Designing User Experience with the Sonic Metaphors

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Abstract. In this paper, we present project three experimental installations under the conceptual topic of Sonic Metaphors. We use sound as the main tools to establish interaction between users' interface, physical and virtual space. We are trying to elicit memories and meanings, which plays a crucial role in designing desirable user engagement. We aim to use sonic metaphors as a tool for interactions and experience design. Furthermore, it offers new creative vocabulary based on sound meanings and utilizes acoustic information patterns as a novel way of enabling access to the digital environment.

Keywords: Sonic interaction design · User experience · User interface design · Multisensory interaction · Metaphors · Spatial interaction

1 Introduction

Sonic Interaction Design (SID) is a multisensory design approach where sound has a primary role in developing users' interactions with electronic devices or digital systems and giving meaning to user engagement [1]. SID research falls within a diverse range of emerging disciplines and research approaches toward a better understanding of sonic experience's various aspects [2]. All those approaches aim to explore everyday human perceptual experience to design more fluid and intuitive encounters with digital technologies [3]. One of the central sonic interaction design questions are; How actions can be guided with sound? How is perception affecting the process of embodiment? Who or what performs the interaction when using sound as a tool for interaction? Sound has spatial and environmental characteristics due to acoustic principles such as resonance, reverberation, diffraction, and refraction. It also has a temporal nature and depends on how we modulate it throughout time, distinguishing it from other sensory modalities. Related to interaction design is also the materiality of a sound and how interaction changes, shapes, or transforms sonic material and how interaction with sound helps form further embodied action [2].

Sonic interactions experience is designed upon the relationship between objects, environments, actions, and sounds, and as such, should be considered an essential element in interactive media art creative vocabulary. Previous works in this field show that

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sonic feedback coupled to action can change human performance and social and aesthetic experience. However, the conceptualization of new experimental interactive installations based on continuous sound and tactile feedback could have benefited from metaphors inspired by real-world manipulations. It can also deepen our knowledge about the utilization of acoustic patterns in tactile information, put them in proper interactive context and perform a wide range of perceptual and motor tasks. This could lead us toward the conception of novel ways of enabling digital information access via movement and sound [4]. In this paper, we will present three experimental interactive installations, "Before and Beyond", "Vroom", and "Sensynesthetic Sculptures", conceptualized to engage users and design their experience through the usage of sound metaphors as sensory stimuli.

We are using Activity Theory, Pragmatist Aesthetics [5] and Merleau-Ponty's integrated view of action and perception for the theoretical framework for our experiments with sonic interaction design. Activity Theory has been used as a theoretical foundation in design evaluation and human-device problem analysis. It serves as a helpful framework for understanding presented works in the broader sound interaction design context. In Activity Theory, the unit of analysis is motivated activity directed toward a goal [6]. In the Sonic Metaphors' interactive installations, this activity relates to given sound control, which helps users enrich their experience through given metaphors. The activity is mediated by the contextual pattern built into the artwork's concept. With an application of Merleau-Ponty's philosophy [7] to human-computer interaction, we got a new understanding of interaction as perception. By seeing interaction as a perceptual process involving both "Body" and "Mind", we overcome the Tool/Media dichotomy. When perception is understood as an active process involving our body's totality, it no longer makes sense to see it as a passive reception of information through a medium.

Similarly, when action is an expression of our being-in-the-world, it no longer has meaning to see as a purely "bodily" activity. For Pragmatist Aesthetics, the aesthetic experience is of the highest importance. It is central to understand an object sociocultural context as an object's meaning and value change with the constantly altering context of experience, between cultures, between persons and even within persons [8]. Petersen et al. agree that aesthetics has an instrumental dimension 'related to actual human needs, values and fears'. In their view, aesthetic interaction promotes curiosity, engagement, and imagination in exploring an interactive system [9].

Key novelties in the Sonic Metaphors Projects are using sonic metaphors as the new tool for interactions, the development of new creative vocabulary based on sound meanings, and utilizing acoustic information patterns as a novel way of enabling access to the digital environment.

This paper will first describe three interactive installations that belong to the Sonic Metaphors research project. Furthermore, we will explain the conceptual and cognitive approach used in the design process. As part of performed user research, we did several informal interview sessions and personal observations during the public artwork exhibitions and controlled lab environment. The results will be presented within the installations descriptions chapter. To conclude, we will validate the interactive concept applied in the design of three experimental installations, "Before and Beyond", "Vroom", and "Sensynesthetic Sculptures", and experiential dimensions possible to achieve in human-machine sound interaction and stimulation.

2 Background

Arjen Mulder – biologist and media theorist, defines the concept of interaction as follow: "interaction is a mode of bringing something into being – whether a form, structure, a body, an institute or a work of art and on the other hand, dealing with it" [10]. An interaction can have different aspects such as visual, sonic, smell, taste and tactile. Moreover, each or a combination of them can be either input or output of an interaction system.

SonicTexting is a system that takes tactile as input and presents it in the form of audio to provide control over the texting process to reduce visual load. Texting in the dark, texting capability for visually impaired people or texting while driving is examples of this project [11]. The Sound of Touch is a system for filling the gap between electronic and acoustic audio by adding acoustic spontaneity to electronic music instruments via sensing the pressure on the instrument's body, bending, and changes in tilt or temperature. This project aims to explore the sound produced by a verity of textures [12]. PebbleBox, CrumbleBag, and Scrubber is another project in musical instruments that tried to extend available perceptual outcomes by maintaining the existing relationship between tactile actions and audio response [13]. Exploring the interaction with a couch based on tactile connection and audio feedback is the aim of ZIZI. In this work, researchers made a couch that is responsive to the actions of users. The couch can express different feelings via sounds related to each action, such as yipping as a sign of excitement, whining when it is boring or growling when the user touches it softly. Authors claim that making couch satisfied can provide user's satisfaction [14]. A combination of new interfaces for musical expression and approaches from human-centred design is presented in the A20 to explore personal music experiences to identify new themes from the listener's daily life interaction with music and propose an advanced interaction approach with these themes [15].

In conceptualizing and designing our experimental interactive installations, we followed some of the ideas related to the usage of sound and sonic interactions presented in the mentioned works. The common ground for all this example is sound as an emotional and cognitive trigger rather than just meaningless audio warning for the system mail function or urgent action required from the user. Multisensory interaction where audio experience has a crucial role in arousing users' meanings and motivation to engage has ultimate value in our user experience designing approach.

3 Interactive Installation Before and Beyond

Interactive Installation Before (our existence) & Beyond (our perception) (https://goo.gl/FhJF5G) is a multisensory interactive metaphorical voyage inspired by String Theory and body distance-related socio-emotional relationships development. As stated in Quanta Magazine, "Among the attempts to unify quantum theory and gravity, string theory has attracted the most attention. Its premise is simple: Everything is made of tiny strings." [16]. According to the California Department of Education, socio-emotional relationships development starts in early infancy as explained: "social interactions with peers increase in complexity from engaging in repetitive or routine back-and-forth interactions with peers to engaging in cooperative activities. Social interactions with peers

also allow older infants to experiment with different roles in small groups and in different situations such as relating to familiar versus unfamiliar children." [17]. Interactive Installation Before & Beyond is conceptualized as a responsive, playful environment where visitors have physical interactions that stimulate their internal processes, such as motivate them to collaborate, bodily interact and communicate. Furthermore, through audio-visual elements to communicate ideas related to the origins of the Universe and human existence and to provoke social interactions between visitors. The installation was exposed at the Maison Shanghai 2016 event as part of the Final Fantasy exhibition. The installation space responds to visitors' body movements, the direction of walking and the distance between participants. The introductory animation represents the author's visual metaphor of the Universe creation, followed by the background sound composed of five of the most mysterious melodies found there. After entering the installation, visitors are attached to the visual String of Energy projected on the screen in front of them, with characteristic colour and sound as an abstract metaphor of their existence in a virtual world they step in. Animated strings with a specific tone, user movements and social interactions are elements of the aesthetical experience. To increase tracking accuracy and the intimate relationship between participants and the projected strings, we are using sensory-based technologies, Kinect movement detection placed on the wall, and Beacons integrated into the medallion around the neck of the participants (Fig. 1).

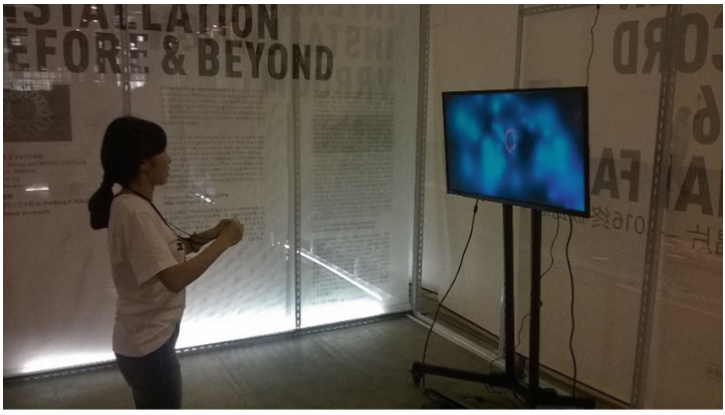

Fig. 1. After entering the installation space, every participant gets his String of Energy projected on the screen (© Predrag K. Nikolic. Photo: Predrag K. Nikolic)

Personal Strings (animated two-dimensional circles, enriched with a specific violoncello's tone and colour) projected on the screen are following the visitor's movements and reacting on distances between them. When participants are close enough to each other, their Strings join in one and vice-versa when they separate the joint String splits back to personal strings (Fig. 2).

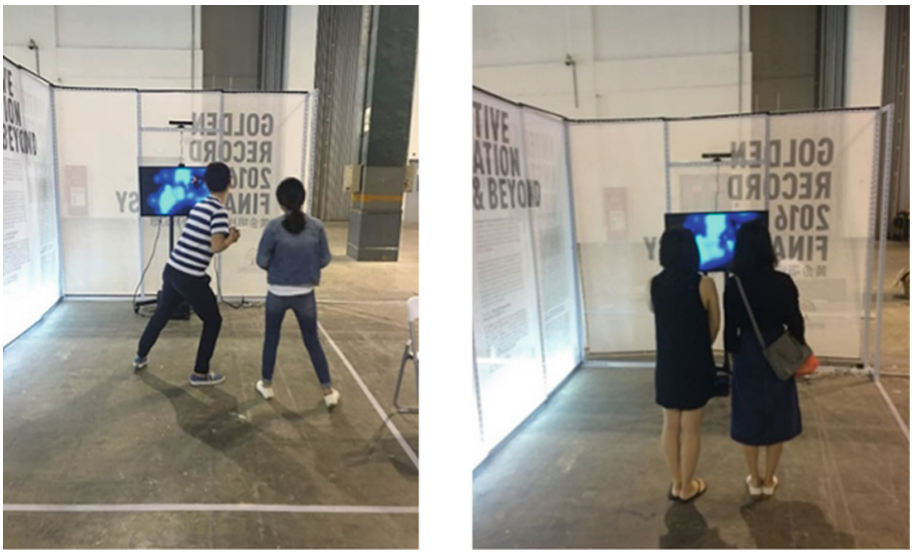

Fig. 2. Depending on the distance and established relationships between visitors visual and audio appearance of the Strings changes (© Predrag K. Nikolic. Photo: Predrag K. Nikolic)

Furthermore, the experience articulates sensory stimuli such as dynamic and colourful behaviour of the strings, background sound and strings' tones. Conceptually they are the perceptive connection between visitors and the artwork's inspiration rooted in string theory and socio-emotional ability to establish positive and rewarding relationships with others [18].

Interactive installation Before & Beyond tends to intrigue visitors to explore their virtual existence and correlate it with others in the artwork's space. During that process, they acquire new personal properties such as colour, shape and sound attached to their String. For example, the given tone is becoming a metaphor for them. By playing and interacting with others in the installation, they make a musical composition based on relationships developed. Sonic and visual personification is giving them opportunities to express themselves and communicate with others in an alternative way. Likewise, to trigger a visitor's social behaviour change and engage them in collaboration, which will result in new relationships development within a given context. The physical and virtual space of the artwork is becoming a place for body and social interactions.

Interactive installation Before & Beyond tends to provoke social situations that affect the installation appearance by using human interactions, multisensory stimuli, scientific context, and playful surroundings. For example, the degree of intimacy and how people will move and behave reflects aesthetic and interaction concepts that will work well [19]. In the installation Before & Beyond users are moving around in the responsive space in front of the display. The interaction space between the users and the display is an agent that connects visitors' efforts and physical space actions with visual and sonic metaphorical outputs. By moving around and interacting with each other, participants shape social space the same way they are doing with their everyday living surroundings.

New types of sonic, visual, and socio-bodily interactions within the artwork can unify participants into groups where all individual efforts are dedicated to shared goals and generate new interpersonal and emotional relationships.

3.1 Observations and Informal Interviews

The installation was seven days exhibited at the Maison Shanghai Finally Fantasy exhibition in 2016. During that period, the author and one research assistant gave instructions to the visitors and observed how they interacted with the installation. Also, the detailed explanation of the installation concept, the author's inspiration, instructions, and the way to interact were printed and presented to the participants before entering the artwork's interactive space (Table 1).

Table 1. User profiles

Gendre	Age	Education	Profession	Experience
Male	28	High School	Carpenter	No
Male	43	High School	Driver	No
Female	37	University	Designer	Moderate
Female	37	University	Designer	Moderate
Female	52	University	Teacher	Yes
Male	21	University	Student	Moderate
Male	23	University	Student	Yes
Male	20	University	Student	Yes
Male	46	High School	Entrepreneurs	No
Female	24	University	Student	Yes
Male	32	University	Administration	Moderate

Observations
We observed the way and time needed for the participants to understand how to use the system. In severe failure or confusion, the research assistant was trained to assist the visitors and give necessary explanations. Also, the author was recording personal video and photo journal.

Interview
We conducted an informal interview with the participants we interviewed just after they finished their interactive session in the installation. Our questions were focused on the following aspects:

- What is your interpretation of the sound in the installation?
- Did you focus on sound during the session? Why?
- How did you correlate your actions with the audio response?
- Do you think the installation would provoke the same reaction and impression without the sound?

3.2 Findings

The sound had an important role in attracting visitors to interact with the installation. They believed that sound was involved to avoid an unwanted collision as they needed to control proximity between other participants. Every personal String had its authentic sound, but they personalized more with their video then audio representation. They did not care much once they lost their sonic identity after merging their strings with others.

The participants who read the introductory text at the installation entrance had a much better conceptual understanding of the sonic experience and the reasons for being part of the installation. Nevertheless, after some time, all the visitors used the sound as the navigation tool to prevent unwanted collisions in physical space and the merging of the strings in the projected virtual space. The users with the previous experience of playing in the interactive installations did focus on the sound despite those without experience who even found it annoying at a certain point. Nevertheless, both groups agreed that sound played an important role, and the installation experience would not be so profound without using it (Table 2).

Table 2. User experience research interview results

Gendre	Age	Interpretation	Correlation	Focus/Need
Male	28	Navigation	Direction/Collision	No/Yes
Male	43	Navigation	Direction/Collision	No/Yes
Female	37	Conceptual/Navigation	Direction/Collision	Yes/Yes
Female	37	Conceptual/Navigation	Direction/Collision	Yes/Yes
Female	52	Navigation	Direction/Collision	Yes
Male	21	Conceptual/Navigation	Direction/Collision	Moderate
Male	23	Navigation	Direction/Collision	Yes
Male	20	Conceptual/Navigation	Direction/Collision	Yes
Male	46	Navigation	Direction/Collision	No
Female	24	Conceptual/Navigation	Direction/Collision	Yes
Male	32	Conceptual/Navigation	Direction/Collision	Moderate

4 Interactive Installation Vroom

The installation is inspired with the children mimicking car engine sound once they want to imitate them driving a vehicle: For example, kids are using every opportunity to jump into father's car, take the wheel and by imitating the sound of a car engine to go on an imagined trip, enter fictional situations, make a story based on sonic narrative. Experience related to mimicking sounds of various vehicles to simulate movement is deeply emotionally attached to our childhood memories. For us, it is a metaphor we are addressing to specific situations and attaching meanings upon which we can develop our sonic stories and even synesthetic experience. In the interactive installation Vroom (https://goo.gl/bW4LKv), visitors were invited to shout the sound of a car engine in the microphone, which had a consequence illusion of moving forward on the road projected on the screen. Depending on sound intensity, they could regulate their speed along the road (Fig. 3).

Fig. 3. Interacting with the road in a virtual environment and controlling movement by making the car engine sound and modulating its intensity. (© Predrag K. Nikolic. Photo: Predrag K. Nikolic)

Additionally, we used road signs and arrows as metaphors related to decisions and choices in our lives and transformed them into visual narrative language. As such, visitors are not exposed only to virtual road trip experience controlled by the intensity of the imitated car engine sound, but they could also have followed and influenced the visual story that goes on the road surface (Fig. 4).

Fig. 4. A dreamful surrealistic story narrated with road symbols (© Predrag K. Nikolic. Photo: Predrag K. Nikolic)

The installation interface was purposely made of dumped car parts and then re-assemble into a new aesthetical form, as an intuitive and narrative metaphor clear enough to trigger desirable interaction between users and the sound installation (Fig. 5).

Fig. 5. The intuitive, meaningful interface made of dump car parts (© Predrag K. Nikolic. Photo: Predrag K. Nikolic)

We followed readymade creative practice and used meanings people are already attaching to particular objects. Hence, we created genuine aesthetical artefact people could interact passively or actively by taking a virtual ride controlled by the specific metaphorical sound required to trigger animated visual respond.

4.1 Observations and Informal Interviews

Like the experimental installation "Beyond & Before", The Vroom was also seven days exhibited at the Maison Shanghai The Final Fantasy exhibition in 2016. We applied the same procedure using observation and interview methods in our user experience research.

In the Vroom installation case, we decided not to go with the detailed instructions and test the intuitive aspects of the interface. This time we selected nine visitors who agreed to answer the interview questions (Table 3).

Table 3. User profiles

Gendre	Age	Education	Profession	Experience
Female	21	University	Student	No
Male	12	School	Student	No
Male	14	School	Student	Moderate
Male	20	University	Student	Moderate
Female	34	High School	Self-Employed	No
Male	35	High School	Self-Employed	No
Male	19	University	Student	Yes
Female	20	University	Student	Yes
Male	22	University	Student	Moderate

Observations
Like in the previous case with the installation "Before & Beyond", we observed how and time needed for the participants to understand how to use the system. In case of confusion, the research assistant was trained to assist the participants. The author was recording personal video and photo journal for later analysis.

Interview
We conducted an informal interview with the participants with interest in:

- What sounds meant to them in this installation?
- Did they find the interface intuitive enough?
- How did they correlate their sonic interaction with the visual response?

4.2 Findings

Once they spotted a microphone in the interface, it was clear to all participants that they needed to produce sound to interact with the artwork. At a glance, they were not sure what kind of sonic input and what output they could expect. However, after they made an analogy between the animated road projection and the microphone stand made of car parts, they were pretty confident that they should mimic car engine sound.

They were pleasantly surprised when they discovered that they could control their speed with voice tone modulation. The first-person perspective had an essential role in recalling memories from childhood and keeping users engaged with car engine sound. Some of the participants did not relate their actions with early childhood memories and

considered sound only as a tool to control the output from the system. This group of users experimented with the volume and type of sound they produced despite the participants who found a strong relationship between cognitive and type of sound they produced as a reflection to that. The visual narrative made of road line and arrows had importance and took their attention for interpretation. Another group that used sound as a tool focused on the system's response to speed and the correlation between audio input and digital output. They did not consider road signs of any importance (Table 4).

Table 4. User experience research interview results

Gendre	Age	Intuition	Interpretation	Correlation
Female	21	High	Cognitive/Tool	Yes
Male	12	High	Tool	Yes
Male	14	High	Tool	Moderate
Male	20	Medium	Cognitive/Tool	Yes
Female	34	Medium	Tool	Moderate
Male	35	Medium	Tool	Moderate
Male	19	High	Cognitive/Tool	Yes
Female	20	High	Cognitive/Tool	Yes
Male	22	High	Cognitive/Tool	Yes

5 Sensynesthetic Sculptures

In the experimental installation Sensynesthetic Sculptures, we used magnetic frictions and contextual sonic metaphors as a creative medium. The multisensory approach to user experience design in the last decade tended to enrich visual reality by adding sound, texture, gesture, haptic sensations, and engaging more than one sense. Nevertheless, our idea was to extend and overcome visual reality limitations by applying an artistic/design process of sensory immobilization. By excluding certain senses from perception, we tried to reveal universal realities and develop experience beyond sensory limitations. For example, proprioceptive is a related phenomenon where one way of improving proprioceptive efficiency is to diminish or block input from other sensory systems such as the eyes [20]. In the broader social context, we are used mixed experiential reality to diminish body limitations and deliver similar multisensory experiences to everybody. The essential phenomenon regarding user experience design involves a relationship between unconscious processes and perception of objects, dreams and fantasies. That is the foundation upon which Sensynesthetic Sculptures are trying to build collective experiences and start the processes between participants and participants and the author. Sensynesthetic Sculptures are completely non-material energy-based artefacts and, as such, purely experiential, capable of responding with energy-based immobilized sensory

feedback to visitors' actions or stimulating emotions upon given meanings by engaged individuals.

With Sensynesthetic Sculptures, we tend to explore and introduce new existing realities significantly beyond visual perception. Our creative tendency is to communicate purely through the sound and tactile language and avoid visual expressive forms such as colours, lines, patterns and forms. By doing that, we are trying to move experiences from dominantly semiotic to more heuristic, oriented toward new qualities of meanings. Accordingly, we are trying to expand the field of expressive, creative mediums choices toward new frontiers where the focus will be on abstract multisensory experiential rather than physical reality, more emotionally than technologically-based (Fig. 6).

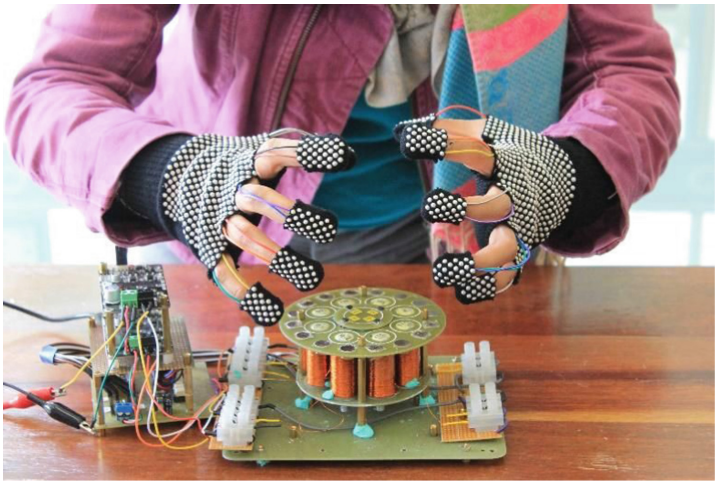

Fig. 6. Magnetic friction and sound as new creative medium (© Predrag K. Nikolic. Photo: Predrag K. Nikolic)

In our design language, we are using creative vocabulary based on audio-haptic modality made of:

- Vibrations
- Collapses
- Collisions
- Elevations
- Repulsions

Sounds corresponding to listed phenomena are based on adequate sonic metaphors. Within the human-spatial interactions, we are designing experiences using interaction techniques that use haptic gloves in combination with a tower of electromagnets. The electromagnets are arranged throughout the tower to provide dynamic magnetic frictions while the participant explores the space around the tower and getting sonic and frictional feedback. The electromagnets are hidden from view, and the frictions are created in mid-air (Fig. 7).

Fig. 7. Haptic gloves in combination with a tower of electromagnets. The electromagnets are arranged throughout the tower to provide dynamic magnetic frictions. (© Predrag K. Nikolic. Photo: Predrag K. Nikolic)

The Sensynesthetic Sculptures are made of magnetic energy, which is abstract and experiential. The Sculptures are placed on a magnetic field holder and approachable only through special magnetic gloves. The design process is based on iterative audio-haptic practice. All parts of the sculpture are organized through repetition, contrast, or absence of constitutive elements (vibrations, collapses, collisions, elevations, repulsions) we are using to achieve the desired experience. We are using a cylindrical tower that hides electromagnets, and users are interacting with the tower while wearing a set of gloves that contain permanent magnets at the fingertips. Previously, others have proposed the use of arrays of electromagnets to produce interactions [21, 22, 23]. However, in our sculptures, we enable both a volumetric sense of space and a time-varying interaction to create new experiences for the users during each pass. Rather than feeling a predefined surface, participants will interact with a dynamic volume that is produced by the electromagnets.

The interactions are produced with a magnetic tower and a glove with a set of five permanent magnets (one located at each fingertip, 2 cm diameter, grade 52). The proposed magnetic tower is a 0.5 m tall cylindrical structure with a diameter of 100 mm. Its outer surface is formed with an array of 1–64 air-coil electromagnets. Dynamic forces are programmed into the tower to produce time-varying interactions. Time-varying forces control at each table with an Arduino. Air-core coils are made with 28-gauge wire and 20–100 mm in diameter. The current supplied to the electromagnets varies from 0–2 A (Fig. 8).

When users move their hands around the magnetic tower's surface while wearing the gloves, they can feel interactions with the dynamic virtual sculpture formed around the magnetic tower and hear the sonic metaphor paired to the specific magnetic energy interactions such as vibrations, collapses, collisions, and elevations.

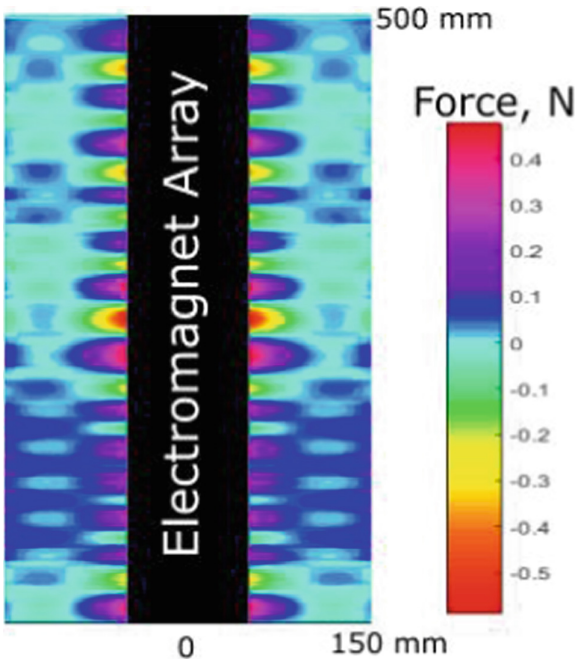

Fig. 8. Sample cross-section of the force felt by a participant's finger when using the electromagnetic array.

5.1 Expert Interview

For the installation Sensynesthetic Sculptures, we interviewed five experts under a controlled laboratory environment with different backgrounds (Table 5).

Table 5. Experts profiles

Gendre	Age	Education	Profession	Experience
Male	37	University	Engineer	Moderate
Male	35	University	Engineer	Expert
Female	28	University	UX designer	Moderate
Male	32	University	Interaction Designer	Expert
Female	51	University	Artist	Expert

We conducted contextual interviews while moving around the magnetic tower with the haptic gloves and defining experienced forms of the sculptures.

5.2 Findings

We were interested in hearing from them opinion about:

- Sufficiency of the used technology
- Detection of the variety of forms
- Sound-Tactile correlation form the UX perspective
- The capability of the medium to communicate inclusive ideas

Considering that it was the prototype of the Sensynesthetic Sculptures technology used, it showed the potential to support the author's idea. The generated magnetic frictions are still tactile sensations rather than 3D forms; we can resemble solid materials such as texture, edge, and surface. Nevertheless, as a new creative medium to offer a new user experience, the experts praised their discrepancies. Under the circumstances where we do not see the material share and feel it under our fingertips, user sonic metaphors attached to specific magnetic friction had a significant role in interacting and engaging with the sculptures and idea they represent.

6 Conclusions and Future Directions

In the Sonic Metaphors projects, we are proposing the use of sounds metaphors in creative practice, which can contribute to user engagement quality during multisensory interactions. Although many questions remain concerning the interfaces proposed, we believe that the suggested design process can deliver genuine user experiences. In the interactive installation Before & Beyond, the sound had an essential role in provoking collaboration between participants' and behavioural changes led by new types of sensory and socio-bodily interactions. Based on sonic features in the installation, user-directed their choices toward establishing new interpersonal and emotional relationships. In the installation Vroom, we invited visitors to interact with the installation by mimicking specific user memories with specific intrinsic values. Relation between the sonic metaphor used and visual respond immersed visitors into unique sensory, narrative and aesthetic experience. Lastly, in Sensynesthetic Sculptures, we use sound to empower magnetic energy as a new creative medium.

We believe sonic metaphors can be used as a creative vocabulary to enrich exiting and novel design practices, significantly when sensory limitations can vastly affect the interaction process and engagement. Hence, our future research directions will be focused on using sound interactions as an integral part of the creative, narrative, and design process within social or personal experiential context toward creating authentic user experiences.

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