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Guiding design students to sound-driven design from the base camp of semiotics

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Abstract: The lack of knowledge in the field of sound-driven design lags our educational efforts to teach BSc students about the role of sound in current design process methodologies. Teaching programs rarely include subjects dedicated to creating a coherent experience using data-to-sound strategies, sound informativeness, or the interactions that users have with product sounds. Understanding sound at the same level as other sensory cues prepares students to enrich the usability, attractiveness, and communicative qualities of products, services, and systems. This contribution aims to provide an integrative and multidisciplinary perspective of sound-driven design through the adaptation and application of the 'Design Framework for Audible Alarms' as a conceptual design tool in semiotics. The framework is exemplified through several design cases carried out in the sessions of the subject 'Semiotics in design' during two academic years, as part of the BSc in Industrial Design and Product Development Engineering.

Keywords: design framework; semiotics; educational design; communication design.

1. Introduction

The current socio-technological context has enhanced the role of sound when designing products, services, systems, environments, and communication processes for our everyday lives. Sound-driven design is a field of human-centered design practice and research informed by technology and listening in the multisensory dimension of interaction. The current extent of this discipline, as a subdomain of design science, has promoted an active ground of inquiry into integrating sound design methodologies within existing design processes. This approach underscores the comprehensive and inclusive nature of "sound-driven" design, amalgamating diverse sonic, experiential, technical, and cultural elements with the creative and purposeful essence of design (Delle Monache et al., 2021; 2022).



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However, the lack of teaching strategies in the field of sound-driven design lags our educational efforts to teach BSc design students how to use sound to create a coherent, and enriched user experience. Curricula in design-focused institutions and programs often lack dedicated content on data-to-sound strategies, i.e. the practice of representing data through sound; sound informativeness; or sound and interactivity. According to the international educational programs collected (ANECA, 2005), sound design processes have been mostly addressed in fields like computer science, auditory displays, and sonic interaction design. Meanwhile, there is a growing call within the design community, especially among sound-driven design researchers and practitioners, for methodological frameworks to incorporate the role of sound and listening experiences into institutionalized educational programs. This demand is evidenced by initiatives such as the establishment of a new 'Special Interest Group' (SIG) on Sound Driven Design, under the Design Research Society (DRS), aimed to establish and spread a design culture on sound and listening.

From a wide perspective, semiotics provides a general framework for the study and design of signs that convey meaning in any social and interaction context (Murphy, 2006); and consequently, an appropriate motivating space to offer audible directions for designers to understand sound at the same level as other sensory cues. Furthermore, in designing multimodal interaction, the use of outgoing sounds enhances the creation of a coherent multimodal experience where visuals and other sensory cues can support each other to enrich the communication process.

This contribution presents a teaching experience that guides students from the base camp of semiotics, inspired by the Design Framework for Audible Alarms (Author et al., 2022). In this case, the framework is adapted as a conceptual tool to introduce novice designers to sound-driven design. The learning process is exemplified through several design cases carried out by students of the subject 'Semiotics in design' during two different academic years and as part of the BSc in Industrial Design and Product Development Engineering. Through a series of workshop sessions, students are presented with a more theoretical design background that can be integrated with a practical approach to improve the outcome of future generations of designers in the conception of the audible design space for users.

This paper is organized as follows: in the 1st section, we follow a theoretical roadmap presented to the design students step-wise, under the umbrella of semiotics and highlighting the role of sound in the design process; in the 2nd section, we present the design framework to be later applied through several design cases developed by the group of students. Finally, we present our recommendations for future application of the design framework as an integrative and multidisciplinary approach to understanding and conceptualizing sound stimuli as part of a whole.

The discussion of each of the stages highlighted relevant topics such as data-to-sound knowledge, how to collect ethical and meaningful data according to current technological advances (e.g. machine learning, AI); the need for methods and tools that support the design process (e.g. participatory approaches); and the understanding of shaping soundscapes from

a human perspective and the listening experience. As a result, this paper shows a teaching experience where semiotics is used as a reliable base camp to provide design students and teaching teams a support tool for sound-driven design practice.

2. The path from semiotics to sound-driven design

The study plan for the subject 'Semiotics in Design' covers 15 weeks (4 hours per week including theory lessons and practical work) distributed during the first semester of the fourth academic year of the BSc in Industrial Design and Product Development Engineering. Through a sequential and iterative curriculum, students take part in a learning experience that solidifies previously learned knowledge and skills and develops the new ones required to delve into sound-driven design.

In this section, we present the path taken and the content during the scheduled program of theory and practice sessions carried out on the subject, according to the phase of design and the curriculum course (see Figure 1). The entire group attended each session which lasted 90 minutes. In the first three sessions, the teaching team presented the theoretical basis. The last three sessions were dedicated to the understanding and application of the framework for sound-driven design. A design case was developed for each team of two students. Below, we delve into the different sessions and the corresponding contents addressed.



Figure 1 The path from semiotics to sound-driven design. A teaching experience.

2.1 Session 1 — Understanding fundamentals of semiotics

Students begin learning the fundamentals of semiotics as the scientific discipline that frames the general theoretical study of signs in everyday life and explores the mechanisms underlying the complex dimension of meaning. Hence, from the applied domain of product design, semiotics are also introduced to design students as a discipline that aims to ease the

communication between products and their users in a certain context of use. Paraphrasing Murphy (2006), the semiotic perspective of the 'study of signs' provides an:

“appropriate conceptual basis to address the design approach and is largely applicable to the analysis of communication through non-speech sounds [...] from a semiotic perspective, the context of use is as important as the properties of individual sound. In structural semiotics, semantic analysis is performed across two different dimensions: syntagmatic and paradigmatic”. (Murphy, 2006, p. 123)

Murphy refers to seminal Saussure's structuralism and the linguistic dimension of the sign as a base for understanding sound design. Inspired by this approach, we plan the design process of the product, in the educational context, as the development of a semiological system where the sign is defined by the elements shown in Figure 2, to build the conceptual structure of communication.

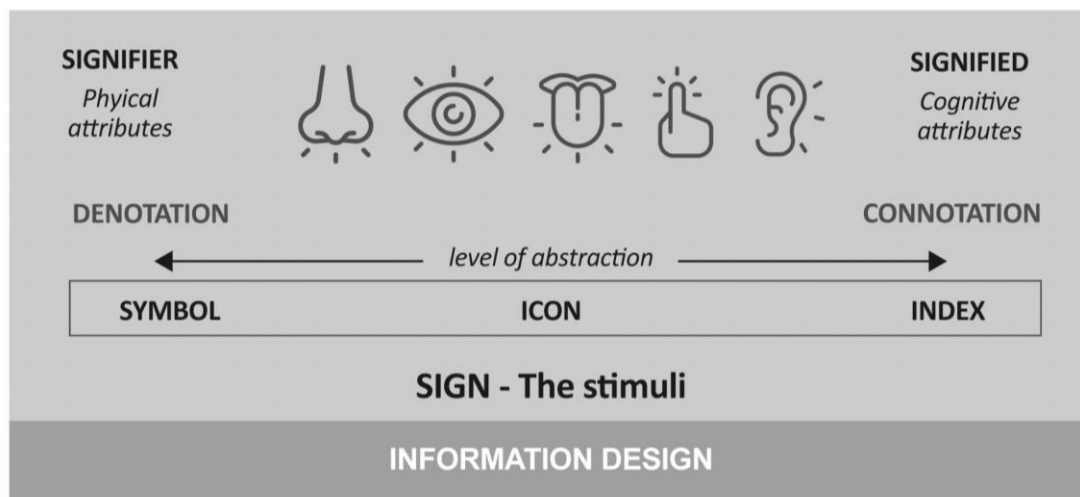


Figure 2 The study of 'the sign' when designing products from a semiotic approach.

Hence, in addition to the semiotic principles and the communication models literature (Miller, 2005; Cobley & Schulz, 2013), information design is the underlying discipline to determine and evaluate the right sensory modality of the sign to transmit the message in interactive contexts. Information designers ensure the aesthetic quality of the audible stimuli by manipulating the physical parameters of sound (i.e., the signifier), and considering the informativeness of stimuli as well as their inherent meanings for the operators (i.e., the signified) (Phansalkar et al., 2010; Wild et al., 2010; Özcan & van Egmond, 2012).

To address the entire product experience, the stimuli must convey a meaningful significance for potential users, and link the perception of physical parameters with consequent judgment. Thus, the sign is a carrier of meaning in a more abstract or symbolic sense, which is explored depending on how literal the relationship between sign and meaning is in semiotic terms (i.e., the symbol-icon-index range). This approach offers us an integrative playground to discover new ways of thinking to prompt creative potential and new design solutions.

2.2 Session 2 — Designing multimodal interactive experiences

The second session starts with a reflection on designing a multimodal interaction and product experience following the principles of a communication process (Schifferstein & Desmet, 2008). Multimodal vs crossmodal options are presented as the modes of communication to consider the needs of the particular context of information and use, in terms of usability, accuracy, effectiveness, and inclusiveness.

Although our perception is multimodal, the design process implies the conceptualization and design of each source of information independently but considering the most appropriate sensory modality for each message or event to communicate. Figure 3 shows the three fundamentally different but interdependent parts of the stimuli design process (i.e., event-sign-action), supported by the contribution of the three major disciplines to designers' knowledge (systems engineering, information design, and human factors).

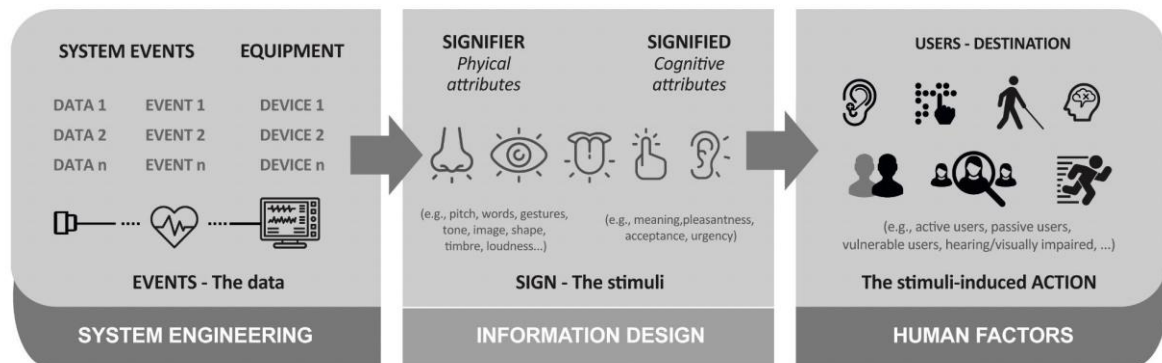


Figure 3 Designing the product multimodal experience from a semiotic approach.

Hence, the design team must list the set of events from data collection that will trigger the stimuli or message in question. Where appropriate, data and corresponding events should be ranked according to their level of criticality to meet the information needs of the particular context of use. Likewise, the set of displays (visual, auditory, haptic...) available to transmit the range of events must be listed and characterized.

Then, the sign (either an auditory message or a visual) is designed according to i) the physical parameters; ii) the cognitive aspects associated with it, regarding the perceptual and emotional situation of the different users; and iii) the type of information that the sound should convey (e.g., identification and localizability of the device or product; a particular association between the stimuli and meaning; the level of training and learning of the receiver; what the receiver should do in response; or an urgency mapping).

Considering these aspects, we define the informativeness of the message and consequently, of the product as a whole. Regarding the action component, the final aim of the product is to call attention to a 'critical, major or minor event' that will give rise to the corresponding action by a range of potential receivers. However, it could not always be obvious in a particular applied domain what the desired and required actions are. Ecological relevance

must be considered by designers to understand the variety of scenarios and actors, noise background, and the most vulnerable users in terms of inclusive design (see Figure 3). As far as the destination of the stimuli is concerned (i.e., the receiver), we should first consider who is the target audience for a particular event, and their needs and capacities. Likewise, the type of response that is required by the receivers must be considered to be able to measure the level of compliance between the event and the desired action.

2.3 Session 3 — Sound-driven design: The role of sound in the design process

The lack of knowledge in the field of sound-driven design lags our educational efforts to teach BSc students the role of sound in current design process methodologies. The teaching programs rarely include subjects dedicated to creating a coherent experience by means of data-to-sound strategies, sound informativeness, or the interactions that users have with product sounds. Understanding sound at the same level as other sensory cues prepares students to enrich the usability, attractiveness, and communicative qualities of products, services, and systems. This contribution aims to provide an integrative and multidisciplinary perspective of sound-driven design through the adaptation and application of the 'Design Framework for Audible Alarms' as a conceptual design tool in semiotics. The framework is exemplified through several design cases carried out in the sessions of the subject 'Semiotics in design' during two academic years, as part of the BSc in Industrial Design and Product Development Engineering.

Although design culture and design learning traditionally revolve around the power of visual communication, sound is a useful alternative to the dominant visual channel for attracting attention to particular events and locations (Author, 2021), but also for exploring new interactive design solutions for the needs of current complex societal systems (Norman & Stappers, 2015). Sound is a good mediator for directing people to a certain task and therefore, deserves a rightful place in teaching design activities that tackle human feedback, response, and action.

During the last theoretical session, we focused solely on the auditory events as a functional entity to convey meaningful messages (Özcan & van Egmond, 2012), specifically in inclusive design approaches, or interactive contexts that require the right level of representation of complex messages, events, or concepts. Nevertheless, information designers may value the approach of an extended study for other sensory modalities (i.e., no auditory messages) such as visual, tactile, or vibrotactile cues in an attempt to also address communication challenges. This approach aims to enhance the overall user-friendliness of interfaces and envision the future of communication that accommodates diverse needs and capabilities.

Thus, the objective of this session is to present students with the sound universe in terms of how the sound event becomes meaningful because it elicits sensory reactions and emotions in listeners. Particularly, a preliminary reflection on the role of sound in attracting attention in our daily lives is offered, in an attempt to achieve future product design solutions that communicate with the same richness as we do when interacting with the world around us.

The future challenge for designers is taking full advantage of new-generation modern abstract sounds, and auditory icons (Cabral & Remijn, 2019) to provide information about the status of a system, device, or event from an integrative and multidisciplinary design approach, understanding the data that precedes the sound stimulus and the subsequent sound-induced action. That is, defining new meaningful stimuli, considering all stakeholders in the ecology system, and the required means to ease their learnability, localizability, unmasking, and the informativeness that an auditory message should convey. Thus, designing with sound implies knowledge from different domains and goes way beyond the physical and psychoacoustic parameters of sound. Particularly, sound designers advocate an interdisciplinary approach involving engineering, musicology, psychology, (psycho) acoustics, and human factors. In this sense, novice designers demand a deeper conceptualization of sound in the early and previous stages of the sound design process (Polotti & Lemaitre, 2013; Hug, 2020; Misdariis & Hug, 2020), as well as a reflection on what kind of sounds we want to hear and feel with our everyday products.

2.4 Session 4 — A framework for sound-driven design

In the following session, the basic components of the audible design are defined, starting from what a sound represents (an event) to what sound triggers (an action), to evidence to students of the complexity of the design process for audible information, and how they can tackle this complexity. Inspired and adapted from the Design Framework for Audible Alarms (Author et al., 2022), we follow the same logic of alarm triangulation (event-alarm-action), adapting it to cases of sound-driven design in the educational context. During this session, the three main pillars (event-sound-action) define the roadmap to guide students and conceptualize the auditory information design process. From the designer's perspective, the sound is at the center of the design process. However, designers must consider the specific requirements related to system data and events (Lenzi, 2022), as well as the actions, responses, and behaviors induced by sound. By doing so, we highlight unexplored correspondences between the distinct components of the loop.

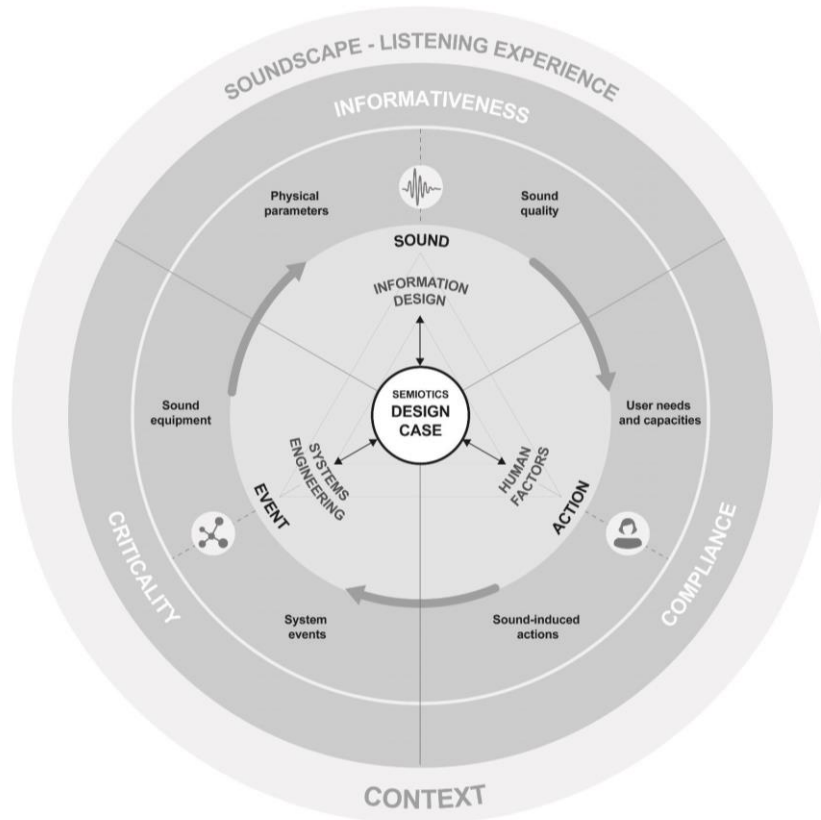


Figure 4 A framework for sound-driven design. Distinct components and subcomponents of the design process: Event (system events, sound equipment); Sound (physical parameters, sound quality); Action (user needs and capacities, sound-induced actions). Three priority-based levels to auditory communication: criticality; informativeness; and compliance.

Figure 4 shows the design framework for sound-driven design, presented to the students in a stepwise fashion: the basic design components and subcomponents of sound-driven design; the conceptual space for sound design around the three priority-based levels (criticality, informativeness, and compliance) that underlies each design component; and the checklist as the tool to support the design process (see Table 1). Next, we will focus on the definition of the sections covered by the checklist for students, so that we can present the most practical approach to this contribution.

Table 1 Checklist of questions to address the sound-driven design case.

Component	Subcomponents	Questions
1. Event	System events	1.1 How are system events hierarchically organized? 1.2 How critical is the incoming device data? 1.3 How to prioritize device events based on data criticality?
	Sound equipment	1.4 What devices/equipment are there to communicate these events?

2. Sound	Physical parameters	2.1 - What are the physical parameters of the sound? (i.e., the measurable properties that define its characteristics)
	Sound quality	2.2- What information does the sound convey?
3. Action	Users' needs and capacities	3.1- Who is the target audience for the auditory message amongst the users?
		3.2 - Who is not the target audience for the auditory message?
		3.3 - What are the roles, needs, and capacities of the users?
	Users' action	3.4 - What type of response is required from the users? 3.5 - What actions does the sound induce?

The prioritization of the design components around data, informativeness, and sound-induced action, is an underlying need to guide students to design auditory messages in interactive contexts of use.

Data prioritization in terms of criticality is key to the definition of 'sound' as an auditory message in communication processes. Thus, 'sound' is the indicator that calls attention to a 'critical, major, or minor event' and gives rise to the corresponding action.

Criticality strongly resonates with issues in hierarchy and semantics in interaction with the equipment that produces sounds.

Informativeness is the novel definition for the term 'sound quality'. A sound needs to attract attention in the first place and then, provide information.

The level of compliance related to the sound-induced action emerges as a space of design possibilities resulting from the abilities of the operator and the characteristics of the environment.

2.5 Session 5 — Design cases and applications

To apply and assess the potential application of the sound-driven design framework defined above, students were presented with a list of design cases to address the semiotic issue. 58 students took part in the workshop sessions in groups of 2 students. Over two academic years (2021-2022 and 2022-2023), as part of the fourth year of the BSc in Industrial Design and Product Development Engineering, a total of 29 projects were undertaken within the subject 'Semiotics in Design'. Each project aimed to develop the communicative strategy of a new everyday product concept proposed by the teams of students. During these sessions, the framework for sound-driven design and the subsequent process was applied through several design cases where auditory information plays a significant and potential role.

Finally, the different design cases were presented and discussed with the rest of the students.

Below we show a selection of three design concepts to exemplify the type and reach of projects developed and how the design framework was applied. Some figures are shown in the original format, whereas the design frameworks have been translated into English to improve the understanding of the content.

Digital thermometer for human diversity in a home healthcare context. Figure 5 shows the data and the material resulting from the application of the framework to the design case. The user has an ability-limiting condition, dependent on a majority of situations, and the need to interpret the result of the temperature measurement. The multimodal proposal involves three sensory modalities: sight, hearing, and touch. The temperature ranges (i.e. data) are ranked according to the level of urgency of the events and are communicated using visual, acoustic, and vibrational patterns. Clear and correctly interpreted information is necessary to induce the appropriate decision.

Wearable for vulnerable road users in a city traffic light context. Figure 6 shows the application of the framework as a conceptualization draft to the design case. Vulnerable road users are visually impaired people, elderly people, and children, which implies difficulty and risk when trying to cross a street or a road. The device consists of a wearable that is detected in proximity to a traffic light crossroad and provides a specific vibro-sound alert to indicate the status of the traffic at that moment, conveying the user to keep walking or stopping. The multimodal proposal involves different sound and vibration patterns that inform about the current traffic situation.

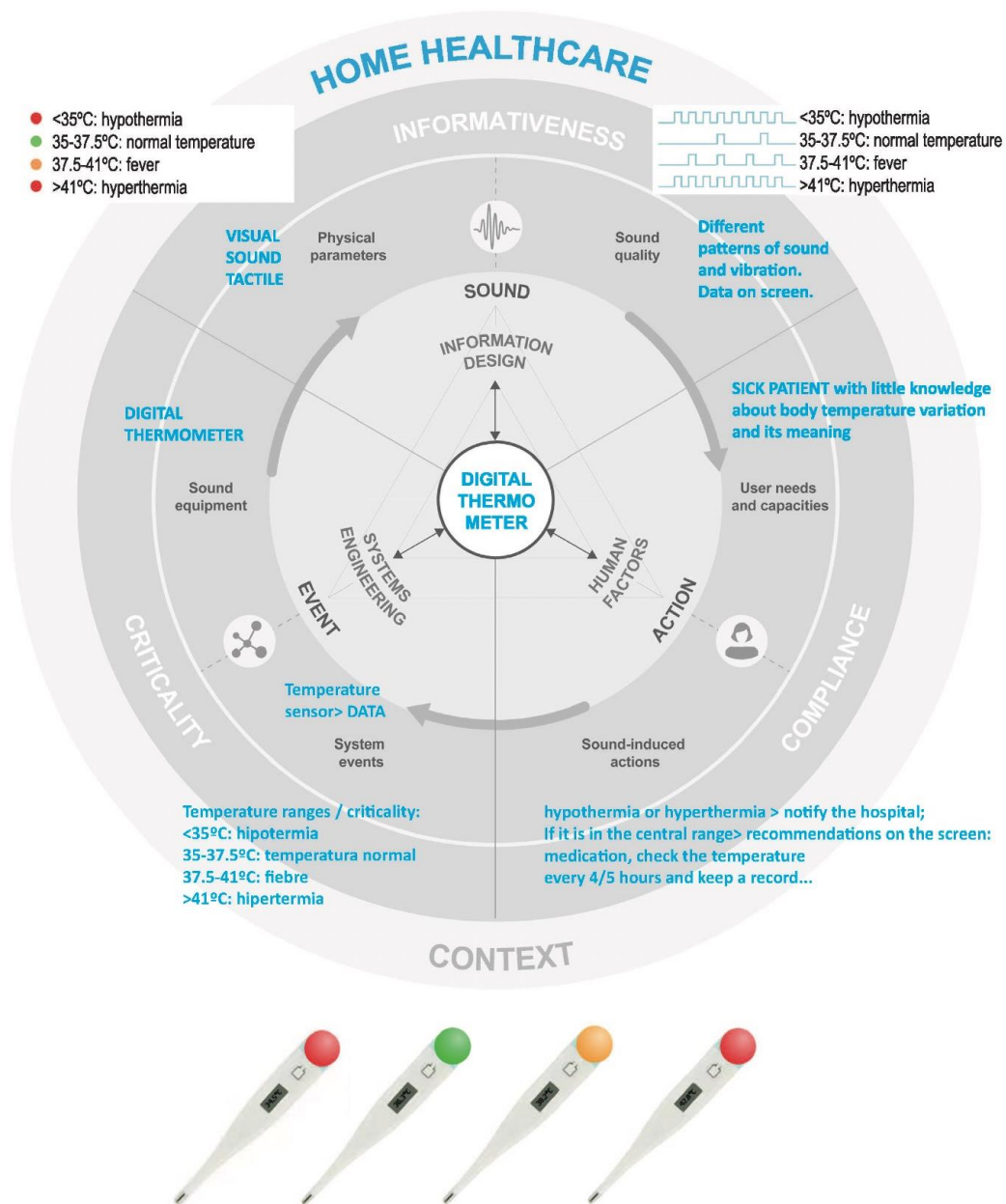


Figure 5 Design Case 1: Digital thermometer for human diversity. Design framework.

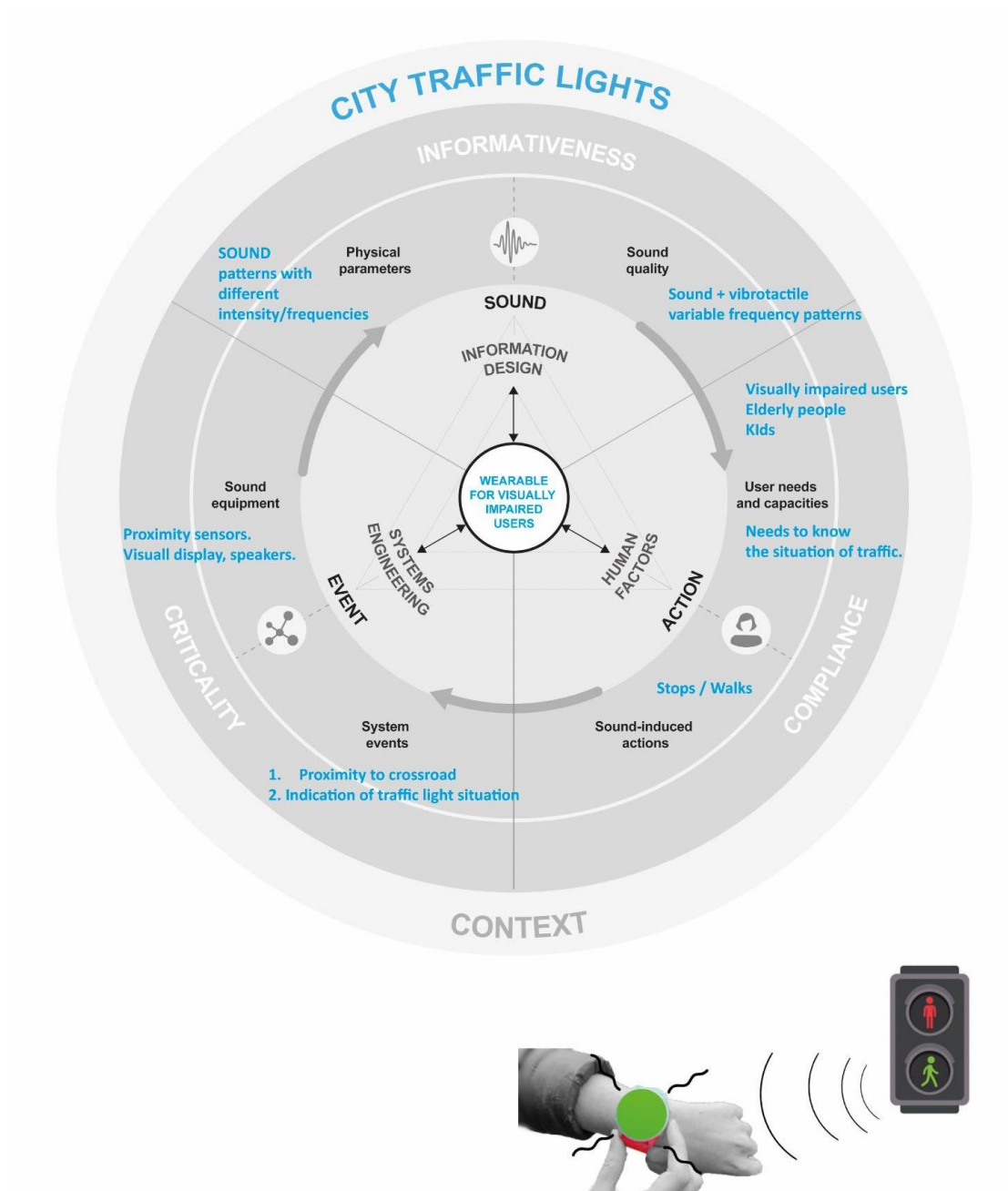


Figure 6 Design Case 2: Wearable for vulnerable road users in a city traffic light context. Design framework.

An alarm system that alerts of electric failure in a domestic context. Figure 7 shows how the design framework was applied to the design case. The user's knowledge of electric installation technology is low or none. The system detects three different system events. The combination of sound patterns and blinking lights gives orientation to the user on how to react. Hence, if the failure has been caused by a common over-demand of supply, the message guides the user to rearm the system. If the failure has been caused by a non-permanent or minor malfunction, the message persuades the user to seek professional

assistance. If the failure has been caused by a permanent or major malfunction with a potentially risky situation, the message urges the user to call emergencies.

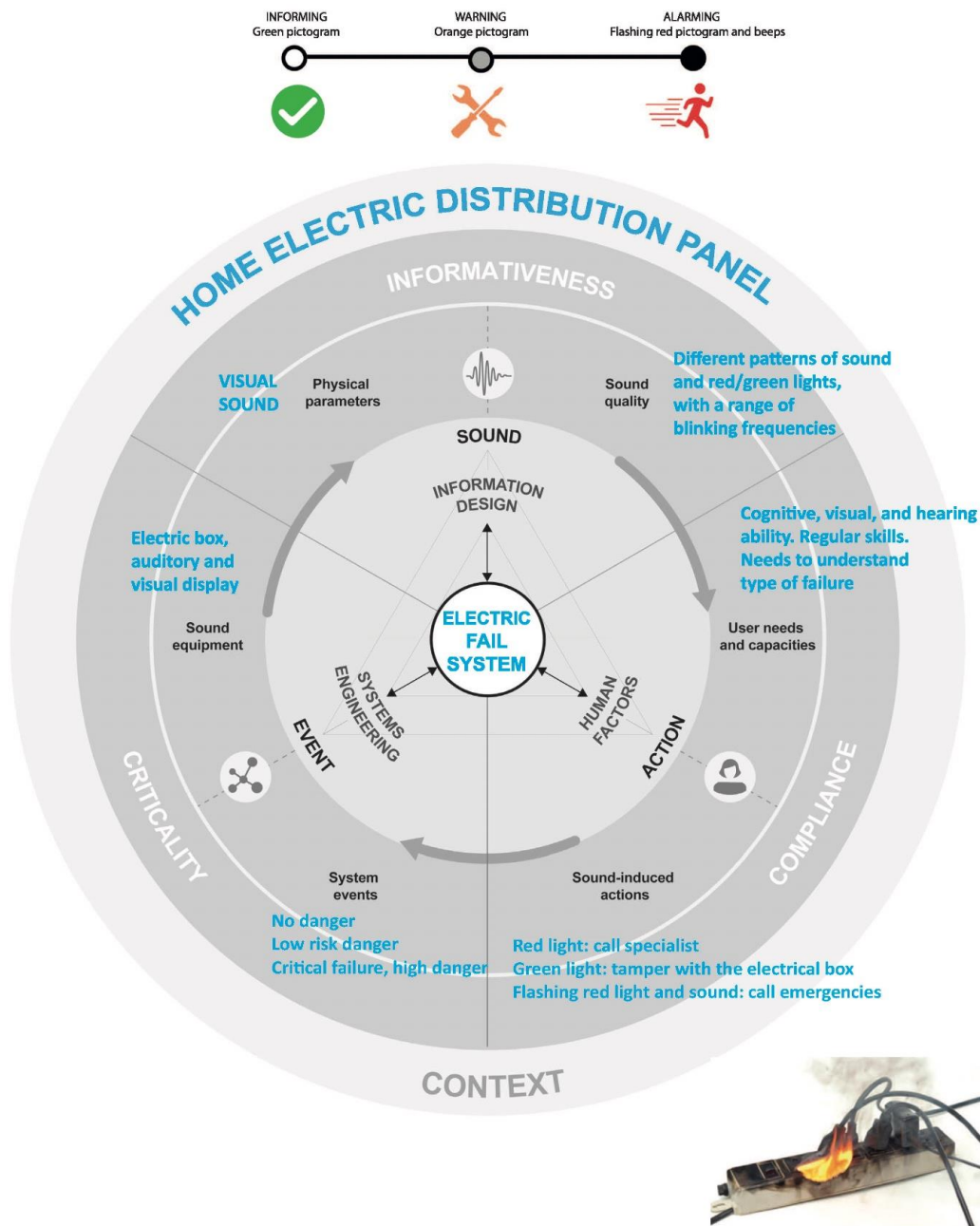


Figure 7 Design Case 3: Electric fail system for a domestic context. Design framework.

3. Discussion and recommendations for future applications of the design framework for sound-driven design

The design framework was applied in the context of studying semiotics as the means to characterize solely sounds as part of the product's communicative strategy. However, this framework is conceived as an onion model to be used with each sensory modality, and in turn, to design each stimulus independently. Although not addressed in this contribution,

the students evaluated the usability, efficiency, and accuracy of their multimodal designs through prototypes and user tests to redefine the proposals according to the feedback received from expert users.

The analytical approach of the design framework by breaking down the entire communication system into its distinct components allowed students to delve deeper into each session. The discussion generated fruitful spaces for reflection on our sound imaginary as designers but also on the sound universe of non-experts or individuals lacking a background in listening. In particular, the analytical approach favoured the diagnosis of the current soundscape in our interaction with everyday objects or in highly demanding professional contexts. After conducting analyses and engaging in group discussions with the teaching team, several key points emerged as significant considerations for future integration into the educational program. The following insights, though informally gleaned, align with ongoing priority research areas within both the broader design community and the specific domain of sound-driven design:

- Embracing a data-driven approach and data-to-sound methodologies and tools. This implies understanding the nuances of big data and acoustic data, as well as refining the categorization techniques for both sounding objects and sound events (e.g., mapping data in terms of its criticality, analysis, and auditory representation).
- Including participatory and collaborative design methodologies tailored to sound-driven design contexts. This approach underscores the importance of engaging diverse stakeholders in the design process to enhance inclusive and innovative solutions.
- Exploring the intersection of information design and sound-driven design, particularly concerning the semantic dimension and narrative potential inherent in auditory experiences.
- Elevating the discourse on listening experiences within sound-driven design, including both active and passive modes of listening from a user-centered approach, considering the capabilities, training, and preferences of end-users. Moreover, careful consideration must be given to the individual and contextual constraints of the specific environment and its inhabitants.

4. Conclusions

We have presented the framework for sound-driven design as a tool to support the design process of auditory communications in the educational environment. The design framework is applied to the subject of 'Semiotics in design' as an organized first roadmap to draw designers' attention to the role of sound in the design space.

The lack of previous educational and training materials in the field of sound-driven design requires that design researchers contribute to the definition of the current issues to address,

integrating knowledge from engineers, sound designers, and human factors experts. As a result of the experience developed through the sessions, we suggest design researchers relevant topics to consider such as 1) acoustic data and data-to-sound knowledge, how to record and collect ethical and meaningful acoustic data according to current technological advances (e.g. machine learning, AI, algorithms); 2) the need for methods and tools that support the design process (e.g. how to design the design process? which methods and tools are more suitable in each stage of the sound-driven design process? how do create fixation mechanisms with new innovative participatory and collaborative design work?); 3) the understanding of the listening experience and how to design soundscapes from a human and user-centered perspective.

Finally, designing with sound implies the contribution of design research in terms of methods and tools that position sound-driven design in the design practice of educational environments. Thus, we will pave the path to motivate and inspire students to shape future soundscapes in everyday and socio-technological contexts.

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