WEARABLE SYNAESTHESIA: SPECULATIVE DESIGN FOR DISABILITY

IBEN ØSTERGAARD FOG *
UNIVERSITY OF SOUTHERN DENMARK
IBEN.OSTERGAARD.FOG@GMAIL.COM
*BOTH FIRST AUTHORS

PETRA PISKOR *
UNIVERSITY OF SOUTHERN DENMARK
PETRAPISKOR11@GMAIL.COM

ABSTRACT

Artificial synesthesia, which in Greek means perception (aesthesis) and together (syn), is the phenomenon, where one sense is being felt through another sense, through a cross-modal mapping device. Inspired by this we developed a sensory augmentation device. We looked into vision-impairment to consider the social and functional requirements of a vision-free device. According to the World Health Organisation (WHO) more than 1.3 billion people in the world today are vision impaired, but the technology to aid them in navigating is not only limited, but often requires compromises. Canes, for example, occupy the hand. They also signify the disability, which can be either useful or problematic. Our speculative prototype, Wearable Synaesthesia, uses haptics to enable vision-free navigation. Gold-leafs are used as on-skin electronics, in a move towards to aesthetically refined wearable whose functionality is completely hidden. While suitable for use by blind people, Wearable Synaesthesia should not only be associated with disability, but rather seen as a super human power, a sixth sense.

INTRODUCTION

Transhumanism and disability:

Artificial Senses are described by the Cyborg Foundation (2019) as an intelligence created by humans but with stimuli collected by technology. It enhances the human capabilities, in contrast to AI, where machines generate the intelligence. Continuing on the transhumanism as a cultural movement, our paper is based on Transhumanist FAQ's (Humanity+, 2019) description of transhumanism, where they "affirm the possibility and desirability of fundamentally improving the human condition through applied reason, especially by developing, and making widely available, technologies to eliminate aging and to greatly enhance human intellectual, physical, and psychological capacities" (Humanity+, 2019). Disability proposes an interesting perspective towards transhumanism. It can be a part of a person's intrinsic self-image, where a solution is not the desired outcome. Chislenko states: "As humans developed sufficient intelligence to embark on the long journey of supplementing their convoluted, undocumented and structurally inflexible biological bodies with intentionally designed extensions." (Chislenko, 1995). We propose that disability opens a possibility of easier enhancement and extensions of the existing senses, that often get intensified when a person is disabled. Design for disability can be used as a pathway to create new tailored experiences.

Aesthetics and disability

Design for disability often focuses on problem solving by using technology as the solution (Cherney, 1999). This can result in a downgrade in the aesthetic aspect of the design, as Wilde and Marti state in their study "The resulting technologies may conform well to medical needs, but they often neglect complex aesthetic needs of the individual" (Wilde and Marti, 2018). Furthermore, wearables, e.g. clothing and accessories, can have a social, cultural, psychical and psychological functions (Wilde and Marti, 2018). By combining technology and aesthetics, one could hope, that disability design can go beyond being only a helping device and become an aesthetic choice, which not only empowers the disabled in a social context, but also acts as a step towards further exploration within the aspects of transhumanism.

'Human-Echolocators

In our project, we used Human-Echolocators as the main inspiration for our prototype. Through literature surveys it is estimated that 20-30% of blind people use echolocation as a navigation. By making sonar emissions, e.g. mouth clicking and tapping cane, the sound that is sent out will reflect back according to the distance and material (Thaler, 2013; Thaler and Goodale, 2016). Other studies show that using echolocation as a blind person, e.g. neuroimaging, such as functional magnetic resonance (fMRI) or positron emission tomography (PET) detects activity in the visual cortex, that normally lights up when a sighted person is using their vision (Thaler and Goodale, 2016).

Furthermore, in a survey study, researchers found that blind people who use echolocation not only have a higher tendency to navigate in unfamiliar places, but also have higher salaries than blind people that navigate without echolocation (Thaler, 2013). This indicates that echolocation improves quality of life and enriches social contribution of the visually impaired.

In our project we explore methods of sensory substitution from both a design and social perspective.

BACKGROUND

Artificial sensory substitution in Human Computer interaction (HCI), can occur across different sensory-systems. Sensory substitution studies have demonstrated that the capacity of the brain to adapt to information relayed from an artificial receptor via an auditory or tactile human–machine interface (HMI) (Bach-y-Rita and W. Kercel, 2003). The term otherwise known as Brain plasticity*,* have been defined as "the adaptive capacities of the central nervous system – its ability to modify its own structural organization and functioning" (Back-Y-Rita, 1990).

In this project we especially focused on tactile-vision sensory substitution. Studies about tactile-vision sensory substitution (Bach-y-Rita and W. Kercel, 2003) have showed positive results when transmitting a picture from a camera or a sonar device into a vibrational or electrical tactile signal through mediation of different skin receptors on the body. For the potential design of the future prototype, and to understand the distances better, we looked into Tacttoo, where Horvath et al., (2014) tailored a design of small silver electrodes combined with the adhesive for *use on the forearm.* They used 4 × 2 array of taxels with an increased electrode spacing of 9*mm* to match the lower tactile acuity of the forearm (S. J. Lederman et al. 2009). The diameter of each electrode is set to 5*mm*, similar to previous interfaces (Gallace and Spence, 2010). For on-skin adhesive output we looked into DuoSkin from MIT (Kao et al., 2016) and their process of creating an on-skin interface with gold-leaf as a conductive material. As a part of our Research Though Design Process (RtD) we developed our speculative prototype. Though a dynamic process, with ideation, prototyping, and user-testing, we were constantly redesigning and reflecting upon the design and functionality of the wearable. RtD can be used as a tool to reflect for designing the future (Zimmerman and Forlizzi, 2014).

DEVELOPMENT - PROCESS

In this project our aim was to create a functional speculative design prototype. We developed the two prototypes though testing sensations and material explorations.

Testing sensations

Based on neurophysiological knowledge within the primary somatosensory cortex, which represents the tactile perception of the human body, we used a somatotopic maps, also referred to as a homunculus. The mouth, hand and fingers are the most sensitive areas, which also correlate to the size of the cortex that belongs to those parts (Bear et al., 2007).

The forearm was chosen as the test area, due to functionality, aesthetics and the sensitivity.

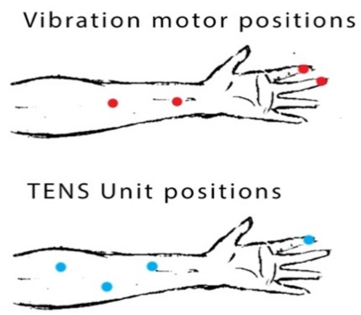


Figure 1: User-testing for optimal focus points: Placement of vibration motors and TENS unit.

Transcutaneous Electrical Nerve Stimulation (TENS) units, which is a battery driven device used for pain relief, was tested on the skin as a possible sensational output (table 1). We decided not to use TENS units for further exploration, due to the discomfort that the test-subjects experienced. On the contrary, user-testing of vibration motors - Ø 12 mm (figure 1) was described as a pleasant sensation. The motors were placed on different focus points on the forearm to find the ideal placement. During the testing, two issues arose; Firstly, the participants reported a numbness from the motors, in our case, a couple of seconds to minutes, which can be explained due to the strong vibration of the motors. Secondly, the placement of the motors had an impact on the test person's ability to distinguishing between the sensation of the two to four motors. This may be both due to the diameter of the vibrator, and differences in the human anatomy, e.g. the placement of tendons and nerve endings. Though user-testing, we discovered that vibration on the index- and middle finger, and on the wrist and middle arm, was the most ideal placement for the motors, in order to separate the sensations from each other (figure 1). The size and distance between the vibration motor had to increase proportionally in order to distinguish the two motors.

	P1	P2	P3	P4
I1	No feeling	Feeling in F	No feeling	T
I2	Gentle T	Gentle T	No feeling	Strong T
I3	T in F	T	Gentle T	T, U
I4	T in F	T in F, U	T in F	Extending to F, U
I5	F twitch, U	Pa, U	Pa	U
I6	Same	Very U	Pa	-
I7	Pa	Pa	-	-

Table 1: User-testing of TENS units

(P = Participant, I = Insensitivity, T = Tingling, F = Fingers, Pa = Painful, U = Uncomfortable)

Material exploration

Various types of materials were explored during the making of the prototype. The material exploration was based on different parameters such as: aesthetics, conduciveness, flexibility, customization and social acceptance. Silicone and 23,75 K gold- leaf met these expectations. The gold-leaf was tested as an on-skin conductive material (Kao et al., 2016) that can be worn as a temporary tattoo. The gold leaf had two purposes: Firstly, to function as a conductive material between input and output and 2) to enhance the aesthetics. By non-gender specific user testing, we discovered that gold was a popular choice of material and was accepted in social settings. Silicone was the second choice, which is a flexible material, e.g. used in soft robotics, and can be made into a variety of shapes and different thickness. Both of the materials support customization and can be used in designing an aesthetic speculative prototype.

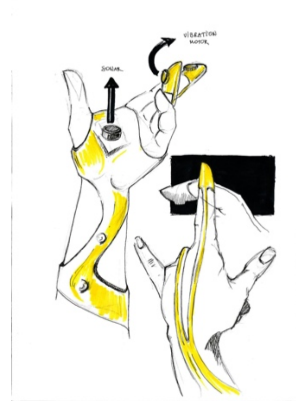
DESCRIBING THE PROTOTYPE

In the first prototype (figure 2) we combined the gold-leaf with a vibration motor into an adhesive vibrating jewellery piece. The second prototype (figure 3) consist of two vibration motors on the forearm and a sonar sensor on the palm of the hand. Furthermore, silicon was embedded around flexible wires of vibration motors and a sonar sensor into a sleeve design. The sonar was coded to detect two different inputs and translate it to one of the two motors. Respectively, the distance of an object, e.g. moving towards a wall, and if an object was moving, e.g. a car passing by. The prototype was functioning with one sonar, which detected the emission in front of it.

Lastly, we addressed the social encounter of a non-functional on-skin embodied wearable - jewellery piece. The first prototype was tested out as a part of the everyday outfit. The people that interacted with our user-tester didn't raise any questions towards the prototype, and it seemed to be socially accepted.

While developing our speculative prototype, we were trying to cover several aspects within developing a wearable, by addressing both fashions, the social aspects, medicine and technology and thereby approaching a business market that is not yet fully explored.

Figure 2: Gold necklace with a vibration motor, activated from sonar emission.



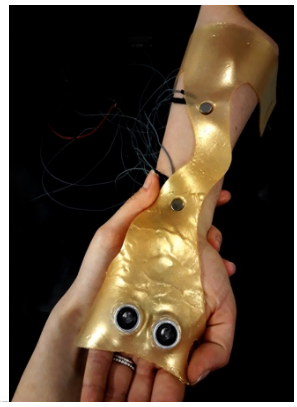


Figure 3: Concept drawing *Figure 4: Silicone prototype from*

DISCUSSION

In the following, we discuss the social impact of designing assistive devices for people with disabilities. If we look at the people with disabilities, supplementing their missing parts or senses is something that modern technologies are far from successfully providing. What modern assistive devices are still missing, is a social impact in perception of an assistive device (Pullin, 2009). Why are we designing assistive devices? Why are we calling it design for disability? We are proposing an idea of designing in another way to create experiences with a potential that there is an actual need or curiosity for. What our existing senses are providing us is a unique human experience tailored accordingly to an individual human. If we are missing one, we are not necessarily lacking the experience, but experiencing a unique one. In our project, we are trying to look at the process of designing for disability from different perspectives than those of assistive devices. One could ask: What happens "When the issues around disability catalyse new design thinking and influence a broader design culture in return (Pullin, 2009). What are the successful examples of design for disability? The only mainstream one that became culturally and socially accepted is the one around eyewear. Glasses became much more than a helping aid; they became a personal extension of the body. With eyewear, the perspective shifted from a medical to a social one. (Pullin, 2009).

CONCLUSION

Based on user-testing, we are proposing using echolocation as an input, gold leaf as conductive material and electro - vibration as an on-skin output. The functional prototype, Wearable Synaesthesia, can be used as a basis for further creation of a fully functional on-skin wearable. Throughout the process, we discovered that shifting from a medical design model into a social one can be beneficial in the future of the design for disability and de-stigmatisation of the individuals with the visual impairment.

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