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The Reciprocity of Speculative and Product Design Research in an Industrial Framework

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Abstract. Wearable audio-tactile devices can be evaluated not only in terms of the perceptual experiences they elicit, but also how they come to exist. In this project case study, we show how the industrial environment influenced the design processes that have structured both the purpose and the form of two wearable audio-tactile devices, here described as design artifacts. We elaborate two design artifacts in terms of speculative and product design processes: the speculative design artifact (the multi-modal harness) which was conceived to challenge the user’s assumptions about hearing, and the product design artifact (Ryzm™) to bring the user an improved listening experience. In turn, we reveal the reciprocity of our speculative and product design processes: the creative interactions that bound the two artifacts’ development created a connection between otherwise distinct scientific and commercial objectives.

Keywords: Wearable technology · Audio-tactile · Design research.

1 Introduction

Our research centers on the creation and study of wearable audio-tactile devices, built to transmit vibrations that stimulate both the senses of touch and hearing. To better understand the potential for body-based listening and the compositional possibilities it affords, we focus on three main axes: the exploration of sensory capacities [1], wearable device design processes, and audio-tactile sensory effect composition [2]. Here, we focus on the second axis: understanding how design processes have shaped the purpose and form of two wearable audio-tactile devices, defined as design artifacts. Both of the artifacts manifest the main objective behind our research: push the possibilities for including more of the body in the listening experience. However, at the start of their development, the devices had contrasting purposes: one aimed for novel experimental possibilities, while the other centered on commercial applications.

In this case study, we position these artifacts of our research in terms of speculative and product design. Our goal in categorizing our work and retrospectively evaluating these design processes is to demonstrate the value of coordinated scientific and commercial work, which has ultimately advanced our research objective and better integrated our project within its industrial environment.

2 Context and Motivations

2.1 Speculative and product design: What’s the difference?

Before we explain the approaches of speculative design and product design, we note that design research differs from pure scientific research: rather than focusing on *products* of an investigation, design research centers on the *process* of investigation itself [3]. In this paper, we explore the concrete outputs of our research in terms of the design processes that supported their creation.

In a nutshell, product design is about a project’s targeted market, and speculative design the discourse surrounding it [4,5]. Product designers find creativity from within the “problem space”, a working space confined by the constraints of the project’s industrial environment: temporal, ergonomic, material, regulatory, etc. [4]. The product designer’s goal is to draw a future product’s path to the market, but an iterative problem-solving process of development and testing must first occur. With our industrial partner, Actronika, we have worked within these real-world constraints in order to find a practical application of our speculative research. The purpose of speculative design is to provoke thought and stimulate debate among designers and consumers by “exploring new aesthetic, functional and cultural possibilities for technology” [6]. Its approach allows us to consider both what we *do not* want and what we *do* want in our tech-infused future [7]. Speculative designs can appear impractical and idealistic because they live in a world with no marketplace constraints. Instead, they seek to expose alternatives and challenge the status quo of the things we build.

2.2 Related Research: State-of-the-Art

Before we detail our design artifacts, we’ll first give some context and introduce some of the research in the auditory and tactile domains that informed their creation. The perceptual ranges and discriminatory limits of hearing and touch are compatible and overlapping. The skin’s ability to interpret vibrotactile information can be broken down into several key characteristics of the presented stimulus: its frequency, intensity, duration, waveform and position on the body. These parameters of vibrotactile signal design have much in common with those of auditory signal design (pitch, amplitude, duration, timbre, spatialization), but the two senses do not process vibrations in the same way [8]. Opposed to auditory perception, which is centralized to the head, our tactile perception of vibrations is dispersed all over the surface of our body [9]. The tactile perception of vibrations in the frequency range between approximately 20-1000 Hz overlaps auditory sensitivity between 20-20kHz. Despite differences in the two sensory organs’ processing capacities, researchers have found that auditory stimulation can affect tactile perception [10,11], and vice versa [12].

Researchers and product designers have therefore naturally investigated the use of vibrotactile technology for augmented sensory experiences of sound by creating body-based interfaces. The “model human cochlea” system, integrated in an armchair-form tactile device called the Emoti-Chair, separates audio signals

into frequency bands from 20-2500 Hz, displayed to the user via 16 voice-coil actuators, arranged in two vertical rows [13]. The Hapbeat and Vibeat were both designed to vibrate in time with music, worn as a necklace or bracelet [14,15]. The Soundshirt, originally designed for deaf individuals to experience philharmonic music, integrates 30 micro-actuators (type unspecified) in a thin, flexible garment [16]. The Soundshirt’s frequency-based organization of tactile stimulations differentiates it from the Subpac, a vest that filters bass frequencies (5-125 Hz) from the audio of a connected device via two large voice coil actuators located on the back [17]. Finally, wearable devices such as the Soundbrenner Pulse and the Body:Suit:Score were developed as tactile musical aids, helping to keep time or follow the score [18,19]. Based alone on their varying dimensions of scale of development, context of use, and underlying theory, the above-listed devices also provide a diverse range of examples in speculative and product design. However, for the context of this paper, we restrict our analysis to a case study of our own research.

Inspired by the works listed above, we distinguish our audio-tactile device design based on how we employ vibration. We aim to elicit sound perception via extra-tympanic conduction (ETC) at specific sites on the human torso, paired with vibrotactile stimulation of the skin. Commonly described as bone conduction, we refer to contact-based sound transmission as “extra-tympanic”, because there is speculation that soft tissue is involved in transmission mechanisms [20]. Notable past investigations of ETC are primarily based on the anatomy of the skull [21], but research has also shown the potential for sound perception via more distant sites of stimulation on the body such as the neck and back [20]. By testing the limits of ETC and the resulting tactile sensations elicited by vibratory stimulation, we explore the main objective of our research: build audio-tactile devices that challenge the common conception of sound perception and show that the body can be as much a part of listening as the ears.

3 Positioning our Work in Design Processes

In this section, we will show how we manifested our research objective in the form of design artifacts. The artifact, a concrete output of a design process, serves as an interface “between an ‘inner’ environment, the substance and organisation of the artifact itself, and an ‘outer’ environment, the surroundings in which it operates” [3]. Building on this idea, in this section we will describe each design artifact first in terms of its surroundings (purpose) and substance (form). By detailing the purpose and form of each artifact, we position them within the processes of speculative and product design. Following this section, we will further illustrate the positive interactions between the two processes to demonstrate their reciprocity.

3.1 Speculative Design Artifact

Speculative Artifact Purpose The multimodal harness (see Fig. 1) was born from the motivation to challenge the status quo of listening experiences, one that



Fig. 1. The multimodal harness. Nine voice-coil motors (Actronika HapCoil) are integrated in the wearable structure inside hard plastic modules on the clavicles, spine and ribs. The velcro straps tighten the modules' contact against the body, whose vibrations penetrate the body to elicit ETC sound perception, and stimulate the skin for tactile sensations. Users receive earplugs and a noise-reducing headset (3M Peltor X5A) in order to protect them from all external noises created by the actuators and ensure they hear only via ETC.

assumes we need properly functioning ears to appreciate sound. This motive naturally led us to create an object that looks strange, even absurd. The notion of hearing through our skin and bones may also seem bizarre, but the multimodal harness makes this a real experience, while keeping it at arm's length from practical everyday use due to its inherent ergonomic constraints and cyborg aesthetic. Beyond its look, the experience of the multimodal harness is also an argument for its classification as speculative design. The act of putting on the harness requires the user to question their assumptions about sound perception. In order to hear, users must first become deaf: when using the harness, they cover their ears from all external, airborne sounds in order to ensure they are only hearing via extra-tympanic conduction. Instead of perceiving the sounds via one central point (the head), the user's torso is covered with vibrating modules that stimulate their skin, muscles, ligaments and bones. The harness is therefore a vessel for speculative debate, blurring the boundaries of auditory experiences.

By using initial interfaces for multimodal effect design, we can create sensory effects that support our hypothesized mode of listening: sounds reach the ears from within the body, paired with accompanying spatialized tactile sensations that expand, slide and dart across the outer skin's surface [2]. During demo sessions of these interfaces, users have commented that after an initial period of adjustment, they feel a rapid connection to their bodies, concentrating only on the sounds and sensations. In this direction of thought, the multimodal harness fits in an alternate timeline of our physical connection to sound... could we design

interfaces to envelop our bodies in sound in the way that headphones envelop our heads?

Speculative Artifact Form The multimodal harness is sci-fi-like in its appearance, its strange protruding structure inviting the user to expect an unusual sensory experience. We defined its form based on two key, albeit contradictory constraints: tight contact against the body, and user comfort. In order to optimize sound transmission and avoid signal attenuation, the point of contact with the body should be made of hard material, secured tightly against the user’s body. Balancing good signal transmission and basic comfort therefore became a principal design challenge. We addressed this via the flexibility of the modules (see Fig. 2) and the ergonomic aspects of the harness structure, co-developed with costume design studio Les Vertugadins.

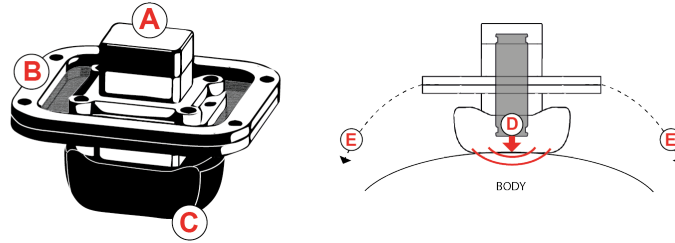


Fig. 2. The vibratory module. The module snaps onto extended fabric, tightened between the edges of the frame (B). A rounded, hard bottom (C) comes into contact with the body, transmitting the vibrations of the actuator to the user. The actuator’s axis of vibration (D) is orthogonal to the body’s surface. It “breathes” within its structural frame, and is pulled against the body by straps attached at all four corners (E).

The technical aspects of the module allow the wearable device to adapt to nine points of stimulation on the clavicles, ribs, and spine. Velcro straps are attached to all corners of the modules, pulling them against the body. The voice coil actuators are connected to a multichannel audio-haptic card (Actronika HSD Mk-1). The card is wire-powered, and a USB audio port allows for wired connection to a computer for signal transmission. Our custom interfaces for audio-tactile effect composition are in a preliminary stage, and we need to conduct more perceptual research before we can fine-tune and calibrate the effects to the body’s sensitivity [2]. The harness cannot be worn for long periods due to its skin-tight fit, so today’s use is limited to experimentation and demonstration.

3.2 Product Design Artifact

Product Artifact Purpose With Ryzm™, we bridge the gap between our ongoing scientific investigation and the tangible value of our work to our research

partner, Actronika, a growing deep-tech business specialized in vibrotactile integration and product development. By adapting to this industrial context, we find ourselves in what is probably a common situation, as “the majority of design research is paid for by the development industry” [22]. To adapt, we identified a use case that fit our initial results and the company’s haptic expertise: tactile-augmented listening experiences. Ryzm™ was imagined as a tactile listening device that will build on things consumers have already experienced about audio technology and haptic accessories, but in a slightly different way. To make new technology more easily acceptable, that degree of difference should sway users’ perception of the product towards an improved existing experience rather than one that is totally new and unusual [23]. If successful, Ryzm™ may allow us to inject an aspect of our research into society at large, communicating that sensory experiences of sound are diverse and arguably under-served by today’s dominant audio technology.

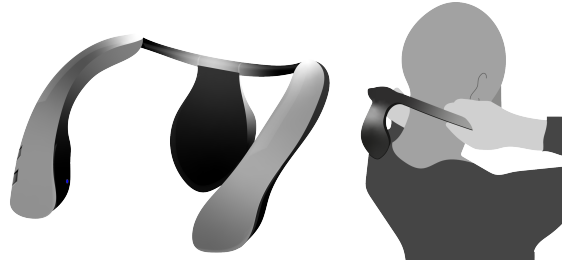


Fig. 3. The product design artifact. A preliminary illustration of the future Ryzm™ device, designed for tactile augmentation of listening. The device integrates three positions of vibrotactile stimulation on the upper neck and clavicles.

Product Artifact Form We designed Ryzm™ in order to consolidate results from our prior research with simplified formal aspects of the multimodal harness (see Fig. 3). The device is to be worn around the neck, targeting three of the most sensitive positions for ETC as found in our prior psychophysical study [1]. On both clavicles and the upper neck, we integrate three voice-coil actuators to transmit the vibratory signals. Vibrations on both clavicles allow for stereo-type effects, and a third point of stimulation on the neck adds potential for tactile effect diversity. The vibratory effects could therefore make sound accessible to all hearing profiles, either via tactile stimulation or in combination with ETC. In contrast to the multimodal harness, Ryzm™’s future design will not require users to wear earplugs. To improve ease of use and comfort, this feature combined with other ergonomic aspects of the product (positioning on the body, tightness, number of actuators) will change the potential perceptual experiences in comparison to the multimodal harness. Future user testing with prototypes will help Actronika to prioritize key features and design better algorithms for

audio signal transformation into vibratory stimuli, displayed by Ryzm™. We defined these features not only based on ergonomics and comfort, but also to draw comparison to existing products on the market: neck-worn speakers are now sold by prominent acoustic companies such as Bose¹ and Sony². Future users' familiarity with such existing devices may ease the acceptance of Ryzm™ as a product designed for listening, despite obvious formal differences from classic headsets.

4 Positive Project Impacts

Through a retrospective view on the artifacts' development, we can give a few insights about the complementarity of the speculative and product design processes. Their reciprocal nature can be demonstrated in terms of three main positive project impacts: it advanced a common objective, defined the product concept, and built mutual understanding between our commercial and scientific partners.

4.1 Positive impact 1: Advancing a common objective

Though their purposes and forms are different, the process of creating the two design artifacts has taken our research objective in a common direction. The act of wearing the multimodal harness forces the user to challenge their assumptions about sound perception and helps to imagine another evolutionary path of personal listening devices. However, its speculative purpose constrains its use to experimentation: it is heavy, wired, requires the use of earplugs, and users can realistically wear it only for short periods of time due to the tight fit. Finding its roots in the same research objective, Ryzm™ offers a compromise between idealism and practicality. The product concept suggests a more easily acceptable, ergonomic and less time-consuming solution to the industrial development of novel audio-tactile wearable technology. Such a product could already introduce ETC and tactile sensations of sound to the upper neck and clavicles, and potentially pave the way for more of the body in future listening devices.

4.2 Positive impact 2: Defining a product concept

In Fig. 4, we illustrate how the “problematic” nature of the speculative artifact helped define the product concept in terms of industrial considerations: the user, the scale of development, the market, and project timelines. We first identified the most impractical aspects of the multimodal harness to define Ryzm™'s future characteristics: uni-size, lightweight, simplified development and use, and familiar appearance. Without the multimodal harness at hand, we would not have had these points of comparison that helped guide the definition of a user-centered product.

¹ Bose SoundWear Companion speaker

² Sony SRS-NS7 Wireless Neckband Speaker

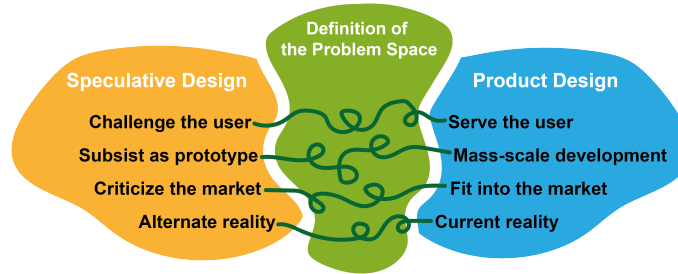


Fig. 4. In our project, the speculative design process influenced the product design process due to the problem space which naturally emerged between them. This problem space was built on contrasting purposes, as shown in the figure. The most “problematic” aspects of the multimodal harness revealed how Ryzm™ must be different in order to be commercially practical.

4.3 Positive impact 3: Fostering mutual understanding

Certain key moments in each artifacts’ development demonstrate the interactions between the two design processes (see Fig. 5). To be able to respond to our industrial partner’s commercial requirements for our project, we needed to understand their expectations and facilitate their understanding of our research: something best done through a collaborative activity. We therefore started the Ryzm™ project during a workshop with colleagues. This resulted in an initial design concept, sketched while we finalized the first multimodal harness prototype. As we developed initial prototypes of the Ryzm™ product, we also developed the second prototype of the harness. By developing the prototypes at the same time, we were able to maintain close contact with Actronika’s mechanical and electronic design teams. Through our research, we also created another connection with Actronika’s co-development partner, Les Vertugadins. The consistent internal communication and integration of our project in our partner’s external network helped to assimilate the speculative research in the industrial context, building mutual understanding and accelerating both artifacts’ development.

5 Conclusion

Through all of these aspects of our case study, we demonstrate that the two parallel design processes had a reciprocal relationship: the interactions between them propelled both speculative and product development, and advanced our research in body-based listening experiences. The industrial environment that gave life to our work has helped to ground our speculative design approach and emphasize the importance of a practical output: an objective of commercial product design. The two design artifacts are interdependent despite their contrasting purposes: the scientific context for developing the multimodal harness could not have existed without the commercial context for developing Ryzm™, and vice versa. While speculative artifacts like the multimodal harness don’t

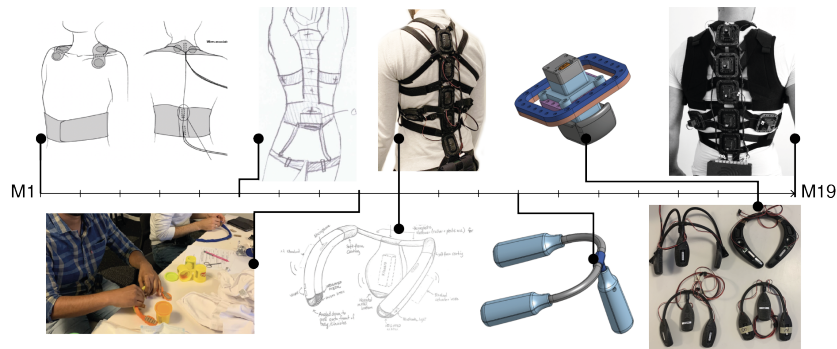


Fig. 5. Overlaid 19-month timeline of speculative (top) and product (bottom) artifact development. Images are taken from project records. The two processes overlap: phases of brainstorming, sketching and prototyping occurred in parallel and provided momentum for both artifacts' development.

target commercial use, they give the design researcher the freedom of imagination. This creative liberty may seem to be at odds with the controlled nature of the scientific method and time-sensitive commercial development, but without it, neither design artifact would exist. Through this case study, we hope to have illustrated the value of a peaceful coexistence between uninhibited creativity (speculation) and practical constraint (commercialization) in an industrial environment. In future work, we will extend this analysis to other audio-tactile device development, with the hopes to expose commonalities and explore the diversity of speculative methods in multidisciplinary product design projects.

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