Haptic Reassurance in the Pitch Black for an Immersive Theatre Experience

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ABSTRACT
An immersive theatre experience was designed to raise awareness and question perceptions of 'blindness', through enabling both sighted and blind members to experience a similar reality. A multimodal experience was created, comprising ambient sounds and narratives – heard through headphones – and an assortment of themed tactile objects, intended to be felt. In addition, audience members were each provided with a novel haptic device that was designed to enhance their discovery of a pitch-black space. An in the wild study of the cultural experience showed how blind and sighted audience members had different 'felt' experiences, but that neither was a lesser one. Furthermore, the haptic device was found to encourage enactive exploration and provide reassurance of the environment for both sighted and blind people, rather than acting simply as a navigation guide. We discuss the potential of using haptic feedback to create cultural experiences for both blind and sighted people; rethinking current utilitarian framing of it as assistive technology.

Author Keywords
Haptic feedback, in-the-wild user study, immersive theatre, visually impaired, blind, sensory augmentation

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H5.2 Information interfaces and presentation: User Interfaces. Haptic I/O.

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Design, Human Factors

INTRODUCTION
'Dining In The Dark' restaurants are appearing throughout the world where diners eat in absolute darkness. Sighted (and blind) people can come and eat while being served by blind waiters and waitresses [24]. The experience is a great leveler, with sighted people fumbling with their knifes and forks trying to fathom out what they are eating, while the blind servers move effortlessly knowing their way around every inch of the restaurant. An outcome is for sighted people to begin to understand some of the aspects of what it means to be blind and to share this with blind people. For the blind person the eating experience is the same but the dining experience is transformed as they share the same perceptual affordances with sighted people.

How might we go further by providing blind and sighted people with other more equivalent experiences of the world? For example, what would it take for blind people to enjoy a painting, a film or a play in a similar way to those who can see them? How could new technologies be designed to facilitate comparable cultural experiences that are accessible by all?

While there has been much interest in developing cultural experiences for visually impaired and blind people[1], efforts so far have focused largely on compensatory measures, such as the use of audio descriptions, tactile artifacts, raised images or through social interaction with sighted people. The experiences are limited, often depending on an accompanying sighted describer helping out, making it difficult for blind and partially sighted people to access the work directly by themselves [11,13,14].

Alternatively, we propose that the design and application of innovative ubiquitous technologies can open up the arts for visually impaired audiences to experience them in similar and even enhanced ways compared with how they are experienced by sighted people. Our approach is based on *sensory augmentation* – a philosophical perspective that considers whether and how it is possible to extend our senses. By building novel augmentation devices, it seeks to explore sensory, bodily and cognitive extensions [2,4,21]. In particular, the aim is to extend the body's ability to sense aspects of the environment that are not normally perceivable by the body in its natural state.

Informed by sensory augmentation, we developed an "immersive" theatre experience for blind and sighted audiences. Instead of a performance taking place on a stage (which cannot be seen by blind audience members), the

[1] The degree of blindness people can have varies from partial to total blindness. We use the two terms as and where appropriate.

dramatic action was moved within the bodily experience of each audience member. Our overarching goal was for it to be experienced by both on a more level playing ground. Specifically, a handheld haptic device was created to encourage enactive exploration [9] of a pitch-black space that was filled with objects to touch and sounds and narratives to hear. A novel form of haptic feedback was provided in relation to how people moved in the space. The idea was to give all audience members the opportunity to experience a 'felt' presence of the environment that would transcend their actual perception [cf 6].

We were interested in discovering how sighted and blind audience members perceived and understood this kind of enactive exploration when in a theatre setting. Would the haptic device become an extension of their own body, augmenting their sensation of experiencing and moving in the dark? If so, how would it feel and would it differ for the blind and the sighted? To address these questions, we conducted an in-the-wild study for a week of public performances held in Battersea Arts Centre in London, where 150 sighted and blind audience members took part. Below, we describe the design of the immersive theatre experience and our analysis of the performances that took place within it.

BACKGROUND

Ubiquitous computing offers new opportunities for augmenting experiences for both sighted and blind audiences. A number of projects have developed new experiences to enhance exploration and navigation.

Augmenting exploration

One of the earliest forays into using pervasive technologies to promote exploration of a mixed reality environment was the 'Hunting for the Snark' [23]. An assortment of mobile and sensor-based devices was developed, including probing devices, as part of an adventure game. Children had to hunt an elusive, virtual creature, called the Snark, who kept changing its shape, appearing and disappearing, depending on the physical actions of the children (e.g., feeding it, flying with it, dancing with it). The sensor-based devices detected movements and responded by revealing aspects of the Snark's personality, likes and dislikes. For example, a 'snooper' handheld device, that used ultrasonic sensing, enabled them to discover invisible 'virtual' objects, which they then fed to the Snark. A main finding was that the *less* direction the children were given as to what to do and how to find the Snark the *more* they explored the mixed reality space.

More recently, a haptic device, Momo, was developed in the shape of a large furry egg intended to be held in both hands [18]. The device was used as a tour guide to indicate the direction someone should take, through leaning forwards or backwards, as well as vibrating. Preprogrammed GPS coordinates set up in a number of parks in New York, enabled visitors to explore the city, without a map, from one destination to another at their own leisurely pace.

Another technological augmentation that has been used *in situ* to transport people to another time or to enhance their experience is audio. For example, Riot!1831 was designed as a historical experience to simulate the riot that took place outside in a town square in Bristol in the UK [22]. Participants wearing headphones, strolled around the square, listening to riotous scenes, such as shouting, screaming and gunshots, at different locations. Aspects of the augmented experience were recounted by one participant as *"deemed to be both moving and memorable and thus are those that people really value"* [22]. In another setting, called Scratch, participants wandered around familiar surroundings, such as their local park, while listening to various narratives, again through headphones, but this time not using location-based cues. The idea was instead to enable them to make associations between their local surroundings and the narrative using their imagination [19].

Most well known, are Benford *et al's* [3] series of mixed reality games played in the streets and online by audiences and choreographed by the theatre company Blast Theory. Various technologies were designed and orchestrated to provide audiences with complex user experiences, to enable them to traverse the digital and the physical in innovative ways. These included Desert Rain and Uncle Roy All Around You. The resulting trajectories extended over space and time involving multiple roles and interfaces.

Most of the novel augmented user experiences have been developed for sighted people. An exception was a 'soundscape' based on a Roald Dahl story, that comprised a tapestry of dialogue, music, sound effects and soundmarks (a unique sound played in one location) where blind and sighted audiences used spatiality to understand, follow and enjoy the narrative [14].

Augmenting navigation

Wearable devices have also been developed as real-time navigation aids using either audio or haptic feedback. These devices primarily aim to help people who have difficulty finding a location in an unfamiliar place. For example, pedestrians and cyclists find it problematic to look at detailed information on small screens while 'on the go' [10]. For blind people, such devices provide extra sensory cues as to the presence of obstacles, such as buildings and kerbs, as well as directions as to where to go next.

Audio interfaces, however, can make it difficult for the person to distinguish between the sounds from the system and those of the environment [26]. Wearing headphones can also prevent visually impaired pedestrians from hearing other sounds [1]. In contrast, haptic interfaces provide feedback that is more distinguishable from the environment, using vibrotactile stimulation on the body. A number of wearable devices, such as a headband [5], a vest [20] and belts [7,8] have been designed. Participants wearing the Haptic Radar headband [5] were able to 'see' objects coming from behind them. The headband sensed range information and provided spatial feedback that buzzed around the head. The Tactile Wayfinder [20], was a torso display that provided tactile location information that was mapped onto the wearer's body, letting them know the next direction they needed to take (e.g., two buzzes on the right indicates 'turn right at the next crossing'). This enabled the wearer to know in advance how the route would continue when reaching a waypoint. Kinesthetic feedback has also been used to generate a force sensation that contrasts with the buzzing associated with vibrotactile feedback, by 'pulling' a pedestrian in a particular direction [1].

The effectiveness of these types of haptic technologies is usually described in terms of whether the (blind) pedestrian is able to locate a specific target or follow a pre-determined route. However, there has been little consideration of the quality of the experience for the wearer when using it to guide their walking. Anecdotal evidence suggests they can be uncomfortable or even annoying to wear and hence may not be acceptable for long-term use.

Sensory augmentation

A number of novel sensory substitution devices have been built to investigate aspects of 'enactive' perception. This refers to where movement of the body in the environment is considered central to how we perceive. Most notable was the TVSS vision-to-tactile system [2]. This essentially consisted of a camera hooked up to an array of tactile stimulators, located on the torso or tongue of a person's body, to enable blind people to perceive the world as if seen through a camera. After some training with the system, some people reported that the experience of being buzzed through the tactile patterns became 'externalized', with a phenomenological feeling that was in many respects similar to vision.

Since this pioneering work in the 60s, research on sensory augmentation has largely focused on how vibrotactile feedback can be applied to a person's body (e.g., head, torso, legs), while they moved through an environment. An alternative approach is to provide a person with something to hold, such as a stick, a ball or a torch, whilst walking. The difference is that holding something affords more distal perception, akin to practical tool use [6]. It is well known that bodily transformations happen through practical tool-use, such as changes in body schema and body image after pointing with sticks, etc., [17]. This suggests that holding something can have a different phenomenological effect on a person than when haptic feedback is applied directly to their body. In particular, people have more control over where to point and move the handheld device. The enactive torch was developed with this in mind, enabling people to 'see' objects by moving their holding arm and pointing at objects in the environment [6]. The device provided a continuous stream of vibrotactile feedback to their hand; the strength of stimulation relative to the distance to the object being pointed at. Similarly, the Haptic Laser was developed to enable people to feel and discriminate between physical objects in a room from a distance [12]. As well as providing a new approach to investigating enactive perception, providing haptic feedback about the transitions between objects, such as tables and bodies, may prove to be more comfortable for people to use.

AIMS AND OBJECTIVES

The goal of our research was to explore whether a handheld haptic device could enhance blind and sighted people's experience of an environment, devoid of visual stimuli but rich in other multi-modal experiences. The objective was to engender sensory augmentation within the dramatic action of a theatre space. A device was designed to provide haptic feedback as to where someone was in relation to spatially located objects and sounds and that the space be pitch black so no-one could see. It was deliberately designed to be suggestive rather than directive to encourage enactive exploration for both sighted and blind people [9].

DESIGN OF THE IMMERSIVE HAPTIC THEATRE EXPERIENCE

The theatre experience, called the Question [25], was developed by Extant, a professional performing arts company of visually impaired people. It comprised a number of different components: (i) a narrative heard through headphones, (ii) sound effects to enhance the narrative, (iii) a tactile set that provide stimuli to be touched and felt, (iv) a live (blind) actor speaking about being blind and (v) the haptic device, to augment the audience members experience through the space.

The narrative, written by the blind Artistic Director, sought to dramatically engage with the issue of blindness both in content and in form. It was inspired by the book 'On Blindness', that describes the dialogues between sighted philosopher Bryan Magee and blind philosopher Martin Milligan [16]. Milligan disputed Magee's claim that the blind person's knowledge of reality differs from that of the sighted person due to their experiental knowledge. Specifically, it was developed as a fragmented path following the thoughts and experiences of a blind geometer, Kalabi. Kalabi is struggling with scientific, philosophical and cultural perspectives on the question of knowledge through sensory translation, and what ultimate impact this has on an individual's identity.

The narrative was enhanced with various recorded sounds: the clunking sound of a person walking through a building, cars crashing into each other, creaking doors that are opening and closing, and fingers tapping on a keyboard. Some of these audio effects were intended to be heard in the background and at a distance, while others at close proximity to provide a more complex and rich feel to the imagined space.

The tactile set comprised four different zones, each based around a particular theme consisting of a set of objects and shapes (e.g., a ruler, a cube). The idea was that an audience member would feel with their hands the shapes and objects in each zone, while listening to audio through their headphones. A further level of complexity was provided through a blind actor who moved through the set and spoke occasionally, while using a gong to mark specific moments in the narrative. Finally, the haptic device, intended to be held in one hand, was designed to augment the way both sighted and blind audience members experience and move about in the dark.

DESIGN OF THE HAPTIC DEVICE

The haptic device evolved from an initial concept of a handheld object that would open and close in response to being near or far from sensor detectors situated in a space. Central to the design was that it should feel comfortable and would facilitate audience members in exploring the pitch-black space. We also took into account how visually impaired and sighted people move in the dark using their existing perception and appreciation of the environment. A conceptual model was used, based on a simple hot/cold metaphor that is often used in games, where people have to find or move to a target: warm is near, cold is far.

Given that the device would be used in live performances in an actual theatre setting, the aesthetics of the experience were considered important. This included the feel of the device in terms of its smoothness and roundedness of corners, and also the experience of using it. The choice of feedback initially considered was vibrotactile feedback. However, the blind members of the design team expressed that this would not be appropriate for the theatre setting, as it felt 'strangely empty' and 'cold'. Instead, we chose to design something that opened and closed – which the blind members of the team felt had a more aesthetic feel about it. A handheld device was envisioned that would be shaped like a lotus flower that could be held in one hand. As a person moved through a physical space the 'flower' would open and close its petals in response to how near that person was to one of the tactile zones.

Prototype I: The air freshener

Figure 1 shows an early prototype for a handheld device, where the casing of a standard air freshener was used as the shell of the device. A mechanical mechanism was added to enable it to open and close. Feedback was provided through feeling the device changing shape and size when holding it.

The opening and closing of the prototype was tested. A series of beacons, that emitted infrared signals in a downward cone were attached to the ceiling of our lab. Each beacon was associated with a number; the proximity of a beacon to a 'target location' determined the number that was transmitted, where zero represented a beacon that is at a target location. The prototype contained infrared sensors that pointed at the ceiling, receiving the infrared proximity information and transforming this into the opening/closing action. By moving the prototype from beacon to beacon, a person is able to determine if they are getting closer or further away from the target zone. The conceptual metaphor was instantiated by providing 'hot' or 'cold' feedback: as a person wanders through a room the device indicates warmer (nearer the target) or colder (further away from the target) by opening and closing.

Figure 1. The first prototype for the sensory augmentation device using an air freshener case shown in its opened state

Figure 2. Shapes explored using low-tech materials for the second prototype

Figure 3. The final Haptic Lotus device that was developed

During a brainstorming meeting, which had three blind team members present, the early prototype was handed around. The prototype expanded and decreased in size in reaction to an infrared signal from the beacon that was placed on the table. A mix of reactions was evoked from the team members on first holding the device and exploring it through touch. For example, one blind person commented: "*it's a dog. It lifts up its head when it's interested*", while another said: "*It perks up, basically. It's intuitive*". One sighted person remarked that the device was up-side down from how she had imagined it. Instead she suggested it rest in the palm of her hand and to open and close its flaps more like a flower. The device was also compared to a stapler, going up and down, and an insect, that was opening its wings. However, the feel and shape of the device itself were considered too clunky for the envisioned theatre experience.

Prototype II: The Haptic Lotus

The idea of a flower opening and closing became the starting point for the second iteration of the device. Suitable types of materials were sourced that would make it pleasing to hold and enable people to perceive both opening and closing movements. A puppeteer technician joined the project team, who came up with potential designs for the device and devised the mechanics for expanding and contracting it. Figure 2 shows the different shapes considered. Eventually, a design was selected based on a trade off between expansion, requiring torque, and the necessary space for putting the electronics and sensors in. The second prototype is shown in Figure 3, having the form of a lotus flower, with petals opening and closing in response to the signals from the beacons.

The final Haptic Lotus device was coupled with an infra-red potential field emitted by beacons. The beacons were located on a grid of scaffold poles placed above the theatre space. Figure 4 shows the layout of the grid of beacons. Each Haptic Lotus contains three infra-red receivers, each with a viewing angle of approximately 30 degrees. The receivers are located on top of the central section of a Haptic Lotus, with one facing directly upwards and the two others at 20 degrees to this. This increases the overall viewing angle while also accounting for variation in hand posture.

The infra-red data transmitted from the beacons to a Haptic Lotus is modulated at 30Hz. The modulation and demodulation of the infra-red signal provides robustness against ambient infra-red, such as sound signals and camera light sources. The data sent by the beacons are RS232 encoded, alpha-numeric characters. After being received by the sensors, data is interpreted by an Arduino Pro Mini embedded device, located in each haptic lotus. Each alpha-numeric character corresponds to a position of the lotus petals. There are eight possible petal positions ranging from fully open to fully closed. The petals (which are made of flexible plastic sheet) are actuated by a single high-torque servo, controlled by the Arduino.

The Haptic Lotus 'remembers' the last value received over the infra-red, thus preventing the device from assuming an arbitrary (and possibly misleading) position when no beacon is in sight. A pack of AAA batteries is located in a flexible pouch, which fits under a person's hand. The Haptic Lotus and batteries together weigh approximately 280 grams. The weight and location of this power supply acts as a ballast, keeping the lotus pointing upwards, which benefits the infra-red sensors.

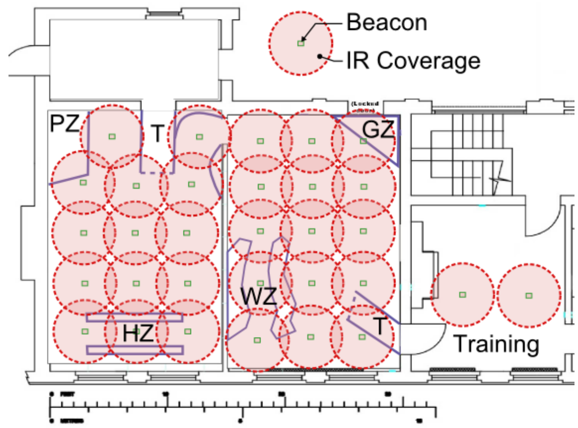

Figure 4. Layout of the beacon grid for the theatre space

THE SET-UP

Two adjacent rooms of equal size, approximately 5 by 8 meters and one smaller room of 4 by 5 meters were used for the performance (see Figure 4). Initial testing of the Haptic Lotus and beacons showed that 2.4 meters was an ideal ceiling height for the array of beacons. A total of 29 beacons were placed on a scaffolding structure at this height. A pattern was used that allowed the beacons to be matched to four themed zones positioned in the space.

The zones were philosophy (PZ), geometry (GZ), history (HZ) and work (WZ). A variety of relevant objects were placed in each zone, and the idea was that on entering a zone an audience member would be able to feel the objects and make connections with what they were hearing through their headphones about a particular theme. For example, in the philosophy zone two philosophers, one sighted and one blind, could be heard arguing with each other about the essence of what it means to be blind. Their philosophical debate is portrayed as a boxing match, with the sound of the roaring crowd in the background and the bell ringing for the start of the next round in this match. Against the backdrop of these various sounds, a number of philosophers can be heard sparring about whether blind people have equivalent experiences and what it means to know and know about.

The tactile set for the philosophy zone was built like a boxing ring, and people could feel the ropes of the ring, the bell, as well as boxing gloves. All the objects in the zones were either made from soft materials or secured in such a way and at such a height that they could not cause harm.

The two largest rooms were used for the performance, while the smaller room was used to prepare member of the audience before entering the rooms and to train them in the use of the Haptic Lotus.

THE PERFORMANCE

The performances took place over a period of a week. Audience members booked online to attend a performance and were assigned a specific time. It was not possible to control for equal numbers of sighted and blind people since it was publically advertised as a live theatre performance,

Figure 5. Two audience members (one sighted and one blind) exploring the geometry zone

Figure 6. A screenshot taken from the CCTV footage in which members of the audience are being monitored (from above) for their own and each other's safety

so the audience members who took part were those who wanted to come. In the end, of the members of the audience that took part, 82 indicated that they were sighted, 6 were partially sighted and 10 were blind.

Each day, five to six sessions took place, lasting 30 minutes. For each session, a group of up to six participants took part. In total, about 150 audience members took part. Before entering the dark space, the audience members were taken into the semi-dark room near the entrance of the dark space, given a short introduction about the nature of the performance they were about to experience, and told to explore, listen, and to feel with their hands. They were then each provided with a Haptic Lotus, a pair of headphones and were given a short training session on how to use the haptic device using the two test beacons in the first room. The audience members were then lead one by one into the dark space, and left alone in it to explore.

Figure 5 shows a sighted (background) and blind (foreground) member of the audience taking part in a performance; one is holding the haptic device and the other touching an object encountered in a zone. Figure 6 shows a bird's eye view of the space from an infra-red CCTV camera. The safety of the audience in the dark environment was paramount and so this camera system was installed to enable someone to continuously monitor the members of the audience during the performances to check if anyone was in distress or having difficulty. Participants were told to raise their arm if they wanted assistance or felt uncomfortable.

EVALUATION

During the week of the performances we conducted a user study to evaluate the immersive theatre experience. We used a mix of methods, comprising observations from the CCTV cameras, questionnaires, 30 open-ended interviews with one or two audience members after each performance and a further five interviews with members of the theatre company. Our focus was on explicating how the haptic form of sensory augmentation worked in an immersive theatre context for both sighted and blind audiences. Below, we describe our findings in terms of:

(i) The phenomenological experience

(ii) Exploration with the Haptic Lotus device

(iii) Arm gestures and ways of moving around the space

(i) The phenomenological experience

The audience members' responses to the overall immersive experience were very positive. Many commented on how much they enjoyed the experience and how it made them reflect upon what it means to explore a novel rich multi-media space using the four senses of sound, touch, smell and taste. For the sighted members, it provided a heightened awareness of these. For the blind, it offered them a way of exploring a rich textured world, akin to a child let free in a candy store, in ways that were not usually permissible or possible.

In the interviews, the blind and sighted members of the audience raised different issues about their immersive theatre experiences. The sighted members became more aware of using these senses to find their way around and discover what was there. For example one mentioned: *"I definitely thought it was about how to rethink about spaces and shapes, and a heightening of my other senses."* Others noted how their perceptions of people around them had changed, even treating them as part of the installation, having a very different experience of how they normally behave around people. Many also lost all sense of time.

There was a notable difference between the sighted and blind people's emotional response to the experience. Some of the sighted people mentioned their struggles in the dark: "*At first it was fun, but as time passed I became a bit unnerved and disorientated*" and "*I was initially nervous, and on hearing those sounds first I jolted*." One audience member gave an account of a particularly unhappy scene: "*I was trapped in a corner. I thought I was curtained in, (.....)*

I tried to break out of this corner and made several efforts". As might be expected, some sighted people strongly missed their lack of vision.

None of the blind members of the audience, however, talked about these kinds of struggle. On the contrary, most blind members of the audience gave accounts of increased freedom and delight, for example: "*To be in an environment where the point is that you are feeling around you the whole time - that is really interesting and liberating because I am blind, and I can't see at all. So I am constantly feeling around and it is my way of looking around. Often when you are in a shop, or most normal environments where it is probably a bit odd, as body language, and you may get told off not to feel the whole time...".* Another blind member of the audience spoke of his excitement when interacting with the zones, mentioning the profound effect when making connections between the narrative and what he felt: *"I was so disproportionately excited when I found something that I recognized. So even though I found it, I can imagine another person would think: "I found a boxing glove…great. But no, when I found it, I was like "I found a boxing glove! It's a boxing glove! Ah!"*

Several blind members of the audience gave extraordinary detailed accounts of what they had felt. One recounted that he had felt: "*a cube with different letters on its four faces, there were geometric shapes on flat surface, there was a bit of plastic film in a like a strip wound over itself, an inflatable dolphin, a smaller cube hanging up. There was a big bouncy rubber ball on the floor, there was a strange rubber creature hanging up with strange rubber fur, and maybe two eyes on it …*". In contrast, most sighted people talked more generally about their experience of feeling objects, and only occasionally mentioned a specific object, like a coffee cup, that they had come across, but never with the same level of detail that blind people provided.

The blind audience members were also able to relate to the overall narrative and integrate the different sounds and narratives they heard with the objects they felt. This was much more of a challenge for sighted people. One sighted woman mentioned that: "*I wanted to hear the space. I think it was a bit of an overload by taking my audio and sight away*". Another said how it made her reflect on the way she usually made use of her senses: "*It made me think about how usually when I listen, I am also processing something visual. Whereas here I couldn't process it all at once. I had to stop from touching things if I was listening to the audio, because I couldn't do both of them at the same time*." For a number of sighted people, therefore, the coordination of their senses in the dark had been the main focus of their experience, meaning they had less attention for the narrative.

There were also a large number of sighted audience members who enjoyed the challenge of being in the dark and how it imposed on their sensory systems. One person gave an account of how she had actively been exploring using her other senses*: "I remember feeling around the space, and then suddenly I got a strong whiff of rubber. I then went down on the floor and noticed several rubber tiles".* Another participant explained that "*the deprivation of sight did seem to bring out different ways of understanding or perception in a way that seemed to wake up a dormant part of the brain.*"

In discussions between blind and sighted participants, there were indications that there was an increased understanding or awareness of what it means to be blind. One sighted participant talked about her bewilderment when, as part of the audio for the performance, she heard that she was asked for directions. She hadn't known what to do or say as the encounter felt very real, but she wasn't sure where she was. Her blind companion was clearly amused by this, as this accurately described something that happened quite regularly to him as a blind person.

(ii) Exploration with the Haptic Lotus device

In the interviews with participants after the performance it became apparent that the Haptic Lotus had provided an experience that is not normally witnessed by blind or sighted people – that could only be experienced through holding the device itself. In particular, their comments suggested that the Haptic Lotus provided them with reassurance and comfort when exploring the space. For example, one person said: "*the device didn't really guide me to the zones but confirmed their location. It 'reassured' me to feel/look more closely in an area and move around in the small area to find things"*. Another commented that: *"The Haptic Lotus gave me something to focus on. I wanted to believe that it guided me to the zones"* and "*The device felt like a little friend. I felt safe, and I guess I might've felt unsafe without it".* One noted "*I enjoyed feeling like it was communicating with me. It added interest."* Hence, the device added special meaning to their felt experience, providing a friendly, reassuring presence.

Many people also commented on the Haptic Lotus as being like an animate object: being alive, pulsating and having a mind. For example, one noted: "*I liked the vibrating beat of that (the lotus)*"; another pointed out that the: "*The device was like a purring cat, or a pet.*' and "*It felt like it knew things. Like things about the space it was in*". One participant even commented: *"It was interesting to have something 'alive' in your hands. It was companionable."*

When asked about their experience of using the Haptic Lotus device, 50% of the audience said that they did not feel it had led them directly to the zones. Furthermore, the respondents were more or less equally divided as to whether they thought the device was helpful (28%), somewhat helpful (36%), and not helpful (37%).

In order to get a clearer picture of whether and how they had used the opening and closing movement of the Haptic Lotus, we asked participants how they had negotiated the dark space and how they reached their first and second zones. Their answers revealed that they had used a number of strategies to find the zones, including 'by chance', 'by touch', 'through following walls', 'following sounds', 'listening to the actor', and 'by using the Haptic Lotus'. Only a small proportion of people said that they had used the Haptic Lotus to guide them through the zones (13% mentioned Haptic Lotus for reaching their first zone, and 25% for their second zone). The diversity of answers suggests that people used a number of different strategies to move around the space, often not being aware of the haptic device directly guiding them to a zone. This suggests that the device may have become an extension of their bodily senses providing a holistic phenomenological experience, that made it difficult for people to put into words how they had reached the zones. Moreover, we noticed that audience members often talked about their experience of moving through the dark space by making a gesture as if they were still holding the device, with their palms turned upwards, their fingers gently moving as if touching the flower with its petals. It appears this gesture had become strongly associated with the experience of using the device.

(iii) Arm gestures and ways of moving around

To examine in more detail how people moved and explored the space we analysed and classified their arm gestures using the CCTV footage. We identified a number of distinct styles for moving around and making sense of the space while holding the Haptic Lotus.

Figure 7a) shows a person with both arms stretched forward and (b) a person moving their arm, that is not holding the Haptic Lotus, to feel the space. The arm movements for (a) and (b) can be seen as fairly standard ways of moving in a dark space, where people seek to avoid bumping into obstacles and are looking for walls or other points to hold onto. Most sighted people demonstrated the arm gestures of (a) and (b) on first entering the space.

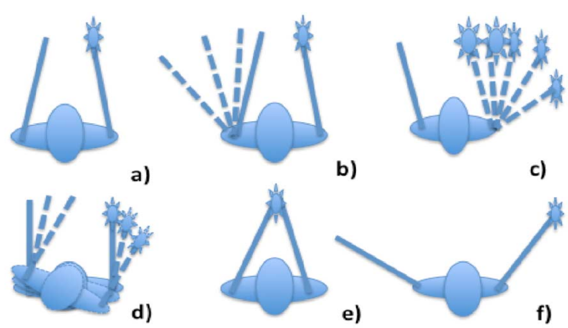

Figure 7. Arm gestures and styles of moving with the Haptic Lotus

After a short time in the area, many people demonstrated a distinct arm gesture with the Haptic Lotus, shown in Figure 7(c). The hand with the Haptic Lotus probed the space, similar to an elephant using its trunk, by moving from left to right and probing high and low. This sweeping movement was used while standing still and when walking. A variation on this was 7(d) where people pivoted around on their own axis, making the whole body move with arm plus Haptic Lotus out, in order to get a feel for the area. People were also often seen circling around themselves with the Haptic Lotus stretched out in front of them, before setting off in a direction.

A smaller number of audience members were also seen bringing their free hand towards the Haptic Lotus, as shown in Figure 7(e), possibly to feel its petals move and check their position. One person was seen flinging their arms wide out in Figure 7(f), moving through the space with great energy until they accidentally caught another person.

These exaggerated bodily movements and arm gestures are not within people's usual repertoire. Styles (c) and (d) were especially unusual and directly associated with holding the Haptic Lotus. They show how some participants were much more physical when exploring a dark space. By using the Lotus as an extended probing tool, the participants appeared to be creating a relationship between their own body and the space around it. However, from our observations of the CCTV footage, we noticed that this way of moving and probing was much more marked in the sighted compared with the blind audience members. The blind audience members were observed mostly walking using style (a) movements, and only moderately using the other probing gestures with the Haptic Lotus. Moreover, they did not appear to use their free arm to avoid obstacles, as in (b). Instead, they appeared to locate the zones by listening, or by hitting their foot against an obstruction which would made them halt to explore the area with their free arm.

To illustrate these differences between blind and sighted enactive exploration, two short vignettes are presented. Figure 8 (left) shows a blind person entering the space at location 1 coming out of the curtained entrance (T). She walked holding the Haptic Lotus in front of her with her free arm hanging to one side. At location 2 she hit with her foot an obstacle. This is the wall of the work zone, which is waist high and has various objects embedded in the structure and top of the wall.

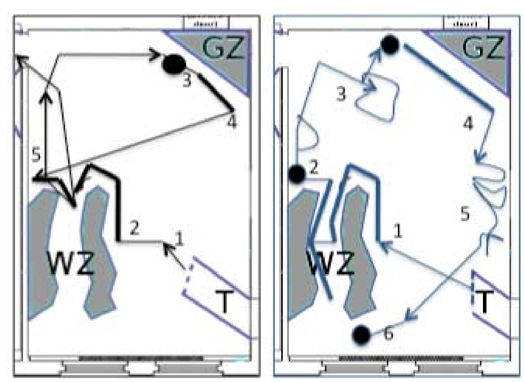

Figure 8. A blind person (left) and a sighted person (right) wandering through the dark space between two zones (Thin lines indicate walking, bold lines indicate exploring objects with hands and dark circles indicate the person standing still)

She then proceeded to inspect the various tactile elements, while slowly moving around the wall structure. She then walked away from this zone, and found herself near the next zone. At location 3 she stood completely still for about three minutes - not moving, presumably listening intently to the narrative through her headphones. She eventually moved on a few steps and noticed more objects, feeling them with her free arm for a while in a tentative manner. She then crossed the room, back to her first zone, where she explored the tactile set, vigorously pulling and tugging at the various objects. Finally, she moved away from the zone and appeared to head straight for the exit of the room.

Figure 8 (right) shows a sighted person entering the same room: he walked slowly, holding the Haptic Lotus in front of him, while carefully feeling with his free arm until he felt the walls. He tentatively explored the objects, moving around the wall structure. He then discovered the adjacent wall structure and continued to explore the tactile set, groping vigorously at the objects. At location 2 he stood still for about one minute, apparently listening. He then moved forward, and while walking quite slowly used the Haptic Lotus by waving it around in big semi-circles. While waving the Haptic Lotus around, he eventually made his way to location 3, where he circled around himself, moving his whole body in a pivoting action (cf Figure 7(d)). He stood still, again presumably listening, but was also seen to gently touch, playfully, the objects in zone GZ. He then shuffled slowly along the edge of this zone towards location 4, all the time feeling objects in the zone. He then moved away, while actively exploring where he was in the dark space, first by feeling the wall, and then bouncing himself towards the centre of the room, using the Haptic Lotus to probe around. He eventually moved away again from this spot, and while gesturing with the Haptic Lotus made for location 6, where he stood still listening.

These two vignettes show contrasting ways of moving around, typical of sighted and blind participants. The blind people appear to have a fairly accurate sense of the shape of the room, remembering where they had been before, and how to find the exit (presumably from hearing people enter the room through that door) – whereas sighted people often spent considerable amounts of time circling around themselves, probing the space. However, on occasions the blind people also used the Haptic Lotus, gently probing it into the space around them, feeling its shape with their free hand (as in Figure 7(e)), and bringing it close to their face.

The sighted person's movements demonstrate an active embodied exploration using the Haptic Lotus. From the way they moved, it seems that they used it to gain an awareness of where they were. Even though several sighted and blind people explicitly said in the interviews that the device hadn't been particularly helpful for finding zones, our observations of their actual behaviour showed them actively using the Haptic Lotus to explore the space.

DISCUSSION

Our findings have shown how haptic feedback can be designed to provide novel sensory experiences as part of an immersive theatre setting. Instead of using it as an assistive technology to help people move from one location to another – as previous research into haptic devices has largely focused on – our research has begun to rethink haptics as a form of sensory augmentation, and as part of a novel cultural experience. Our study showed that using haptic feedback in this broader context enabled both sighted and blind audience members to have equivalent and different cultural experiences. But importantly, the differences were not in terms of one being better than another but in how enabling both to focus on enactive exploration, and not seeing or substituting seeing, resulted in other ways of experiencing the world. Through physically exploring the space with the Haptic Lotus acting as a distal tool, both gained an increased awareness of and connection with the space they were in. Hence, the differences were in how sighted and blind people immersed themselves in the darkness. Being more at ease in the dark, the blind audience members were observed to use the Haptic Lotus in quite subtle ways. Furthermore, upon reaching a zone, they spent considerable time systematically feeling the different objects and making connections between them and the audio narrative they were listening to. In contrast, the sighted people appeared to experience the space in a more random way, as and when they happened upon something in a zone, or bumped into another audience member or the actor. Moreover, they tended to use the haptic device more vigorously and dramatically, waving their arms more to probe the space, suggesting that they were developing compensatory strategies for their temporary lack of vision. They also found the device to be reassuring when wandering in a strange dark space.

The positive experiences recounted by all audience members suggest that enactive exploration could be developed further in other cultural settings, such as museums, galleries, outdoor parks and gardens, to provide sighted people with quite different ways of experiencing them in order to understand what it means to be blind and to share this with blind people. Moreover, it suggests novel sensory experiences can be experimented with by everyone, through designing an assortment of ubiquitous technologies that engender different ways of perceiving and being in the world. Just as in the book 'On Blindness' they could encourage discussions between sighted and blind people about what they experience when augmented with various forms of haptic feedback.

CONCLUSIONS

While much research on haptic navigation has mainly focused on directly buzzing a person on their body, usually on their skin, and on measuring the efficiency of such devices for helping people get from A to B, our study has shown that haptic feedback can be used in a quite different way to enhance the experience of what it means to perceive, sense and move about in a space. In particular, it can enhance the holistic experience of connecting and moving between objects in a space. This suggests that distal haptic devices, such as the Haptic Lotus, can be used in a wide range of cultural settings, to enhance and extend both sighted and blind people's encounters with them. In sum, haptic feedback offers new opportunities for supporting enactive exploration that moves beyond simply navigation aids, by enabling alternative kinds of cultural experiences that are accessible by all.

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