf. Entering Bardram's three scenarios of dialogue [25] to interpret auditory artefacts, active listening becomes structural to the auditory activity:

1. In a *co-ordinated* dialogue, there is a subconscious interpretation of the auditory artefact through a previously learned set of actions-responses, following culturally established routines of interaction. Auditory cues in a video game, for example, are designed according to an assumed gameplay goal. The artefact responds to the player's position in the field as an enemy approaches, and the player decides the next move according to that perception. There is a triggering interaction, where both the artefact and the player perform their actions focused on the success of their individual activities: the artefact follows a designed script of rules and events; the player tries to reach the end of the game following a set of learned behaviours; both maintain the general interaction flowing. In the case of a DMI (Digital Musical Instrument), when its performer is knowledgeable of the sonic exploration space of the instrument and of the required techniques to play it, the script of rules is known and the dialogue naturally unfolds.

2. When the involved entities focus on a shared objective to consciously understand the sonic artefact, we enter a *co-operative* dialogue, where each participant has to balance their actions with the others. This sense-making process challenges current objectives and the established action repertoire, which the participant becomes aware of, possibly questions and, consequently, leads to learning new routines. In a game scenario where a sonic space can be explored, each movement produces an auditory change or response. This becomes a cooperative exchange, where there is an operational learning curve necessary to reach the desired, culture-sharing goal of playing. The reason for each action emerges during the interaction, with the user ques-

tioning each movement in a co-operative process of action-perception and a contribution for sensemaking. Taking the DMI example, in a beginning state where the performer has yet to learn how to operate the instrument and its practises, the cooperative exchanges take place until the player implements an effective action repertoire, in a set of operations, to reach the desired goal of playing.

3. The *co-constructive* dialogue rises when the motive and potential exploration of the sonic artefact is co-constructed in context, and takes shape within the interaction itself. While reappropriating the artefact, the meaning behind each action is unveiled and understood iteratively in the context of the new motive, gradually establishing a new action repertoire for the activity that comes to be in interaction. While playing a game, the meaning and potential exploration of the sonic artefact can be co-constructed in context, when the player finds opportunities to explore its sonic expression, e.g. as an instrument or a way to communicate with other players, possibly leading to formulating a new motive for playing, and developing new goals and interactions. In the DMI example, co-construction occurs when the purpose for playing an instrument is questioned: a new space of interaction possibilities arises when a new motive emerges, e.g. a strings structure becomes a percussive element, bringing new objectives and, eventually, new routines of playing.

5. THEORETICAL REFRAMING OF THE SIX-APPROACH EVALUATION FRAMEWORK

The three introduced dimensions following the *Artefact-Interaction-Participant* structure can now be applied to characterise Seiça et al.'s evaluation approaches to auditory artefacts [7], illustrated with examples retrieved from the community:

1. "LISTENING": describes artefacts as linear, single-ending compositions, with a passive attitude towards external stimuli, in a monologue interaction where the participant is a spectator of the experience. A large set of proposed sonifications as listening experiences and mapping evaluations enter this first approach, such as last year's proposal for a sonification of the solar system to complement a visual environment within a planetarium environment [26], or a study of auditory cues to identify the security level of WiFi networks, with a comparison between two data-to-sound mappings [27]. Consequently, evaluation approaches usually focus on listening exercises without control over the stimuli, to reach an objective measure of success in auditory communication across the participant population.

2. "ACTIVE LISTENING": the interaction grows from the first approach as a co-ordinated set of actions, where a reactive artefact responds to control actions from the participant, who plays the role of a spectator with an active listening attitude. The stimuli is produced as a coordinated response enabling directed attention towards a listening path, among several. Sonifications that support parameter adjustment or a set of commands to control aspects of the display are examples of this approach, as an exploratory sonification regarding consumption data, where the users could rewind/forward or change the tempo [28], or the Sonifyer platform that allows the import of multiple datasets in an interface for navigation [29]. Evaluations can vary between

a focus on successful perception and interpretation of desirable listening paths, across a mostly spectator population. In this approach, a mix of listening exercises with qualitative content analysis of interpretations can be helpful.

3. "SEARCH LISTENING": describes scenarios where the artefact acts as an instrument with an active attitude and agency in the soundscape creation. An artefact design in this approach can reactively or actively produce sonic compositions in response to user's actions. This way, the artefact engages with the participant as a performer in a co-operative dialogue, enabling the development of the player's action repertoire. Interactive sonifications are an example, as the Photone installation, which combines colored images with musical sonification [30] or a multi-touch surface to explore model-based sonifications [31]. Evaluations should take into consideration the communicability of a base layer of the composition, but also how effective are the artefact's attempts at directing attention, amplifying perceptions and designed interpretations and appropriations.

4. "LISTENING while doing": evolves from the previous one through a co-constructive dialogue of the experience, with the artefact as a score to be performed/written during the interaction process, as it evolves its responses depending on the participant's actions as a composer. An adaptable artefact also anticipates listening intentions, expanding or modifying a composition for a better fitness or orchestration of desired action goals. Examples of participatory workshops for collaboratively designing sonifications fit this fourth categorization, as a set of workshop sessions with sonification experts, data domain experts, and programmers to design a sonification of climate data [32], or to incorporate non-visual interaction and haptic feedback in DAWs (Digital Audio Workstations) for visually-impaired people [33]. In addition to previous goals, evaluation methods in this approach seek to demonstrate how adaptations taken by the artefact amplify the participant's construction of motives and goals that go beyond the designed interpretations;

5. "DOING while listening": returns to the artefact as an instrument, behaving reactively or actively in performance scenarios of co-operative dialogue. A report on multiple bio-sensors developed for real-time interaction through auditory or visual responses in artistic performances [34] is an exemplary study within the community of this approach. Evaluation approaches are built over action or practice-driven scenarios, where the performance is the valued outcome and the performer is the main evaluation actor; predictability of the artefact's behaviour becomes an important measure to achieve learned practice and exploration of the performative space, both for range and expressiveness;

6. "DOING": as sound becomes complementary (and possibly expendable) in action-driven scenarios, the artefact returns to a linear composition, in a co-ordinated dialogue with the participant's actions. A reactive artefact, responding to interactions, can turn the participant into a performer and the driving agent of the experience. Sonic contributions can enhance perception of the related operations' opportunity and feedback. Evaluations can assess how influential or valuable are the sonic contributions to the action experience;

Coming back to our initial questions, we will here take stock of the insights. Retrieving the *user-centred / system-based* di-

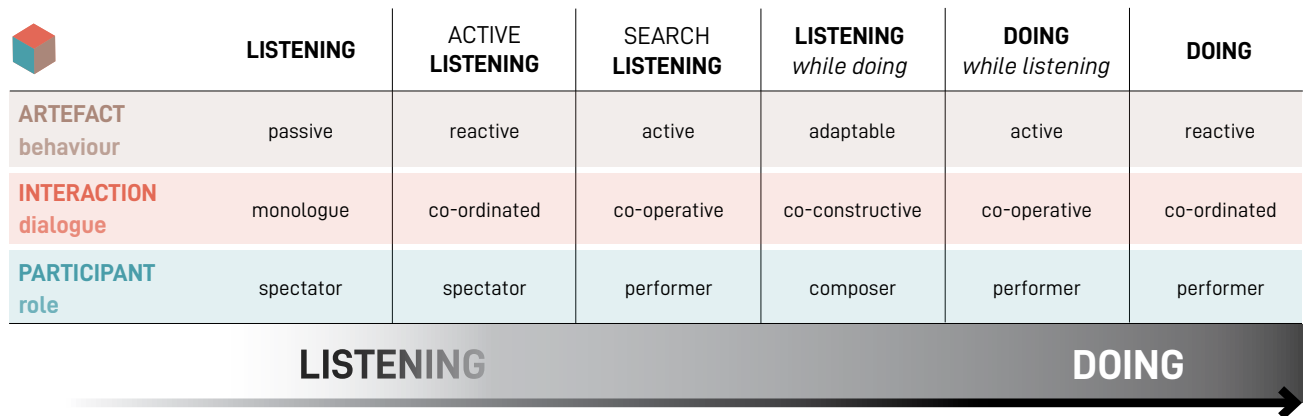|	LISTENING	ACTIVE LISTENING	SEARCH LISTENING	LISTENING *while doing*	DOING *while listening*	DOING
ARTEFACT behaviour	passive	reactive	active	adaptable	active	reactive
INTERACTION dialogue	monologue	co-ordinated	co-operative	co-constructive	co-operative	co-ordinated
PARTICIPANT role	spectator	spectator	performer	composer	performer	performer

LISTENING   DOING

Figure 3: Reinterpretation of the Six-Approach Evaluation Framework

chotomy, we considered: 1. how the artefact's behaviour helped distinguish its influence in the interaction space 2. how this influences or is influenced by the participant's role; and 3. how the sonic experience unfolds in monologue or dialogue between these. The analysis of the six approaches reveals that the artefact's behaviour influence what can be evaluated from the auditory experience, and how. The engagement of the participant generates specific interaction dynamics compatible with each artefact behaviour; however, evaluation must be reconsidered in each context, according to a perspective of what is valuable in that context. Could there be more intrinsic dimensions to each element that may expand the initial proposed parameters? A deeper look into aspects and dynamics of sound perception, as well as an integration of modes of listening, could further expand our understanding of participant agency and the detailed flow of interaction.

A theoretical understanding of the elements involved shows the six approaches as representative of a spectrum of possibilities; however, more complex artefacts can mix diverse shapes and behaviours; multiple interaction dynamics can also appear combined. These aspects solicit further research work to generate insights into how existing evaluation techniques can be combined and transformed to generate more complex, alternative approaches.

6. CONCLUSION

We provided an overview of theoretical contributions from sound-related communities, reflecting on how current models inform audio-centred perspectives on interaction with artefacts. We considered how the conception and evaluation of auditory artefacts could be influenced by a theoretical reinterpretation of the six-approach framework with the *artefact*, *participant* and *interaction* elements. We formed new theoretical explanations on what and how to configure these approaches, from which the reader can foresee the synthesis of complementary approaches.

This work is a first step towards identifying a body of knowledge on the participant's experience, how the act of listening takes place and how the subsequent action-perception loops that comprise the interaction dynamics evolve as dialogical spaces for making sense of the auditory experience. With this work, practitioners can generate insights into how existing techniques for creating auditory artefacts can be configured and transformed into new, alternative approaches.

7. ACKNOWLEDGMENT

8. REFERENCES

[1] M. Chion, *Audio-vision: Sound on Screen*, C. Gorbman, Ed. New York, USA: Columbia University Press, 1994.

[2] B. Truax, *Acoustic communication*. Norwood, New Jersey: Ablex Publishing Corporation, 1984.

[3] R. M. Schafer, *The soundscape: Our sonic environment and the tuning of the world*. Simon and Schuster, 1993.

[4] J. G. Neuhoff, *Ecological Psychoacoustics*. Elsevier Academic Press Amsterdam; Boston, 2004, ch. Ecological Psychoacoustics: Introduction and History, pp. 1–13.

[5] S. Bly, "Presenting information in sound," in *Proceedings of the 1982 Conference on Human Factors in Computing Systems*, ser. CHI '82. New York, NY, USA: Association for Computing Machinery, 1982, p. 371375. [Online]. Available: https://doi.org/10.1145/800049.801814

[6] J. G. Neuhoff, "Is sonification doomed to fail?" in *In Proooceedings of the 25th International Conference on Auditory Display (ICAD 2019)*. Georgia Institute of Technology, 2019.

[7] M. Seiça, L. Roque, P. Martins, and F. A. Cardoso, "Contrasts and similarities between two audio research communities in evaluating auditory artefacts," in *Proceedings of the 15th International Conference on Audio Mostly*, ser. AM '20. New York, NY, USA: Association for Computing Machinery, 2020, p. 183190. [Online]. Available: https://doi.org/10.1145/3411109.3411146

[8] S. Serafin, K. Franinović, T. Hermann, G. Lemaitre, M. Rinott, and D. Rocchesso, *The Sonification Handbook*. Berlin, Germany: Logos Verlag, 2011, ch. Sonic Interaction Design, pp. 87–110.

[9] P. Sengers and B. Gaver, "Staying open to interpretation: engaging multiple meanings in design and evaluation," in *Proceedings of the 6th conference on Designing Interactive systems*, 2006, pp. 99–108.

[10] D. Svanaes, "Interaction design for and with the lived body: Some implications of merleau-ponty's phenomenology," *ACM Transactions on Computer-Human Interaction (TOCHI)*, vol. 20, no. 1, p. 8, 2013.

[11] T. Hermann, "Taxonomy and definitions for sonification and auditory display," in *Proceedings of the 14th International Conference on Auditory Display*, 2008.

[12] A. Hunt and T. Hermann, *The Sonification Handbook*. Berlin, Germany: Logos Verlag, 2011, ch. Interactive Sonification, pp. 273–298.

[13] S. Roddy and D. Furlong, "Embodied aesthetics in auditory display," *Organised Sound*, vol. 19, no. 1, pp. 70–77, 2014.

[14] S. Roddy and B. Bridges, "Sounding human with data: The role of embodied conceptual metaphors and aesthetics in representing and exploring data sets," in *Proceedings of the Music Technology Workshop*, 2016.

[15] P. Vickers, B. Hogg, and D. Worrall, *Body, Sound and Space in Music and Beyond: Multimodal Explorations*. London and New York: Routledge Taylor Francis Group, 2017, ch. Aesthetics of sonification: taking the subject-position, pp. 89–109.

[16] M. Seiça, L. Roque, P. Martins, and F. A. Cardoso, "A systemic perspective for sonification aesthetics," in *Proceedings of the 26th International Conference on Auditory Display (ICAD 2021)*. Department of Computer and Information Sciences, Northumbria University, June 2021.

[17] K. Vogt, "A quantitative evaluation approach to sonifications," in *Proceedings of the 17th International Conference on Auditory Display (ICAD 2014)*, Budapest, Hungary, 2014.

[18] K. Vogt, V. Goudarzi, and R. Parncutt, "Empirical aesthetic evaluation of sonifications," in *Proceedings of the 16th International Conference on Auditory Display (ICAD 2013)*, Lodz, Poland, 2013, pp. 175–179.

[19] M. S. O'Modhrain, "A framework for the evaluation of digital musical instruments," *Computer Music Journal*, vol. 35, no. 1, pp. 28–42, 2011. [Online]. Available: https://doi.org/10.1162/COMJ_a_00038

[20] A. Prechtl, R. C. Laney, A. Willis, and R. Samuels, "Methodological approaches to the evaluation of game music systems," in *Audio Mostly 2014, AM '14, Aalborg, Denmark, October 1-3, 2014*, M. Grimshaw and M. Walther-Hansen, Eds. ACM, 2014, pp. 26:1–26:8. [Online]. Available: https://doi.org/10.1145/2636879.2636906

[21] J. Barbosa, J. Malloch, M. Wanderley, and S. Huot, "What does 'evaluation' mean for the nime community?" in *Proceedings of the International Conference on New Interfaces for Musical Expression*, E. Berdahl and J. Allison, Eds. Baton Rouge, Louisiana, USA: Louisiana State University, May 2015, pp. 156–161. [Online]. Available: http://www.nime.org/proceedings/2015/nime2015_301.pdf

[22] D. Brown, C. Nash, and T. Mitchell, "A user experience review of music interaction evaluations," in *Proceedings of the International Conference on New Interfaces for Musical Expression*. Copenhagen, Denmark: Aalborg University Copenhagen, 2017, pp. 370–375. [Online]. Available: http://www.nime.org/proceedings/2017/nime2017_paper0070.pdf

[23] E. T. Hall, *Beyond culture*. Anchor, 1989.

[24] S. Bødker and C. N. Klokmose, "The human–artifact model: An activity theoretical approach to artifact ecologies," *Human–Computer Interaction*, vol. 26, no. 4, pp. 315–371, 2011.

[25] J. Bardram, "Designing for the dynamics of cooperative work activities," in *Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work*, 1998, pp. 89–98.

[26] E. Elmquist, M. Ejdbo, A. Bock, and N. Rönnberg, "Openspace sonification: complementing visualization of the solar system with sound," in *In Prooceedings of the 26th International Conference on Auditory Display (ICAD 2021)*. Georgia Institute of Technology, 2021.

[27] J. Ferguson and S. Brewster, "Evaluating the magnitude estimation approach for designing sonification mapping topologies," in *In Prooceedings of the 25th International Conference on Auditory Display (ICAD 2019)*. Georgia Institute of Technology, 2019.

[28] M. Seiça, P. Martins, L. Roque, and F. A. Cardoso, "A sonification experience to portray the sounds of portuguese consumption habits," in *Proceedings of the 25th International Conference on Auditory Display (ICAD 2019)*. Department of Computer and Information Sciences, Northumbria University, June 2019. [Online]. Available: https://doi.org/10.21785/icad2019.050

[29] F. Dombois, O. Brodwolf, O. Friedli, I. Rennert, and T. Koenig, "Sonifyer: A concept, a software, a platform," in *In Prooceedings of the 14th International Conference on Auditory Display (ICAD 2008)*. Georgia Institute of Technology, 2008.

[30] N. Rönnberg and J. Lowgren, "Traces of modal synergy: studying interactive musical sonification of images in general-audience use," in *In Prooceedings of the 25th International Conference on Auditory Display (ICAD 2019)*. Georgia Institute of Technology, 2019.

[31] R. Tünnermann, L. Kolbe, T. Bovermann, and T. Hermann, "Surface interactions for interactive sonification," ser. CMMR/ICAD'09. Berlin, Heidelberg: Springer-Verlag, 2009, p. 166183. [Online]. Available: https://doi.org/10.1007/978-3-642-12439-6_9

[32] V. Goudarzi, K. Vogt, and R. Holdrich, "Observations on an interdisciplinary design process using a sonification framework," in *Proceedings of the 21st International Conference on Auditory Display*, Graz, Austria, 2015, pp. 81–85.

[33] O. Metatla, N. Bryan-Kinns, T. Stockman, and F. Martin, "Sonifications for digital audio workstations: Reflections on a participatory design approach," in *In Prooceedings of the 21st International Conference on Auditory Display (ICAD 2015)*. Georgia Institute of Technology, 2015.

[34] Y. Nagashima, "Interactive multimedia performance with bio-sensing and bio-feedback," in *In Prooceedings of the 7th International Conference on Auditory Display (ICAD 2002)*. Georgia Institute of Technology, 2002.