DOI: 10.61782/fa.2023.0761

forum acusticum 2023

DESIGN GUIDELINES TOWARDS PROTOTYPING TOOLS FOR SONIC SKETCHING IN UX DESIGN

Diana Vardanyan[1*] **Gijs Huisman**[1] **Dave Murray-Rust**[1]
Stefano Delle Monache[1]
[1] Faculty of Industrial Design Engineering, Delft University of Technology, The Netherlands

ABSTRACT

When done right, sound design can greatly enhance both physical and digital products. The sounds used to underscore interactions with products are typically short, with an emphasis on timbre and shape, focusing on character rather than musical features, which requires particular approaches to sound sculpting.
However, designers often lack the needed tools and skills, including the language to describe sound features, to integrate sound design in their process, particularly in early stage design activities.
This study presents and discusses a set of requirements for sonic sketching tools specifically tailored to UX (User Experience) designers. The requirements were distilled by means of generative design research methods, including interviews with UX experts, context mapping, prototyping activities and user testing. Currently, Timbreworld, a workbench prototype for sonic sketching in UX is being built, tested and iterated, and early results are outlined.

Keywords: *sonic sketching, design tools, UX design, sound design*

1. INTRODUCTION

Most of the products currently produced emit sounds. These can be mechanical, consequential sounds resulting from the choice of embodiment and material, as found in our kitchen appliances for instance, or the carefully composed, intentional chimes of our mobile applications. The latter are artificial and composed, they are integrated in products via electroacoustic reproduction, and exist separately from the physical qualities of the products and their material decay, as such they can be fully designed and customised [1, 2].
Sound has proven to be an integral part of the user experience. By providing an additional channel of communication with the user, sound not only embodies information, but can also guide the interaction between the user and the product, while supporting specific brand values and identity [3, 4]. While sound plays a role in the UX (User Experience) design, sound design itself is often a separate professional expertise [5, 6]. Since the visual and material qualities of a product are prioritised in the design process, sound design usually enters the detailing phase, after the completion of the product development. However research shows that integrating sound design at various levels of the UX design process can help achieve a cohesive product experience [7].
Sound design tools typically consist of DAW's (digital audio workstations) and music programming languages such as Cycling'74 MAX[1] which can be combined with controllers, from the keyboard to knobs and knots, and sensors of various kinds [8, 9]. A certain level of expertise is needed to be able to use these complex interfaces in a dynamic, reflective and responsive manner that is expected from an iterative prototyping activity, essential in UX design [10].
Lack of sound expertise, appropriate tools and semantic gaps are some difficulties that UX designers may experience when incorporating sound in their projects: UX designers, as well as sound designers, may use metaphors and analogies to communicate their sonic visions. However such, subjective, mental representations are often used differently and inconsistently. The participation of other stakeholders,

[*] ***Corresponding author***: *diana.e.vardanyan@gmail.com*

[1] https://cycling74.com/

target groups and clients, may also affect the communication and collaboration, resulting in misunderstandings and delays in the design process [11].

A design solution should take in account the needs and the practices of UX designers. Hence, we performed a series of generative design research activities aimed at distilling design guidelines to integrate sonic sketching in the current practices of UX designers.

In this paper, we report the iterative design process that led to formulation of design guidelines and that we applied in the conceptual design of Timbreworld; a tool that embraces the perspective of UX designers and allows them to collaborate on the sonic sketching of artificial, intentional sounds in the context of UX.

The paper is organised as follows: in Section 2 we characterise sonic sketching as a form of conceptual representation with sound; in Section 3 we report the design research activities and formulate the design guidelines; in Section 4 we introduce Timbreworld, we discuss our findings and conclusions in Section 5.

2. BACKGROUND

2.1 Sketching with sound

Sketching is a reflective activity which creative professionals engage in to elicit interpretation and understanding, especially in the early stages of the project, where multiple options are considered. Typically associated with the production of visual representations, sketching may well involve other forms of sensory representations, physical props and sounds, as long as it supports the generation, communication, evaluation and selection of design ideas [12]. In the context of this study, we are interested in sonic sketching, that is generating and communicating design ideas "with" sound. The emphasis on "with" is intentional, to stress the experiential and integrative application of sound from the very beginning of the project, that is to explore the interplay between sound and the other sensory design elements (i.e., visual, tactile) of the product early on [13]: Designers need to consider how sound interacts with other design elements and sensory cues to provide a contextually-relevant, cohesive and engaging user experience. Anything can be repurposed as a tool for sonic sketching as long as it supports the fast-paced, iterative, nature of sketching. Designers may use their own bodies and engage in vocal scribbling [14], create their own Foley boxes and produce electroacoustic mock-ups [15]. The former could be used in combination with approaches that focus on the material qualities of product sounds [16].

2.2 Words4sounds: a Lexicon for sound descriptions

In order to fill the semantic gap between the sound designers and product designers, facilitating the verbal communication about sound is as important as externalising ideas in sonic representations. Carron et al. [11] formulated a lexicon of 35 words frequently used to describe sounds: *words4sounds* is designed to improve the communication between designers, engineers and other stakeholders on the perceived characteristics of a sound. Available as SpeaKweb[2] interface [17], the lexicon is organised into three categories: General Qualities (e.g. intensity, *'Quiet/Loud'*), Timbre (e.g. brightness, *'Dull/Bright'*) Morphology (e.g. temporal variations *'Fast/Slow Attack'*). Each word pair is underpinned by sound samples and experiential descriptions to facilitate the understanding and communication of nuanced sonic visions and support users in developing their own sonic vocabulary. Examples include musical instruments, female/male voices, environmental sounds, elementary and complex sounds to stress the contextual occurrence.

Word pairs, that is the attributes of the Timbre category, include *dull/bright, smooth/rough, dry/resonant, nasal/rich, non-/round, non-/warm, non-/strident, non-/ metallic*. In turn they can be described based on nuanced configurations of five perceived sound properties[3]:

- **Amount of high-frequency energy**: high / medium / low;
- **Temporal Asperities**: absent / present;
- **Prolongation of Energy**: present / absent;
- **Cover of the Audible Range**: high / low;
- **Attack**: slow / fast.

The *words4sounds* lexicon was extensively used in our design research activities and the timbre attributes were finally embodied in our prototype Timbreworld.

3. DESIGN RESEARCH ACTIVITIES

Our goal is to propose design tools that facilitate the integration of sound design in the current practices of UX designers. We performed a series of generative design research activities aimed at 1) understanding the current practice of expert UX designers; 2) exploring and possibly

[2] https://speak.ircam.fr/en/lexique/lexique-ircam/

[3] See, e.g. the description of the *smooth / rough* attribute in SpeaKweb.

integrating sonic sketching practices in UX design activities. For 1), we consulted design experts in order to gain deeper insights into the design process, and inform 2), by involving design students in generative design activities. The research produced a set of design guidelines, formulated at the end of this section.

3.1 Design research 1: Context mapping through interviews

We performed a series of semi-structured interviews with UX experts to understand the current practice of integrating sound in UX design.

3.1.1 Methodology

We interviewed four UX designers (*M age = 44.25 years, SD = 3.11, expertise > 10 years*) with specific expertise in serious game design, digital interfaces design, interaction design and design research. Participants were asked to describe how sound design is currently incorporated in their projects and to imagine how they could sketch their projects with sound, that is how to embody sonic sketching in their process.
The interviews were audio-recorded for the purpose of note-taking. Thematic analysis, 'on the wall', suitable for smaller research populations (<10 participants) [18] was applied to extract generalised results from the interviews.

3.1.2 Results and discussion

In the following we summarise the most prominent insights, resulting from the data analysis.
Sound is a relevant UX design element: all the interviewees acknowledge the role of sound in their practice. Sound design activities are triggered once the desired interaction qualities are defined in the brief.
Brainstorming, sampling, sharing: UX brainstorming with sound goes together with the browsing and collection of samples to share and discuss first within the UX design team, usually for the purpose of achieving a shared view of the desired ambiance. Both browsing the sound libraries and iterating it between discussions is extremely time-consuming.

"Finding the right sounds takes time. If we don't agree in the team, we try to understand what does not work. We take a step back and look for alternatives." - P1

Shared agreement and decision-making: Decision making is often collaborative, yet designers wish a way to quickly iterate through multiple options and adjust them dynamically, to facilitate and support the process.

"We need a palette [like a painting palette], to try different things out and experiment" - P3

Outsourcing and communicating to sound designers: The final sound design is usually outsourced to professional sound designers. UX designers often rely on metaphors, analogies and experiential examples to communicate about sound within the design team and with stakeholders, e.g. sound designers.

"When talking to the sound designers we tried to communicate through analogies and describe experiences we wanted to evoke. The technical terms that they used flew over our heads." - P3

Overall the designers agreed on the value of integrating sound design in their activities, and yet in a way that may more easily fit their workflow.

3.2 Design research 2: Introducing sonic sketching methods in UX

To explore the sonic sketching practices in UX and their integration possibilities, we developed and tested a paper-based prompt generator, shown in Figure 1.

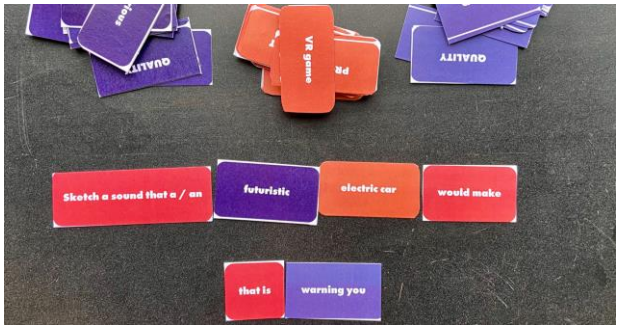

Figure 1. Paper-based design prompt generator. The product (orange tile) with its interaction vision (dark purple) and the function (light purple) are framed in the sketch command (red tiles).

This paper prototype facilitates quick brainstorming sessions on sonic visions within the context of UX projects. Without claiming to be all-encompassing, it consists of prompts that represent common outputs of UX projects: digital and physical interfaces and products.

3.2.1 Methodology

Six novice designers (*M age = 24.33 years, SD = 1.37, expertise < 5 years*) participated in individual brainstorming sessions. The participants engaged with the prototype to prompt a sonic sketching brief. They were allowed to use any available material, including a set of

sounding objects arranged in a small Foley box. The individual sessions were recorded for note-taking and thematic analysis "on the wall" [18]. Each session had a duration of 45 minutes, organised in introduction, exploration of the prompt generator, and debrief.

3.2.2 Results and discussion

The participants used verbal descriptions and imitations, word-like (e.g."buzzing") and non-verbal (e.g. "bzzzzzt") to convey their ideas. They explored the sound of the Foley and of the surrounding objects and their bodies, to play and create sonic sketches.

The "the sound" and the "with sound" approaches to sketching UX: Participants approached the UX design prompts in a dual way [8]. Three participants focused on the product and recalled from memory **"the sound"** of similar existing products, thus rather focusing on the production and articulation of the audible form, that is sound as a material, e.g. if the prompt was to design a microwave sound within a specific context they would think of their own microwave and the sounds it makes, in order to look for meaningful variations. In the **"with sound"** approach to UX sketching, three participants rather focused on the context and functions of the sound first, while abstracting it from existing products. For example, one participant designed the sound for a mobile application that counts steps, and focused on the context "walking" and on the function "counting steps" to convey the interaction quality "supportive" **with sound**, rather than proposing generic mobile application sounds.

All six participants commented on their relatively low experience with sound design, and with practical approaches to sonic sketching in particular. They would have preferred to have an entry point, such as a set of examples that they could choose from.

Three participants mentioned their discomfort in using vocalisations in a team setting, and their preference to work with prefabricated sound samples. The prototype itself represents one possibility within the full spectrum of sonic sketching applications in UX, as only a limited selection of prompts was made available.

3.3 Design research 3: Co-creation session

We ran a co-creation session to generate conceptual ideas to support UX sound design interactively, and to create rapid prototypes of sonic sketching tools.

The participants were asked to design a sonic sketching interface for one of the two scenarios: 1) user interface sounds of a ticket machine for a public transport company in Amsterdam (e.g. confirmation sounds); 2) user interface sounds of a VR game menu (such as 'clicking' sounds when a user chooses an option). The two scenarios were concrete cases reported by the interaction designer and the serious game designer.

3.3.1 Methodology

Four novice designers *(M age = 25.25 years, SD = 1.09 years, expertise < 5 years)* took part in the co-creation session. After a short introduction to the topic of sonic sketching in UX, the participants were split into pairs and introduced to their specific scenario. Both pairs had 5 minutes to brainstorm their scenario and ask questions. Further, a collective discussion of 10 minutes on sonic sketching tools for UX was facilitated. Finally, the two pairs produced a quick prototype of a sonic sketching interface in 15 minutes. Data were collected through observations, note-taking and post-session debrief with the participants, and analysed qualitatively [18].

3.3.2 Results and discussion

In the ticket machine for the public transport scenario, one pair of designers proposed a sonic sketching interface in the form of a decision-making tree. Users can select the right sound by listening to sound samples and deciding on which direction to continue looking.

In the VR game scenario, one pair proposed a paper-based tangible interface that utilises physical objects to represent sound samples and sound design functions (i.e., basic sound processors). The interface affords the physical manipulation of the sound sample by, e.g. placing a filter object directly on top of a sample object, or adjusting its duration by cutting off parts of the object representing the sample. This pair reflected on how to provide a clear overview of all available functions and the perceptual effect deriving from the alteration of the sound sample.

3.4 Formulation of the design guidelines

The insights gained through design research depicts the process of sonic sketching in UX as an iterative group activity. The design brief with its interaction qualities represents the entry point to the exploration and sketching phase. UX designers essentially explore which sounds fit their contexts and how they can be adjusted. The result is a set of sonic sketches to compare and share with other stakeholders. As a consequence, a sonic sketching tool acts primarily as a mediator between sound design instances and the UX design process.

Taken together, the design research activities generated rich insights regarding the overall design requirements for sonic sketching tools in the context of UX design. We formulated

a hierarchy of design guidelines, of which we report the most prominent ones, arranged thematically based on the generating research activity.
The tool should (interviews with UX experts):
1a. Support the sketching process of starting broad and gradually resolving towards specific sounds;
2a. Be clear in its form and functionalities in order to facilitate collaboration and discussion;
3a. Let users create / compare multiple sonic sketches;
4a. Be clear and accessible to users with different degree of expertise;
5a. Support a shared language in order to bridge the possible semantic gap between the participants.

The tool should (brainstorming and co-creation):
1b. Provide participants with possible starting points through sound samples and examples.
2b. Translate sound processing into design functions meaningful to designers and non-sound experts;
3b. Provide users with a clear overview of the available sound design functions.

The following additional functions illustrate specific possibilities of a sonic sketching tool for UX design:
1c. Enable users to add their own (contextual) samples to the interface;
2c. Be easy to transport and set up;
3c. Enable the users to save and share samples;
4c. Allow to embed the sonic sketch in its use context.

The proposed design guidelines provide designers with scaffolds to prototype tools for sound design in UX. Hence, we prototyped Timbreworld, a conceptual, interactive tool, that serves as workbench to evaluate as well the effectiveness of guidelines in facilitating the design of sonic sketching tools for UX.

4. TIMBREWORLD: INTERFACE PROTOTYPE FOR SONIC SKETCHING

Shown in Figure 3, Timbreworld consists of an interactive, digital interface which arranges sound sample libraries according to their timbral qualities. The interface embodies the *words4sounds* lexicon on timbre [13], which represents the category of descriptive words closest to the vocabulary used by UX designers, e.g. strident and bright sounds resonate to interaction qualities such as alarming or energetic.
The interface provides a conceptual visual representation of a given sound library in the space of timbral attributes, arranged in zones with different colours and textures. The spatial overlaps suggest possible perceptual and semantic connections, e.g. some metallic sounds could also be considered bright and / or strident.

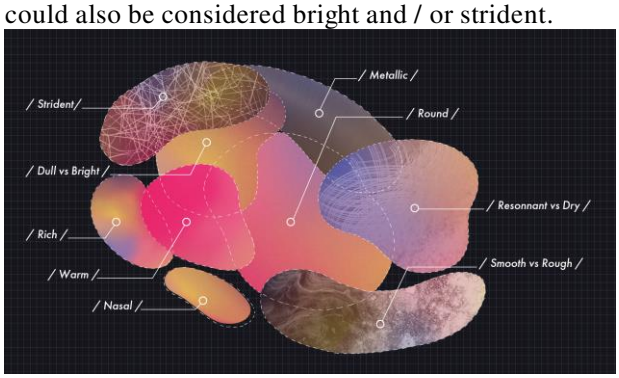

Figure 2. Timbreworld, visual representation of the timbral space of a sample library.

In its first realisation, this proof-of-concept has been manually populated with a selection of the elementary and complex sound available in SpeaKweb: The timbre library provides the user with a wide range of sounds to explore, yet in a reasonably limited quantity. This fits well with the sketching nature of casual browsing, where the UX focus is on establishing general guidelines and design directions rather than producing finalised sounds. In the future, Timbreworld could be automatically populated, so as to provide a navigation tool based on the visual representations of timbre descriptors [19].
Overall design objectives were to provide a transparent and accessible tool, in terms of immediacy of use, while exploring how to introduce meaningful sound design functions with clarity (guidelines 4a, 1b, 2b).

4.1 Evaluating the design guidelines and their integration in Timbreworld

The Timbreworld workbench was developed through iterative steps of evaluation and design. The prototyping activities served to assess as well the effectiveness of the design guidelines introduced in Section 3.4.

4.1.1 Methodology

Five novice designers (*M age = 25.25 years, SD = 1.09 years, expertise < 5 years*) participated in individual sessions of free exploration of the tool. Each session had a duration of 40 minutes. Observations, think-aloud, and semi-structured interviews were used to collect data about the contextual relevance and effectiveness of Timbreworld, including the comprehensibility of the sound properties displayed and the effectiveness of the SpeaKweb timbre

library of sounds in providing a source of inspiration for sonic sketching. The interviews provided rich data on which sound design functions UX designers would need to start creating sketches with sound, and how to include them in the interface.

4.1.2 Results

The visuo-spatial presentation of the timbre library conformed well to the visual way of thinking of designers.

"I am a very visual thinker and I suppose a lot of designers are too. Making the sounds into something visual really helps me to remember them better and understand how they [the sounds] work" - P2

Although not immediately intuitive, the audio-visual combination sparked creative associations in an explorative way, although more information on its rationale is desirable, especially to ground the argumentation when communicating with stakeholders.

"This Timbreworld looks very creative and I would like to explore it but it would be nice to get more information on why the sounds are positioned that way ... right now I am not sure what these sounds mean exactly" - P3

The participants emphasised the value of balancing the low complexity of sound manipulation with the creative freedom of applying meaningful changes.

"I would like to change these sound properties [Sec. 2.2] ... There should be a balance, if you can't change a lot it will feel like the samples are pre-designed already" - P3

"I would like to take the samples and move them around this Timbreworld and see how the sound changes when I go from for example 'bright' to 'nasal'" - P1

Taken together, the features of the conceptual tool seem to embody the design guidelines considered. The Timbreworld's visual interface communicates as well in the language of sound design. Non-sound experts can potentially develop and expand their sonic vocabulary, through discussion and exploration. We further iterated the prototype by including richer visual representations combined with basic sound processing features.

4.2 Iterating Timbreworld prototype with sound design functions

In the current iteration of Timbreworld, we introduced the possibility to manipulate the available sound samples by adjusting, reducing or exaggerating their timbral quality. This provides the user with a relatively constrained creative freedom to explore variations and produce provisional examples to support the discussion during the sketching activity. The outcomes are sonic sketches, that is sound-based temporary representations that can be used during the research, ideation and conceptualisation phases of design projects.

Table 1. Basic set of sound processing units proposed to explore timbral qualities, according to perceived sound properties.

Perceived sound property	Sound design function
Amount of high frequency energy	3-Band equaliser
Temporal asperities	Amplitude modulation with adjustable depth
Prolongation of energy	Short delay with adjustable feedback
Cover of the audible range	Bandpass filter with adjustable width and center frequency
Attack	Overall amplitude envelope

The user manipulation of the timbral qualities are achieved by means of a basic chain of five sound processors associated with the five perceived sound properties underlying the timbre characterisation, discussed in Section 2.2 and reported in Table 1.
Figure 4 shows the corresponding sound design functions, which have been simplified to ease contextual relevance and use.

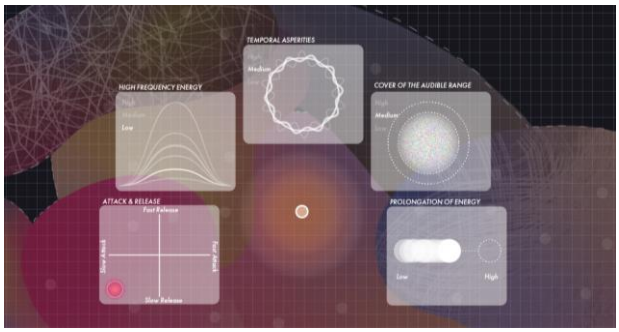

Figure 4. Selecting a sound sample (white dot) gives access to interactive sound design functions and their visual representations.

Subjectivity is necessary here, as there is a wide space of possibilities in the translation of timbral qualities in sound processing configurations. In this respect, design

guidelines 1b and 2b provide as well the necessary constraints for a preliminary evaluation of technologies aimed at supporting the sonic sketching process in UX. The interactive interface has been programmed in p5.js[4] and Ableton Live[5] for the sound processing part via the Open Sound Control communication protocol[6]. The sound sample - processor association has been conceived to preserve the logic and reversibility of the process (e.g. a reversible smooth/rough transition is possible when the amplitude modulation is applied to the smooth sound).

5. DISCUSSION AND CONCLUSIONS

The design research activities stressed the significant role of sound in UX design. Our study problematises the integration of sound as design element in the overall UX design process, from the perspective of the design culture of UX practitioners. The difficult integration of sound design practices in UX design can be ascribed to the inherent ambiguity of the object and actions involved in designing sound, which encompass diverse yet complementary framing, tools and methodology [13].
The emerging semantic gap is not only linguistic, but also methodological and currently reflected in the late, outsourced involvement of sound designers in the final stages of the product development [20]. The iterative process of design research activities provided insightful results on the needs of UX designers, regarding the incorporation of sound as a collaborative and fast-paced medium to channel design directions in UX projects.
Conceiving design tools concerns both the technology and embodiment, that is supporting specific, contextual activities, e.g. conceptualisation, communication, and collaboration [21], and fitting in a given, established workflow. Conceiving sonic sketching tools and methods share challenges similar to Digital Musical Instrument design, including issues of expressivity, consolidation of a repertoire of use, and all the contextual factors that affect the adoption and refinement of a novel instrument [22].
The resulting design guidelines facilitate the conceptualisation of sound prototyping tools in UX. They are formulated in general terms, yet their weight should be compared against the specific use context of the intended tool. That is, they are not meant to provide a list of desiderata for an all-in-one solution. We applied the guidelines in the design of a conceptual prototype for sonic sketching: Timbreworld. The tool provides the user with an interface to navigate the timbral space of a given sound library. Although it may resonate with many graphical interpolators for sound design [23], the added value of Timbreworld is the semantic and contextual orientation of its navigation rationale, which proposes a simplified strategy based on a validated subset of perceived sound properties with strong semantic implications [11, 17].
The early evaluation of the Timbreworld interface proved the value of the proposed design guidelines, at least of those embodying immediacy of use and accessibility (guideline 4a). Currently, the sound design functions (guidelines 1b, 2b) are being evaluated. An extended period of experimentation in context is needed to assess the value of Timbreworld in supporting the typical funnel-like shape of sketch-thinking as well the facilitation of a shared mental model among stakeholders (guidelines 1a, 2a, 3a, 5a). This step requires the move of Timbreworld from its conceptual state to a working prototype, including the set of primary functions (1-4c). Timbreworld is currently a screen-based interface with input constraints limiting its potential in collaborative prototyping. A tangible translation of Timbreworld could improve its physicality, expressivity and learning [24, 25].
By creating tools for UX design we are empowering designers to integrate sound in their design process, and to develop and promote a design culture on sound.

[4] https://p5js.org/
[5] https://www.ableton.com/
[6] https://github.com/genekogan/p5js-osc

6. REFERENCES

[1] E. Özcan, R. van Egmond and J.J. Jacobs: "Product sounds: Basic concepts and categories," International Journal of Design, vol 8, no. 3, pp. 97-111, 2014.

[2] D. Hug, "Genie in a bottle: Object-sound reconfigurations for interactive commodities," Proc. of 3rd Audio Mostly Conference on Interaction with Sound, pp. 56–63, 2008.

[3] R. Sanz Segura and E. Manchado Pérez: "Product sound design as a valuable tool in the product development process," Ergonomics in Design, vol. 26, no. 4, pp. 20–24, 2018.

[4] D. Rocchesso, S. Delle Monache and S. Barrass: "Interaction by ear," *International Journal of Human-Computer Studies*, vol. 131, pp. 152-159, 2019.

[5] A. Ikonen: "On the importance of listening," *Foundations in Sound Design for Embedded Media*, pp. 380-395. New York: Routledge, 2019.

[6] M.L. Austin: "Sound and UX design," *Foundations in Sound Design for Embedded Media*, pp. 318 - 334. New York: Routledge, 2019.

[7] J. Maculewicz and K. Osz: "UX Research and Sonic Interaction: Towards Human-Centric and Intuitive Sound Interaction Design in the Context of Autonomous Driving," *User Experience Design in the Era of Automated Driving. Studies in Computational Intelligence*, vol. 980, pp. 335-357, 2022.

[8] E.R. Miranda and M.M. Wanderley: *New digital musical instruments: Control and interaction beyond the keyboard*. Middleton: AR Editions, Inc., 2006.

[9] R. Tubb and S. Dixon, "An evaluation of multidimensional controllers for sound design tasks," in *Proc. of the 33rd Annual ACM Conference on Human Factors in Computing Systems,* pp. 47-56, 2015.

[10] B. Buxton: *Sketching User Experiences: Getting the Design Right and the Right Design*, Canada: Morgan Kaufmann, 2007.

[11] M. Carron, T. Rotureau, F. Dubois, N. Misdariis and P. Susini.: "Speaking about sounds: a tool for communication on sound features," *Journal of Design Research*, vol. 15, no. 2, pp. 85-109, 2017.

[12] S. Delle Monache and D. Rocchesso: "Sketching Sonic Interactions," *Foundations in Sound Design for Embedded Media*, pp. 70-101. New York: Routledge, 2019.

[13] S. Delle Monache, N. Misdariis and E. Özcan: "Semantic models of sound-driven design: Designing with listening in mind," *Design Studies*, vol. 83, pp. 101-134, 2022.

[14] G. Lemaitre, P, Susini, D. Rocchesso, C. Lambourg and P. Boussard: "Non-Verbal Imitations as a sketching Tool for Sound Design", *Sound, Music, and Motion. CMMR 2013. Lecture Notes in Computer Science,* vol 8905, pp. 558–574, 2013.

[15] D.H.M Kemper and D. Hug: "From foley to function: A pedagogical approach to sound design for novel interactions," *Journal of Sonic Studies*, vol. 6, no. 1, pp. 1-23, 2014.

[16] D. Dal Palù: "Sound as a project requirement: evolution of an experimental tool for psychoacousticevaluation of materials in architecture and design, " in Materials Experience 2: Expanding Territories of Materials and Design, pp 127-130, 2021.

[17] P. Susini, O. Houix, N. Misdariis, P. Faramaz and G. Pellerin: "The SpeaK project: A collaborative platform for presenting and sharing sound lexicons," in *16ème Congrès Français d'Acoustique*, 2022.

[18] E.B.-N. Sanders and P.J. Stappers: *"Convivial Toolbox"*, Amsterdam: BIS, 2018.

[19] Schwarz, D., Schnell, N., and Gulluni, S.: "Scalability in content-based navigation of sound databases," in *Proc. International Computer Music Conference (ICMC)*, pp. 13-16, 2009.

[20] D. Hug: : "How do you sound design? An exploratory investigation of sound design process visualizations," in *Proc. of the 15th International Audio Mostly Conference*, pp. 114-121, 2020.

[21] R.J. Jansen, E. Özcan and R. Vanegmond: "PSST! Product Sound Sketching Tool," *J. Audio Eng. Soc.,* vol. 59, no. 6, pp. 396-403, 2011.

[22] R. Medeiros, F. Calegario, G. Cabral and G. Ramalho: "Challenges in Designing New Interfaces for Musical Expression," *Design, User Experience, and Usability. Theories, Methods, and Tools for Designing the User Experience*, vol. 8517, pp. 643–652, 2014.

[23] D. Gibson and R. Polfreman: "Analyzing journeys in sound: usability of graphical interpolators for sound design," in *Pers. Ubiquit. Comput.,* vol. 25, pp. 663–676, 2021.

[24] A. Jönsson, R. Breslin, and M. Ma: "The Ambience Table: A Serious Gaming Interface for Aiding Sound Design," *Serious Games Development and Applications. SGDA 2013. Lecture Notes in Computer Science*, vol 8101, pp. 151–164, 2013.

[25] A. Colter, P. Davivongsa, D.D. Haddad, H. Moore, B. Tice and H. Ishii: "SoundFORMS: Manipulating Sound Through Touch" in *Proc. of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16)*, pp. 2425–2430, 2016.