Participatory Design Using Sensory Substitution Devices with Tactile and Audio Feedback

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ABSTRACT

Blind or visually impaired persons may experience challenges forming a mental map of the world around them. Our goal, in this participatory study, was to bridge the gap found in current technologies for a blind woman by creating a model utilizing tactile feedback. To achieve this goal, we designed three prototype sensory substitution systems. These prototypes attempted to aid our participant in crafting a world around her by providing auditory or tactile feedback in accordance to her proximity to an object. Each used a different form of output for the user: audio, vibration, or pressure. All of the stimuli produced by the models was managed by a researcher in place of a computer-vision algorithm. From our participant's feedback, we hope to develop a device that will provide the user a physical sensory substitution experience of sight.

CCS Concepts

•**Human-centered computing → Accessibility systems and tools;** *Accessibility design and evaluation methods;*

Keywords

Accessibilty; participatory design; blind individuals; sensory substitution; tactile feedback

1. INTRODUCTION

With the rate of advancements in computer vision and haptic feedback technologies, a great number of sensory substitution devices using both tactile and auditory feedback have been developed to aid individuals who are blind or visually impaired [3]. However, no available technologies exist that the subject of this study, denoted as TC, has found to fulfill her needs. Blind from birth, TC has occasionally experienced some physical sensations that she associates with sight, such as feeling her eyes "pulled" towards a bright area like a window. Visual depth perception exploits parallax due to different location of eyes to estimate distances to objects; eye muscles assist in moving and focusing the eyes to objects at various distances. While TC has tested various technologies, she has found that many tactile sensory substitution technologies, such as the tongue based electrotactile vision substitution system [2], are difficult for her to use and do not provide the physical experience of sight that she described to the research team. Likewise, TC has had little success with auditory simulation systems, ruling out the use of a system similar to EyeMusic [1].

Our intent is to work with TC over a period of time to develop assistive technologies which are unobtrusive and which suit her expressed needs, rather than what a sighted researcher believes her needs to be. The sighted researchers' misunderstanding of the descriptions of a physical sensation by the participant has been a significant challenge of the research team, similar to challenges in navigation assistance noted by Williams et al. [5].

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Figure 1: From left to right: LEGO Mindstorms motor; Third prototype apparatus; Third prototype evaluation setup.

2. EXPERIMENTAL EVALUATION

Our research is a preliminary step in the participatory design process through which a system will be created which uses computer vision to analyze images from a video camera and translate the results of the analysis into some form of haptic output. Due to the nature of this project, we chose to begin by developing the output system. The design of the output is key because it delivers the physical experience of sight to the user. In order to focus on the design of the output, we decided to substitute possible computer vision processes with a human researcher (i.e. a "Wizard of Oz" experiment).

2.1 Apparatus

We developed three prototype devices to perform a preliminary evaluation case study with TC. The first device used sound as the stimuli. This device was chosen due to the existence of many other assistive technologies which incorporate sound [2]. A researcher manually played a beeping noise from a laptop to indicate the distance between TC and another researcher. The second device was similarly constructed to test a stimuli common in assistive technologies. It used a small LEGO Mindstorms motor run at different speeds to generate vibrations that indicated distance. The third prototype incorporated a device made up of two yardsticks connected by a bolt in the middle in such a way that the device could be opened and closed like scissors. The device exerted pressure on TC's hands depending on how far different objects were from her, simulating parallax. TC held onto one side of the device, and the other was manned by a researcher. Though the pressure device was tested using distance, the original design was inspired by TC's desire to understand the shape of different objects using pressure, like one would when making pottery.

For the first two tests, TC wore a Samsung Gear VR headset that recorded first-person video. A Samsung phone was connected to this headset that streamed the current video feed to the laptop of a researcher. That researcher could then identify what TC was looking at and the distance to said item using the Distance Meter application. The researcher then administered the stimuli depending on which prototype was being implemented.

2.2 Procedure

While all three prototypes varied in the nature of stimuli, each was tested in a similar manner. TC was first introduced to each prototype and gained confidence through a few trial sessions. The test was then performed and TC gave feedback about the usefulness of each prototype. This feedback was recorded by a researcher.

The first test used sound as a cue for distance. While TC sat and looked directly ahead, one of the researchers would move toward and away from her. Depending on the distance between TC and the researcher, a corresponding number of beeping sounds were played in succession.

Following our evaluation using auditory feedback, we implemented a similar system using tactile feedback with the LEGO Mindstorms motor. Once again, TC was seated with a researcher a few feet away. The motor, controlled by another researcher, vibrated at an increased rate the closer the first researcher was to TC, and likewise decreased in intensity the further the researcher was from TC.

The final test used pressure as the outputted stimuli. Using the aforementioned device with yardsticks, a researcher moved TC's hands closer or further apart depending on the distance between TC and the researcher. Though the VR headset could have been used in this test, we decided against it since its video output would have been obstructed by a researcher controlling the handheld device.

2.3 Results

With our first prototype that utilized auditory feedback, TC felt that she "could gauge pretty accurately how far [away] someone was", which met our goal of providing a basic measure of distance. However, TC noted that incorporating auditory complexity into a more developed system would likely provide challenges and speculated, "I might not be able to make sense of it".

The LEGO Mindstorms prototype, presented a method of conceptualizing space through tactile feedback (vibrations) using the motor's technology. Our one-dimensional system of decreasing rumble intensity when moving further away from TC proved effective in allowing her to measure distance. However, its simplicity and limitations were noted. In a debriefing meeting, TC stated "speed is a key facet of my visual experiences" and proposed that using vibration intensity as an indicator of object density may be a possible modification to the prototype.

The final test using the pressure prototype garnered the most positive feedback in our trials. TC was excited to see progress on a model that attempted to simulate eye movement and found the prototype "easy to understand." She suggested that for a more complete model "incorporating rotation would be important." Following this suggestion, we disassembled part of the third prototype to allow for rotation of TC's hands and evaluated this new system of conveying parallax. TC gave a positive response to the rotational system and noted that it may lead to the inception of a useful product in the future.

3. CONCLUSION

After completing our evaluation, we have concluded that our future focal point will be to enhance the pressure prototype, which was the device built to exert pressure on TC's hands in order to better fulfill her desire for a physical experience of sight that she described. We intend to simulate eye movement by incorporating rotation in order to express distance. We plan to introduce TC to a vibrotactile device inspired by the VibroGlove [4]. Our next device would provide the sensation of a user's hands being pushed and rotated in different directions, mimicking the ways in which eyes move. This would enable the user to identify the distance to an object in front of him or her. TC's wish of visualizing an environment through utilizing tactile feedback can be approached through this model, and we believe the model we have presented typifies TC's aspirations.

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