ABSTRACT

USING HAPTICS AND VIBRO-TACTILE TECHNOLOGY TO ASSIST HARD-OF-HEARING WAREHOUSE EMPLOYEES

by Yashodhan Vikas Mandke

79% of warehouse and third-party logistics providers report they are unprepared for the skilled shortage, and additional sources suggest this may keep getting worse. (Labor Shortages in the Warehouse, 2017). 2 to 4 in every 1,000 people in United States suffer from a particular type of deafness which includes complete deafness, partial deafness, deafness due to age and veterans of military services who have experienced deafness during their time in war zones (Callis, L. L., 2015). Hard-of-hearing individuals are well acquainted and comfortable with the haptics with the sense of touch for communication (Harkins, J. et al., 2010). This thesis aimed at understanding the opportunities in how the hard-of-hearing employees can be a part of the skilled labor force of the warehouses which might require design intervention through haptics. The researcher conducted a field visit to the warehouse and interviewed the hard-of-hearing employees and the subject matter experts on the subject. With safety and communication emerging as the biggest hurdle for the hard-of-hearing a universal design intervention of push notification system using vibrotactile technology has been proposed so that the hard-of-hearing employees can be aware about the work environment and emergency situations in the warehouse. This social innovation not only makes hard-of-hearing more independent and safe but also help them explore different roles in warehouses.

USING HAPTICS AND VIBRO-TACTILE TECHNOLOGY TO ASSIST HARD-OF-HEARING WAREHOUSE EMPLOYEES

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Dedication

This project is dedicated to all the hard-working individuals from the differently abled community especially the hard-of-hearing. Your strength and determination to work despite the odds is a motivation for everyone.

Acknowledgments

INTRODUCTION

INTRODUCTION

This research was designed to explore ways people who are hard-of-hearing can become the part of diminishing skilled warehouse workforce through haptics and vibrotactile technology. Based on a review of existing literature, there is a gap between the ease of communication between the non-hard-of-hearing and hard-of-hearing employees in the workhouse, and there is no standard solution or a universal platform where the effort is being made to design inclusive devices through the technology for the hard-of-hearing. This thesis research aims at understanding how the hard-of-hearing employees do their given task in the warehouse and where are the loopholes which might require design intervention.

PROBLEM OF SKILLED LABOR SHORTAGE

According to a study conducted by the Capgemini Consulting, the warehouse and logistics sectors are facing a severe labor shortage. 79% of third-party logistics providers report they are unprepared for the deficit, and additional sources suggest this year may get worse – especially during the 2017 end of year holidays (Labor Shortages in the Warehouse, 2017). This research plans at helping the businesses who are struggling for skilled labor.

DESIGN FOR SOCIAL INNOVATION

Coming from a developing economy like India, the researcher has closely seen the struggle of the underprivileged masses to be part of the mainstream and get the opportunities they deserve. The researcher has spent time in the North-Eastern part of India and lived there for two years which is one of the most vibrant yet underdeveloped parts of the country. Having traveled across the region, the researcher has seen how the lack of accessible infrastructure can hamper the development of the people and area as a whole, especially the differently-abled population. The motivation to work for social innovation and inclusive design is the significant factor that has inspired this study. This research will target social change for businesses to improve their workplace conditions and offerings for individuals who are hearing-impaired.

There are 28 million individuals who are deaf or hard of hearing in the U.S. Thousands of new cases of deafness occur each year, including veterans who return from war with hearing loss and those who lose hearing as part of the aging process (United States Dept. of Labor, 2017). If warehouses were to upgrade themselves to accommodate this hard-of-hearing population, they might be more likely to reduce the problem of a diminishing workforce in the United

States while also enabling people with hearing-impaired conditions access to stable employment. The research provides an opportunity to hard-of-hearing people be the part of the mainstream workforce through inclusive design.

PROBLEM STATEMENT

Office of Disability Employment Policy (ODEP), a non-regulatory federal agency wants people with disabilities are fully integrated into the 21st Century workforce (United States Dept. of Labor, 2017). The research conducted plans to create a universal design intervention to ensure that hearing impaired employees get accommodated in the warehouse environment in a much better way than those that exist today.

For the first time since 2007, according to a November 2016 survey released by PeopleReady, there has been a severe skilled labor shortage (Palmer, T., 2017), because of which various warehouse companies are trying to solve the issues by opening the door to the differently abled population. Supervisors and managers are being trained to hire and accommodate these differently-abled employees. But not a lot of effort had been put to assimilate them into the warehouses like the rest of the employees. In case of hard-of-hearing employees, various crude methods like use of cell phones, the paper is used to accommodate them into the job. There is a scope for a comprehensive design intervention which can work in different warehouses. However, the willingness of the warehouses and various industries associated with it in integrating differently abled employees provides an

opportunity to help not only warehouses but also the hearing impaired population. The impact of these innovations will benefit people in the communities whom these businesses serve through increased access to employment.

RESEARCH GOALS

The research endeavors to identify real and perceived obstacles that inhibit people who have hearing conditions from becoming part of the warehouse workforce.
The objective is to identify obstacles first, then to reduce them for the hearing-impaired employees working in the warehouse environments.

The research aims to study and understand what are the biggest hurdles that make hearing impaired employees' job difficult and get suggestions on how we can mitigate them to make the experience of working in the warehouse environment better for the hearing impaired.

DEFINITION OF TERMS

Haptics: Sensory data and sensation derived from the sense of touch and localized on the skin.

Vibro-tactile: Perception of vibration through touch.

Hard-of-Hearing**:** Weakened or damaged in the perception of sounds.

Warehouses: A large building to store raw materials or manufactured goods before

** According to the National Association of Deaf, the term "hearing impaired" is a derogatory term and should no longer be used. For some the term is considered "highly offensive" (Community and Culture, 2016)

their distribution for sale.

Distribution Center: Specialized building, often with refrigeration or air conditioning, which is stocked with products (goods) to be redistributed to retailers, to wholesalers, or directly to consumers.

Workforce: The people engaged in or available for work, either in a country or area or in a particular firm or industry.

Social Innovation: The action or process of innovating for the good of society, community or its organization.

Push Notification: A message that pops up on a mobile device. App publishers can send them at any time; users don't have to be in the app or using their mobile phone tools to receive them.

ASSUMPTIONS, LIMITATIONS, AND DELIMITATIONS

The scheduled interviews were with reputed and big companies of the United States of America who have the long association with hiring the warehouse employees and are expert in warehouse operations. It assumes that the warehouses in the United States of America follow similar working and hiring pattern with the hard-of-hearing employees. Due to the limitation of the time as it is done for a degree requirement, the research was carried out in the limited locations and with limited employees. It considered that the situation of the warehouses and hearing-impaired employees would differ in other companies or sites/countries from those visited for research purposes.

CONCLUSION

The study aims to benefit the warehouse businesses in the USA, which are struggling with the labor shortage. The study provided avenues for the hearing-impaired people to be the part of mainstream warehouse workforce. The research planned to impact the industry and society in a positive way which will not only generate employment opportunities but if successful, it might trigger similar research studies in the design for social innovation and inclusion.

LITERATURE REVIEW

INTRODUCTION

This research wants to explore various avenues where hard-of-hearing can become the part of diminishing skilled warehouse workforce. According to a study conducted by the Council of Supply Chain Management Professionals (CSCMP), the warehouse and logistics sectors are facing a severe labor shortage (Talent shortage permeates logistics and supply chain organizations, the annual survey concludes, 2014). As the talent shortage gap grows, the competition for talent increases, too.

With this competition for the labor and talent, it is important to make opportunities accessible to differently abled people. In this case, people who are hard-of-hearing would not only help the businesses who are struggling for labor but also provide an opportunity for them to be the part of the mainstream - A social innovation to the companies as well as the community.

This Literature Review focuses on studying and finding different avenues which can facilitate the hard-of-hearing people especially with haptics and vibrotactile technology in the warehouse environments. The Literature also aimed at understanding how communication in the warehouse happens and what works for the accommodation of hard-of-hearing employees in the warehouse environment.

UNIVERSAL DESIGN FOR INCLUSION

Office of Disability Employment Policy (ODEP) is the non-regulatory federal agency that promotes policies and coordinates with employers and all levels of government to increase workplace success for people with disabilities (United States Dept. of Labor, 2017). ODEP wants to ensure that people with disabilities fully integrate into the 21st Century workforce. In the ODEP website, it coins the word 'Universal Design' (UD) as a strategy for making products, environments, operational systems, and services welcoming and usable to the most diverse range of people possible.

The evolution toward Universal Design began in the 1950s with a new attention to design for people with disabilities. By the 1970s, parts of Europe and the United States were beginning to move beyond the emphasis on special solutions tailored to individuals and toward the idea of normalization and integration called as UD (What is Universal Design).

There are measurable economic and social benefits for everyone when universal design is considered–women and men, elders and children, people with disabilities and those without, people using different languages and from different cultures. Practicing UD broadens markets and increases consumer

satisfaction as it addresses differences and preferences of all types. (Blanck, P., 2016)

To better understand how UD works, here are some examples of it in action: An ironworks shop in Montana lowered all of its work tables to an appropriate height for a skilled blacksmith who uses a wheelchair, everyone benefited. Employees who previously had to stand throughout the day and who were uncomfortable at the "average" higher tables, and customers visiting the shop to view work in progress have all thanked the shop's owner for the change.

In digital thermometers, the large LCD display makes it easy to read the temperature. The large, flat shape of the probe enables it to be held stably in the armpit. This provides a more usable design for everyone, from small children, who can't sit still, to older people, who may have trouble reading a small display.

INCLUSION OF HARD-OF-HEARING PEOPLE INTO THE WORKFORCE

2 to 4 in every 1,000 people in the United States suffer from a certain type of deafness which includes complete deafness, partial deafness, deafness due to age and veterans of military services who have suffered deafness during their time in war zones (Callis, L. L., 2015). Studies have shown that workers with disabilities are viewed as dependable, loyal, and responsible (Callis, L. L., 2015). They also tend to have overall positive job performance ratings. One study found that deaf and hard-of-hearing employees rank among the highest safety ratings in the workforce (Callis, L. L., 2015). Thus, industries should plan and provide opportunities for the differently abled people to enter the workforce which will

not only provide them an edge over their competitors but also help the community by helping differently abled people join the mainstream.

HAPTICS AND VIBROTACTILE PRODUCTS FOR HARD-OF-HEARING

For those who are hard-of-hearing, haptics can be a useful means for enabling communication. Due to limited hearing capability, touch offers a private means of communication and serves as a powerful personal communication tool. Touch provides subtle nonverbal cues and acts as an extension of the physical body (Chang, A. et al., 2002). Contact is a universal medium used by the general population and the sensory-impaired. In research about 'Active touch sensing,' it was concluded that touch sensing is something of a 'scientific hammer' with which animals including humans, make sense of, and become attuned to their surroundings. (Prescott, T. J., et al., 2011)

Lights can be an excellent visual sensory input for the hard of hearing. But with lights, comes the limitation of visible range. A study conducted on hard-of-hearing people showed that 82% had lights for signaling on their devices, but one-third of those with the feature did not use it. (Harkins, J. et al., 2010) The main reason being device was not in line-of-sight at the time. When asked about the use of vibration on their cell phones, 100% respondents reported using vibration to alert them to incoming e-mail, 90% to SMS, and 66% to instant messaging. These statistics show that hard-of-hearing people are well acquainted and comfortable with the vibrotactile technology with the sense of touch.

COMMUNICATION AND TECHNOLOGY USED TO MANAGE THE WAREHOUSES

Communication is the key to a warehouse to function efficiently (Vielhaber, J., 2015). Within any logistics and warehouse network, there are various stakeholders which makes communication between those vital. Researcher, during his previous observational studies in warehouses, witnessed the discussion being done using the two-way radios, walkie-talkies, or the supervisor's microphones connected to the headphones of the workers and other employees. There are some warehouse management applications, and currently, the following communication technologies are used for these (5 Ways to use Technology to Run a More Productive Warehouse, 2014):

Collaboration: Wireless technologies that integrate and work together in the warehouses. E.g., radio, laptop or smartphone which is real-time efficient.

Receiving: When warehouse receives inventory materials, accurately recording the quantities and conditions allows warehouse managers to plan shipments and storing. Various 'Enterprise Resource Planning' (ERP) software are being used to update the inventory in the databases. If errors persist, incorrect information can cause suppliers to oversell or undersell the products and create frustrations for customers. Products with a system of barcode scanning or RFID are used.

Picking Procedures: Automation products like 'Crown QuickPick® Remote Order Picking System' by Crown Equipment Corporation allows employees to spend less time traveling around inside your facility to pick-up the materials, increasing productivity and safety.(Crown Equipment

Earns Eighth Innovation Award for Crown QuickPick® Remote Order Picking System, 2016)

Loading and Shipping: GPS systems are being used to optimize loading, routing, and deliveries from the warehouses. The administrators and managers in the warehouses use these for communication.

PRODUCTS WITH VIBROTACTILE TECHNOLOGY

Due to the limitation in hearing capability, it is essential to have a different mode of communication for the hard-of-hearing employees in the warehouse. Haptics and Vibro-tactile are excellent to have contact as it relies on the sense of touch than hearing. Deafblind people can use a variety of tactile communication languages. (Chang, A. et al., 2002) This search majorly tries to identify products with existing vibrotactile (touch and vibration) research. There are various devices in the market like Gunther's SkinScape which used vibration as a mode of communication to distribute throughout the body to enhance the audio experience by immersing audience members in musically synchronized tactile compositions (Gunther, E., 2001). Research conducted by Tan, Reed, and Durlach proved that the hand-based reception language of Tadoma could transmit very accurate information. Tan's Tactuator, a three-fingered sensory substitution device, used a tactile interface for improving the reception of speech (Tan, H. Z. et al., 1996). These findings suggest that a touch-based communication language can be a versatile communication tool. Assessment of the following commercial products allowed to develop an idea of technological advances and market needs.

The Aura Interactor is a wearable force-feedback device developed by Aura Systems that monitor an audio signal and uses Aura's patented electromagnetic actuator technology to convert bass sound waves into vibrations that can represent such actions as a punch or kick. This first commercially available haptic suit is currently used only for the games. The interactions from the games are conveyed to the gamer, and this technology can benefit the hard-of-hearing employees in the warehouse especially where communication is required with their supervisors. (Aura Interactor. (2017, April 28). Retrieved November 04, 2017, from https://en.wikipedia.org/wiki/Aura_Interactor)

BSG System's Intensor chair is a highly immersive gaming experience chair system with chair base and subwoofer. There's physical feedback through high-end driver (tweeter) close to the head and a big bass driver that makes the user "feel" the sound. The chair works in conjunction with just about anything that has audio-outputs. Considering the audio-outputs like announcements for the emergency situations in the warehouse can inspire the outcome that can assist the hard-of-hearing employees. (Staff, I. (1998, October 14). Intensor. Retrieved April 23, 2018, from http://www.ign.com/articles/1998/10/14/intensor)

Geomagic Touch is a motorized device that applies force feedback on the user's hand, allowing them to feel virtual objects and producing true-to-life touch sensations as the user manipulates on-screen 3D objects. The researcher had personally used this device in India. Leading companies integrate the Touch and haptics into their work to achieve compelling solutions using the realistic sense of touch. This technology can be a tremendous inclusive inspiration for the warehouses to increase productivity with interactive training for the workforce including hard-of-hearing employees in experiencing work simulations. (Touch. (n.d.). Retrieved November 04, 2017, from https://www.3dsystems.com/haptics-devices/geomagic-touch)

Twiddler is an input device, a mobile, compact and wireless chording keyboard that allows for single-handed mouse and alphanumeric input. Termed as a "Natural User Interface," this is ideal for people with a low range of motion in their hands. Studies have found many people suffering from arthritis, and carpal tunnel syndrome finds the Twiddler much easier to use than traditional keyboards. Twiddler is a great inspiration on how to develop ergonomic devices for the inclusion of differently abled people. (Twiddler. (n.d.). Retrieved from https://twiddler.tekgear.com/)

Logitech's iFeel mouse translates the on-screen actions into tactile cues. When the mouse cursor passes over a particular icon or action bar, the mouse responds by producing a slight vibration. The quality of the vibration can be adjusted to provide a range of sensations- rubbery, crisp, metallic, steely, etc. This product is an excellent example of the use of a variety of tactile cues and can be an inspiration for its use in different modes of communication in the warehouses especially with the hard-of-hearing employees. (Logitech's iFeel. (n.d.). Retrieved from https://www.logitech.com/en-roeu/press/press-releases/1183)

MotionSavvy UNI is the two-way communication software for the deaf. UNI translates American Sign Language (ASL) into speech, and speech into text. It utilizes a special camera to track the

location of both hands and all ten fingers. This a great example of inclusive design and technology which can inspire the training of the hard-of-hearing employees with the people without any disability and also the smoother interaction between the both. (Szczerba, R. J. (2015, April 21). 4 Game-Changing Technologies For The Deaf And Hard Of Hearing. Retrieved November 04, 2017, from https://www.forbes.com/sites/robertszczerba/2015/04/21/4-game-changing-technologies-for-the-deaf-and-hard-of-hearing/#c050899570a8)

The new **Uber driver app** signals a new trip request with a flashing light in addition to the existing audio notification notifying riders when a driver is deaf or hard of hearing. This revolutionary feature first time has been utilized on such a large scale which has benefited the community of hard-of-hearing drivers to take up the profession of driving Uber cab service and earn their livelihood through it. (Hardwick, T. (2017, September 29). Uber App Offers Basic Sign Language Tips to Chat With Deaf or Hard of Hearing Drivers. Retrieved November 06, 2017, from https://www.macrumors.com/2017/09/29/uber-app-sign-language-hard-of-hearing-drivers/)

A team from Qatar University had developed the **VibroHear** in 2013. VibroHear is a bracelet designed for the deaf-blind to allow them "see" and "feel" sound. When the device picks up high volume signals, it vibrates and flashes green or red LEDs. These signals communicate to the user the volume and distance of the sound, alerting them to possible dangers in their vicinity. The technology is relatively primitive, but it can be implemented cheaply in the case of the hearing impaired in warehouses. (VibroHear. (2016, January 11). Retrieved November 26, 2017, from http://www.abledata.com/product/vibrohear)

Many tactile aids for the deaf translate audio signals into vibration. Multimodal communication devices, such as the Tactaid device, are often used when the information transmitted using a particular single modality could be lost due to the environment or the abilities of the individual (Chang, A. et al., 2002). These examples are valuable to understand how vibrotactile mode of communication can be useful and primarily can be used in various scenarios in warehouses as the connection is so vital which will benefit the hard-of-hearing employees.

THEORETICAL FRAMEWORK

Symbolic Interaction Theory (SIT) from psychology was selected to guide this study especially the observation study to bound the research focus on the ways hard-of-hearing employees in the warehouse learn and communicate from one another and adapt to their work environment.

SIT is a micro-level theory that focuses on the relationships among individuals within society ("Symbolic interaction theory." Wikipedia, 2017). Considerable research has shown that communication, the exchange of meaning through language and symbols is believed to be the way in which people make sense of their social worlds. The theory states that the goal of interaction is to create shared meaning. It's a useful theory especially for the observation study on how interaction for the hard-of-hearing and non-hard-of-hearing people can take place to create shared meaning as they will be working in the same environment.

CONCLUSION

The literature review explored various factors that are around the research question to get a holistic view of the issue of hard-of-hearing employment in the warehouse and the vibrotactile technology. Severe labor shortage, the requirement of 'Universal Design' for the inclusion and 28 million individuals who are deaf or hard of hearing in the USA calls for a need for research which can find the problem in the warehouses which might require a design intervention benefiting the hard-of-hearing and contributing to solving the problem of labor shortage. Researcher got a chance to talk with the hiring and training manager from a reputed warehouse company, and he got to know that there is no standard communication system for the supervisors and managers with the hard-of-hearing employee. Some use screens of the forklift, some tie some device in their neck which is connected to the speaker of the person speaking. These issues provide an opportunity for thorough and in-depth research on what are the real problems that hard-of-hearing employees face while using these crude methods. It has been evident through previous research that hard-of-hearing people are applied to the haptics and vibrotactile technology and can easily relate to it. There are various products available in the market which are efficiently using the haptics and vibrotactile technology enhancing experiences for users.

Some products are available in the market which addresses the issue for the hard-of-hearing but not the ones who are employees in the warehouses providing an excellent opportunity for this research to find loopholes for the hard-of-hearing in becoming the employees for the warehouses. The theoretical framework will guide the research in understanding the target audience in detail shaping the potential outcome.
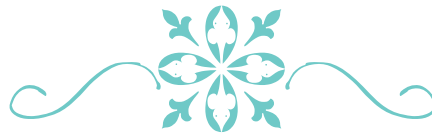
METHODOLOGIES

INTRODUCTION

Challenges faced by people who are hard-of-hearing in warehouses are personal, and complicated, creating problems for efficient working as well as emotional frustrations. For this reason, qualitative methods were primarily used so participants' feelings could be recorded in their own words. The researcher secured an IRB approval for this research study (IRB approval email can be found in the appendix). The participants for this research included two different groups- Subject Matter Experts (SME) of warehouse employment and Hard-of-hearing employees working in the warehouse. 3 SMEs from reputed companies in the USA were interviewed. The researcher visited a distribution center in Windsor, CT on March 16, 2018, to observe the hard-of-hearing people working in the warehouse environment and also talk them understanding the difficulties currently they face. The research study expects to benefit the warehouse businesses in the USA, which are struggling with the labor shortage. The study will also provide avenues for the hard-of-hearing people to be the part of mainstream warehouse workforce.

RESEARCH DESIGN

The research was designed to understand the current problems for the hard-of-hearing employees at warehouses through observational studies and collection of qualitative data through interviews and focus group interviews based on the voluntary participation of SMEs and the hard-of-hearing employees of the warehouse respectively.

The research study made subjects know that they are an integral part of the warehouses and efforts are being taken to empower the future hard-of-hearing employees by making their job easy and work in the warehouses accessible.

One of the primary goals for the research was to impact the industry and society in a positive way which will not only generate employment opportunities but if successful, it might trigger similar research studies in the design for social innovation and inclusion.

Participants

1. 'Subject Matter Experts' (SME) of warehouse employment
Subject Matter Experts included supervisors, team leaders, and trainers working in warehouses actively with hard-of-hearing or differently abled workers. The age of Subject Matter Experts was limited to adults who are 25 to 50 years old. These individuals had at least three years of experience working in the warehouse related industry, and they were able to converse fluently in English.

2. 'Hard-of-hearing employees' working in the warehouse

Each person who participated in the study had at least three months of experience working in the warehouse related industry, and they were to communicate fluently in English. The age of the subject population was limited to adults who were 25 to 50 years old. A person's hard-of-hearing status was determined when a research participant self-identified as hard-of-hearing. No medical testing to establish the level of impairment was conducted.

The research population for this project did not include people who were completely deaf. Sign translators weren't used. No members of a vulnerable population beyond those with the characteristics listed above were involved as subjects in this research.

Setting and Location for the Research

1. SME Participants

Research with SMEs was limited to interviews. Interviews with the SMEs happened via Skype audio/video call. The information about the SME was obtained from a reputed Forklift company through their network of clients. The researcher sent an email which included research information and FAQs to those SME and schedules an interview as per the availability of the SMEs. They were assured about the protection of their identity (FAQs email can be found in the appendix) and how they could deny the interview or any particular question at any moment. It was mentioned that this research or their answers would not affect their employment status in any way. The interviews were conducted after getting the permission and sign from the SMEs on a consent sheet. (Note- Consent Sheet can be found in the appendix)

The interviews with the SMEs helped in understanding the detailed insights about the existing technologies and designs used in the industry to address the issue of hearing impaired inclusion in the warehouse workforce.

2. Hard-of-hearing Participants

Research with hard-of-hearing Participants included Observations and Interviews. The observation study and interviews aimed at understanding how the hard-of-hearing employees do their given task in the warehouse and where challenges exist that suggest a design intervention may help mitigate these challenges.

Observation Study

The observation study took place in the warehouse on March 16, 2018, where hard-of-hearing employees work. The information about the warehouses was obtained from the SMEs who were interviewed during the first phase of primary research. Observations of this nature are commonplace in warehouses and observations for this research was conducted in the same manner as any other professional training site visit. The following aspects were conveyed verbally to the employees by the coordinator/SME before or on the day of site visit:

There was going to be a visit from a researcher from Miami University who would be observing and studying how the hard-of-hearing employees of the warehouse do the work.

The researcher's observation study wasn't going to affect the work schedule, and that work will be done as any other day as per the schedule.

The researcher would just be observing the work from a safe distance and would not meddle in the daily activities of the working employee that would disturb them, or affect their work. In case you feel that this observation study made you uncomfortable or influenced your work, please convey it to the coordinator or researcher, and he/she would make sure that necessary steps would be taken in order not to affect your work or made you uncomfortable.

Hard-of-hearing employees interview
Interviews with the hard-of-hearing employees took place on March 16, 2018, in the lounge of the warehouses where the subjects were comfortable. The coordinator/SME in the warehouse assisted in obtaining consent from hard-of-hearing employees to volunteer and become interview participants. The coordinator was provided with a printed flyer with information about the interviews which he/she used to inform the hard-of-hearing employees about the research. The following aspects were included in the flyer (Flyer design can be found in the appendix):

During the break or end of the shift, there would be an interview conducted by the researcher who is visiting warehouse for observations today.

The participation was voluntary, but employees who considered themselves hard-of-hearing were encouraged to participate. Not participating in this research or denying to answer any of the questions would not affect their employment status in any way.

The answers were confidential and would never be used in any way that would identify you.

This research planed at mitigating the problems for hard-of-hearing and would benefit employees like themselves in becoming part of the warehouse workforce. Their participation in the interviews would not affect at all on their daily activities and work schedule. Participants were allowed to do the things they usually do during a break while participating like eat or drink, go to the bathroom, etc.

The locations of the interviews were such that provided confidentiality promised in the consent information and was conducted inside a room/section of the worksite where others were not able to overhear the interview or see the subject (Consent form can be found in the appendix). Locations, where the research took place, were approved by the entities who control those spaces.

Research Questions

The interviews with the SMEs concentrated on understanding the current situation of hard-of-hearing employees working in the warehouse and the assistive technologies that are currently used. These interviews revealed frustrations that can suggest opportunities for design interventions that could mitigate workers' challenges. (Interview questions for the SMEs can be found in the appendix)

The observation study at the warehouse and interviews with the hard-of-hearing employees aimed at understanding what difficulties are being faced by them while working in the warehouses and what are the opportunities to solve them through design intervention. Especially with technology or interaction involving touch.
(Interview questions for the = hard-of-hearing employees can be found in the appendix)

DATA COLLECTION

The interviews were audio recorded and later transcribed. Audio recording occurred on a secure phone that only the primary investigator had access. The audio recordings were downloaded to a computer with the safe flash drive attached. The files were given the participants random name and then transferred to the drive. Once the audio data had been moved onto the secure drive, they were immediately deleted from the phone. Once all participant responses were transcribed, the original files were deleted which only left the randomized and unidentifiable text behind. This text was utilized to create various themes that related to the research questions and provided insights into having a design intervention for the project.

DATA ANALYSIS

The research data collected has been represented in a way that individual information is not identifiable. The researcher made sure that there won't be a way to identify the subjects or the employees. According to Saldana's coding scheme, the first cycle of coding was done using structural or holistic coding. For the second time, the researcher did focused coding for categorizing the coded data during the first cycle. (Saldaña, J., 2010) The codes that arose the most times were collated into themes that directed the development of design interventions. (Images of the coding can be found in the appendix) The analyzed data was represented into a data visualization so

that it's easy to comprehend what has been learned through this research.

CONCLUSION

This qualitative method research was conducted for this project to ensure both efficiency and emotions were captured from the research study. The interviews with the SMEs was an excellent source to understand the current situation in the warehouses and what is done to make it easy for the differently abled workforce, especially the hard-of-hearing workforce. SMEs are the critical stakeholders in creating the positive changes in the warehouse environments as most of them are part of supervising, managing, hiring or training the hard-of-hearing employees for the warehouse.

The observation study was an essential aspect of this study as the researcher got the chance to be in the environment and see the hard-of-hearing employees in action. The observation study was a valuable experience which helped the researcher to understand the target user of this project intimately and developed the required empathy to understand the ground reality of the employees and what are the real issues faced by them while working.

The interviews with the hard-of-hearing employees were designed to not affect the schedule and work of the employees. Interviews were an apt research method as the hard-of-hearing employees felt confident about raising the issues privately rather than in group which could have been awkward at times due to some hard memories that they can have.

RESULTS & FINDINGS

INTRODUCTION

Interviews with the SMEs and time spent in the field observing and talking with hard-of-hearing employees rendered rich data that, once analyzed, produced results that reinforced some initial hypotheses but also provided some discoveries. The SMEs represented the most reputed companies in the USA who have worked extensively for the diversity and disability inclusion in their warehouses and distribution facilities. Each one's unique view on the issue of integration of hard-of-hearing was valuable to the research. The researcher's visit to the Walgreens distribution center in Windsor, CT on 16 March 2018 for observation study was fruitful as the facility is known to hire a lot of disabled employees and especially the hard-of-hearing. The observation study followed by the interviews with the seven hard-of-hearing employees themselves. Each participant had a different level of hard-of-hearing and worked for various applications in the warehouse. This chapter summarizes the results and interpretation of those findings.

RESULTS

After completing the interviews with the three SMEs from the reputed companies in the USA and observations studies followed by the interviews with seven the hard-of-hearing, some fascinating results came out of it which propelled the process to solve those issues through design intervention.

All the three SMEs highlighted that there was an issue of skilled labor shortage and that their companies are trying to hire more employees who are differently abled.

All three SMEs said that their companies hired hard-of-hearing employees and they have a significant number of them already working in their warehouses.

2 out of 3 companies studied mentioned that they hire sign language interpreters during the training of hard of hearing. But, they also stressed that it is not a viable option because there are different types of sign languages and if people speak different words, it can often make that option useless. *"There are different languages and different sign languages, which make it difficult to hire sign language interpreters"*

All the three companies studied said that they use writing to communicate with the hard-of-hearing employees through pen and paper or text messages. Which isn't working for all as one of the SMEs mentioned- *"Pulling group together during emergency can be difficult"*

All the three companies consider safety as a biggest concern when hiring the hard-of-

hearing employees.

"Safety concern is the most important for employers & employees"

One out three companies use haptics for safety alerts with the help of pagers which vibrate violently in case alarm starts to ring.

Only 1 out of 7 hard-of-hearing employees said that he/she felt discriminated. Sometimes the supervisors or managers forget the fact that not everybody can hear what they are saying which can create the dissatisfaction among the employee who mentioned-
"Sometimes my supervisor forgets me"

4 out of 7 hard-of-hearing employees thought that it was difficult to communicate with the peers.

5 out of 7 hard-of-hearing employees stressed on the fact that they would like to feel safer as they can't hear any safety alarms. One of the employee mentioned-
"It will be good to have flashing devices with fire alarm"

100% of the hard-of-hearing employees interviewed were used to using haptics or vibrotactile technology in one or the other ways through their cell-phones, alarm clocks, etc. in their day to day life. One of the employee said-
"I use my phone 24/7 on vibration. Also Alarm clock"

FINDINGS

After analyzing data collected for this study, some findings emerged which have been grouped into following categories:

Communication & Safety
The researcher endeavored to identify real and perceived obstacles that inhibit people who have hard-of-hearing conditions from becoming part of the warehouse workforce. Communication and safety are the two crucial aspects that are challenging to the hard-of-hearing employees. SMEs highlighted that employers are very particular about the safety of their warehouse and employees including the ones that are hard-of-hearing. There is no tolerance towards anything that can be seen as dangerous such as not wearing safety glasses, not following safety procedures, etc. All people who are hard-of-hearing do not have the same level of disability. Communication with the managers or supervisors is another factor which was stressed by both, the SMEs as well as hard-of-hearing employees. Each of

Figure 4.1- No to them campaign poster
This poster was captured when the researcher was doing observation study at Walgreens distribution center in Windsor, CT.

the three companies with warehouses and distribution centers in the USA that were studied was trying to tackle this issue in their ways. Two of the three studied companies decide to hire sign interpreters for training, some practice texting and writing back and forth. But currently, there is no solution developed on a larger scale which can address the issue of communication. In the observation study, the researcher noticed that hard-of-hearing employees also often suffer from a communication disorder such as stuttering, voice impairment or complete muteness that can make communication even more difficult with their peers in warehouses. With the current crude methods like writing, texting or reading the lips, it is difficult to manage all these different communication channels for the managers and supervisors when they communicate with the hard-of-hearing employees.

Hiring more hard-of-hearing employees in warehouses
Considering the shortage of skilled labor in the market, every SME the researcher spoke with shared that they are trying to hire more people into the workforce with many companies having a different department set-up to increase the differently abled employment and make it easier for them to work. In the Windsor, CT facility that researcher visited, a new campaign has been active on the floors of the distribution center to reduce the discrimination against the differently abled employees. It's called 'No to them.' During the visit, the SME stressed the importance of having this campaign and how it has made the work culture the warehouse better.
The industry has realized the importance of having skilled labor and is looking to provide different avenues to the differently abled including the hard-of-hearing employees to have better inclusion experience. The

observation studies and the interviews reveal that there is scope for improvement in having a solution that can solve these issues for the warehouses and distribution centers around the USA.

Different Hurdles that make the job difficult for hard-of-hearing employees
The observation study and the interviews with the hard-of-hearing employees revealed some of the critical barriers faced by them in their jobs. Hard-of-hearing employees sometimes feel that they can do more challenging work than they are given. Considering the safety standards and policies of the employers, the hard-of-hearing employees can get non-risky tasks even though they might be capable of performing those which can lead to discrimination. Hard-of-Hearing employees sometimes felt that they were ignored by manager/supervisor as they couldn't hear them and needed more attention than the other employees. Communication between the other employees who are not hard-of-hearing is also an issue. The companies try and get sign language interpreters on some occasions of training and orientations, but there are different types of sign languages and employees may speak a different language at home other than English. There is not a universal way of communication. The warehouses try different crude methods to solve it through writing, texting and lip reading. The hard-of-hearing employees also mentioned that safety is a big concern for them as they are always dependent on the other colleagues to notify them during the case of emergency. They wish to be more self-reliant on that front.

Hard-of-Hearing are comfortable with the Vibro-Tactile technology
The interview with the hard-of-hearing

employees made it clear that they are used to vibrotactile technology. All the participants said that they had used the technology in one or the other ways through their cell-phones, alarm clocks and even vibrating beds which vibrate when your doorbell rings. It has enhanced their experience in their day-to-day lives, and thus the technology will be apt to be used considering comfort and awareness about the technology.

Symbolic Interaction Theory
One theory that framed the observation study was Symbolic Interaction Theory ("Social cognitive theory." Wikipedia, 2017). Before conducting fieldwork, the researcher expected that he would find the shared meaning of the interaction between the hard-of-hearing and non-hard-of-hearing people as they worked in the same environment to support this theory's premise. Findings from this study did support the theory as a practical framework for studying ways people who are hard-of-hearing find workarounds when overcoming barriers. The researcher's observation study made him understand how hard-of-hearing employees interact, and how these worlds shape individual behaviors. The observation study revealed that hard-of-hearing employees had to communicate with their managers and supervisors mostly. The interactions are elementary for hard-of-hearing like asking supervisors about their schedule, demonstrate the task, call managers in case of any questions or asking a supervisor for help if required. These interactions happen in a very crude structure with the use of texting (if the employee has his cell-phone with him/her), writing on the notepad back and forth or

in some case where an employee can read the lips, the supervisor talks slowly to the hard-of-hearing. These kinds of interactions make hard-of-hearing employees dependent on the other people even to communicate these small interactions between them and their supervisors/managers.

CONCLUSION

The research helped the researcher to understand various issues that are persistent for the employers to employ the hard-of-hearing impaired employees to be the part of warehouses. Fear of safety is the primary concern raised by the SMEs of the most reputed companies in the USA associated with the warehouses. The observation study done at a distribution center in Windsor, CT by the researcher was crucial in understanding how the hard-of-hearing employees work in the warehouse environment and what are their issues. Communication was an important aspect learned here and how there is the scope for the improvement via design intervention. The hard-of-hearing employees are acquainted with the haptics and vibrotactile technology and are comfortable using it efficiently with various devices like cell-phones, alarms clocks, and vibrating beds. The researcher also found out that hard-of-hearing employees find issues while interactions with their peers and supervisors and are worried about being dependent on them in emergency situations. These results its interpretations indicate a definite need for a design solution with can address these issues facilitating the warehouse companies to hire more hard-of-hearing employees with a better inclusion experience.

PHENOMENA RESEARCH CONCLUSIONS & DISCUSIONS

INTRODUCTION

The research with the SMEs and hard-of-hearing employees gave a lot of insights on what currently hard-of-hearing employees find it difficult to be a part of warehouse workforce. These will be the primary users for the design intervention, but the most important is the customer for these which are the employers with warehouses and distribution centers. The researcher also interviewed the SMEs from the reputed companies with warehouses on this issue. The SMEs were an excellent source to understand what is the current situation of hiring the hard-of-hearing in the warehouse and what current technologies are being used to address the issues faced by them. The creation of user personas and user journey map helped the researcher to visualize the hard-of-hearing experience through their eyes. After gathering the data, the researcher used affinity analysis technique doing data analysis and data mining technique that discovered the co-occurrence relationships among activities performed by the hard-of-hearing in the warehouse as well as interviews with the SMEs. This technique helped in understanding the different themes that were important to come up with the design intervention. The researcher created a systemic view of the hard-of-hearing employees and solving their issues with various stakeholders who helped in deriving the concept map with potential design intervention for enhancing the experience of the hard-of-hearing in the warehouses.

PERSONA CREATION AND USER JOURNEY MAP

After the observation study at the Walgreens distribution center in Windsor CT, and interaction with the hard-of-hearing employees on March 16, 2018, researcher was able to understand what are the real problems of the users and what a day for them looks. Based on the findings, the researcher created three user personas of the hard-of-hearing employees (These aren't the real people but representation of who might be the potential users). Personas are vital because they drive design decisions by taking everyday user needs and bringing them to the forefront of planning before the design has started. (What is Persona Development and Why is it Important?, 2017) Personas provided the researcher with a shared understanding of hard-of-hearing users concerning goals and capabilities.

Diego Fransisco

An experienced warehouse employee

A dream doesn't become reality through magic; it takes sweat, determination and hard work...

59 years
Born in 1959
Forklift Driver
Home-Schooled
St. Marys, OH

Hashtags#
Happy but In-secured
Hard-working
Family Oriented

Activity
Reading
Do Church activities
Gardening

Story
Diego has worked in a warehouse environment since he was a teenager. His Dad worked in the warehouses and once Diego was a young able man, he joined the workforce. He has wide experience of working in different applications and jobs of the warehouse. Due to old age, Diego is experiencing hearing loss and now has been categorized in 'hard-of-hearing' employee. He can hear slightly if someone speaks to him loudly but cannot hear properly without a hearing aid.

Scenario
Due to the hearing loss, Diego is finding it difficult to adjust to his work. Due to safety reasons, he isn't allowed to wear his hearing aid in the warehouse. These are making things bad for Diego. Even being experienced in the his daily activities, Diego has to be cautious and it makes him feel in-secured considering how dangerous warehouse operations can be. He has seen a lot of mishaps during his tenure as warehouse employee and he doesn't wish to be involved in any of those.
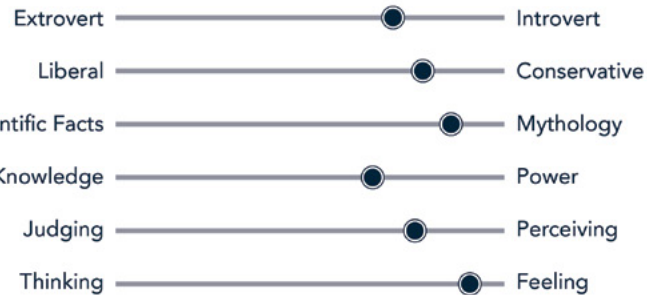
Behavior
Does his work sincerely
Respect his subordinates

Motivation
Getting work done in time
A stable salaried life

Opportunity
Be more confident and secured
Utilize his expertise better

Extrovert ————●————	Introvert
Liberal ————————●—	Conservative
Scientific Facts ———————●—	Mythology
Knowledge ———●————	Power
Judging ——————●—	Perceiving
Thinking ————————●—	Feeling

Goal
Retire as an ideal employee
Wishes to train new employees

Frustration
Due to old age and hard-of-hearing, not being able to do work quickly like when he was young

Favorite TV shows
All In The Family
CHiPs
Fox News

Brands

Dodge Ram

Bob Evans

Budweiser

Levis

Figure 5.1- Persona 1
Created based on the data collected during the interviews with hard-of-hearing employees

Kayla Wagner

A single mother and sole bread-winner in the house

"My mission in life is not merely to survive, but to thrive; and to do so with some passion, some compassion, some humor, and some style"

32 years
Born in 1986
Welder
High School Graduate
Pittston, PA

Hashtags#
Independent
Cheerful
Creative

Activity
Drop kids to school
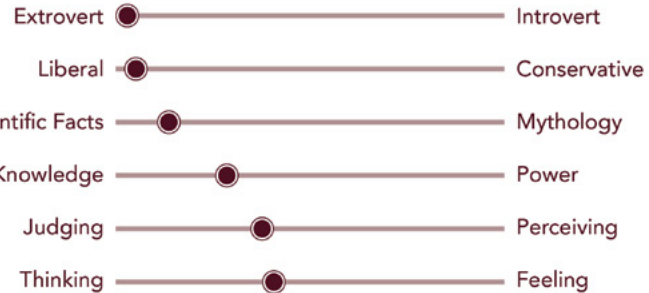Watching movies
Going to Picnic

Story
Kayla is a dynamic and active warehouse employee. Shes a single mother who manages a full-time job and her 2 kids. She has been hard-of-hearing since childhood. Due to a high fever in childhood, Kayla was affected by low hearing capabilities. Her fighting spirit and confidence helped her in overcoming her hearing loss. She believes in living life to fullest and enjoy every second of it. She loves her job as it makes her independent and live her life her way.

Scenario
Being a hard-to-hear employee in the warehouse, Kayla has been asked to wear a orange jacket which is different than rest of the employees who wear a yellow one. Its for the safety reason where in case of emergency, other employees can assist her. Kayla knows that this is for her safety and thus made peace with this idea. But given a choice, being an independent and strong woman, she would like to be seen as equal to the rest of employees.

Behavior
Loves doing her job
Create a good rapport at work

Motivation
Getting compliments by team
Being independent

Opportunity
Equality in the warehouse
Have more hard-of-hearing people at work

Extrovert ●———————————	Introvert
Liberal ●———————————	Conservative
Scientific Facts ———●———————	Mythology
Knowledge ———————●—————	Power
Judging —————————●———	Perceiving
Thinking —————————●———	Feeling

Goal
Have a good quality lifestyle
Work with best of her abilities
Encourage other women to work at warehouses

Frustration
Equal treatment of all the employees working in warehouse

Favorite TV shows
Game of Thrones
Friends
Unbreakable Kimmy Schmidt

Brands
Netflix   Forever 21   Goodwill   Apple

Figure 5.2- Persona 2
Created based on the data collected during the interviews with hard-of-hearing employees

Andre Gayle

A war veteran who served in the USA military

Valor is stability, not of legs and arms, but of courage and the soul...

28 years
Born in 1990
Order Picker
High School Drop-out
Hartford, CT

Hashtags#
Obedient
Brave
Thankful

Activity
Gym-ming
Going on road-trips
Playing Football

Story
Andre was a football player in the school. He was always interested in applying to armed forces. Andre was an active military personnel at USA army. He served in the military for almost 6 years before he met with an accident in the war zone. Accident caused him to be hard-of hearing due to exposure to loud blast noise. Due to the accident and being a hard-of-hearing personnel, Andre decided to retire and come back to the USA to start a career as a warehouse employee to feed his family.

Scenario
Being a young employee, Andre wants to establish himself as a good employee. Being hard-of-hearing has curtailed the number of jobs which he thinks he can do because of the trust deficit from the employers. Employers care about the safety or Andre as well as other employees and thus are willing to keep Andre in only permitted jobs. Trust an important issue between the employers and the employees. Coming from a military background, Andre wishes to be completely trusted with the job he handles.

Behavior
Complete work before deadline
Respects everyone at work

Motivation
Being with his family
Free time on weekends and holidays unlike when in army

Opportunity
Work hard and grow his career

Extrovert	——●——	Introvert
Liberal	——●——	Conservative
Scientific Facts	——●——	Mythology
Knowledge	——●——	Power
Judging	——●——	Perceiving
Thinking	●——	Feeling

Goal
Work hard and make most out of his living with the family
Promote to Supervisor position

Frustration
Trust deficit with the employers
Being an underachiever

Favorite TV shows
Spartacus
House of Cards
Homeland

Brands

New England Patriots   Nike   Popeyes fried chicken   US Army

Figure 5.3- Persona 3
Created based on the data collected during the interviews with hard-of-hearing employees

21.

During the site visit to Walgreens distribution center, observation study and interactions with the hard-of-hearing employees made researcher know more about them and thus these personas were created based on the data collected. The researcher created a user journey map based on the daily activities of a hard-of-hearing employee in a warehouse. It enabled the researcher to understand how users see things at key touch points in the journey. Mapping also helped in identifying pain points across different tasks performed by the hard-of-hearing that impede the user journey.
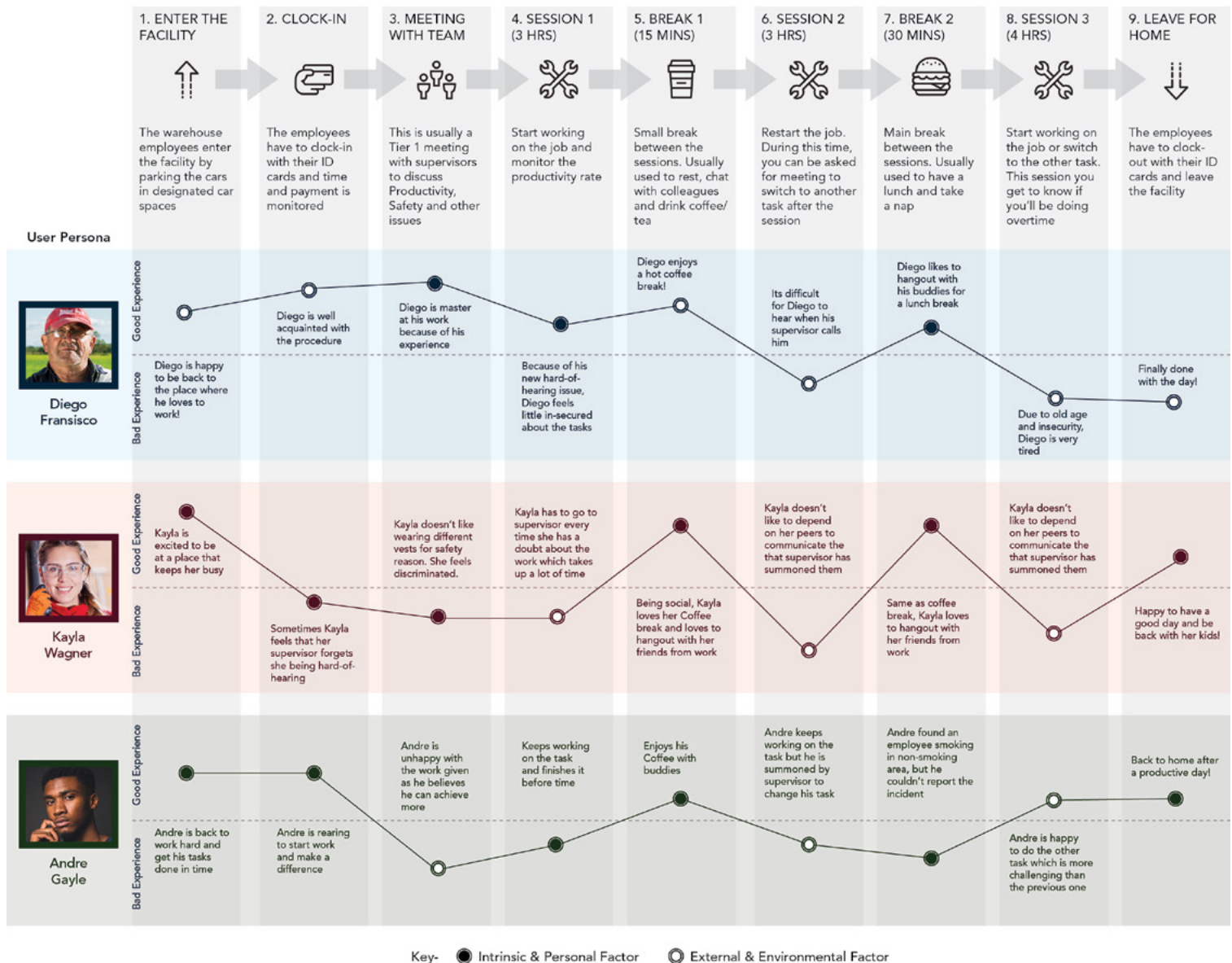
Figure 5.4- User Journey Map
Based on the daily activities of a hard-of-hearing employee in a warehouse

GENERATED THEMES

Based on the data collected from the interviews and observation study, the researcher generated themes using structural or holistic coding. Coding helped categorize data which the divided data in main umbrellas. Some of the data overlapped over two umbrellas like Communication and Challenges and thus creating a new group of Communication Challenges. The split data helped in understanding the various themes. The central themes were Communication, Safety, and Experience (Employee and Employer). Below are the main themes after coding the data.
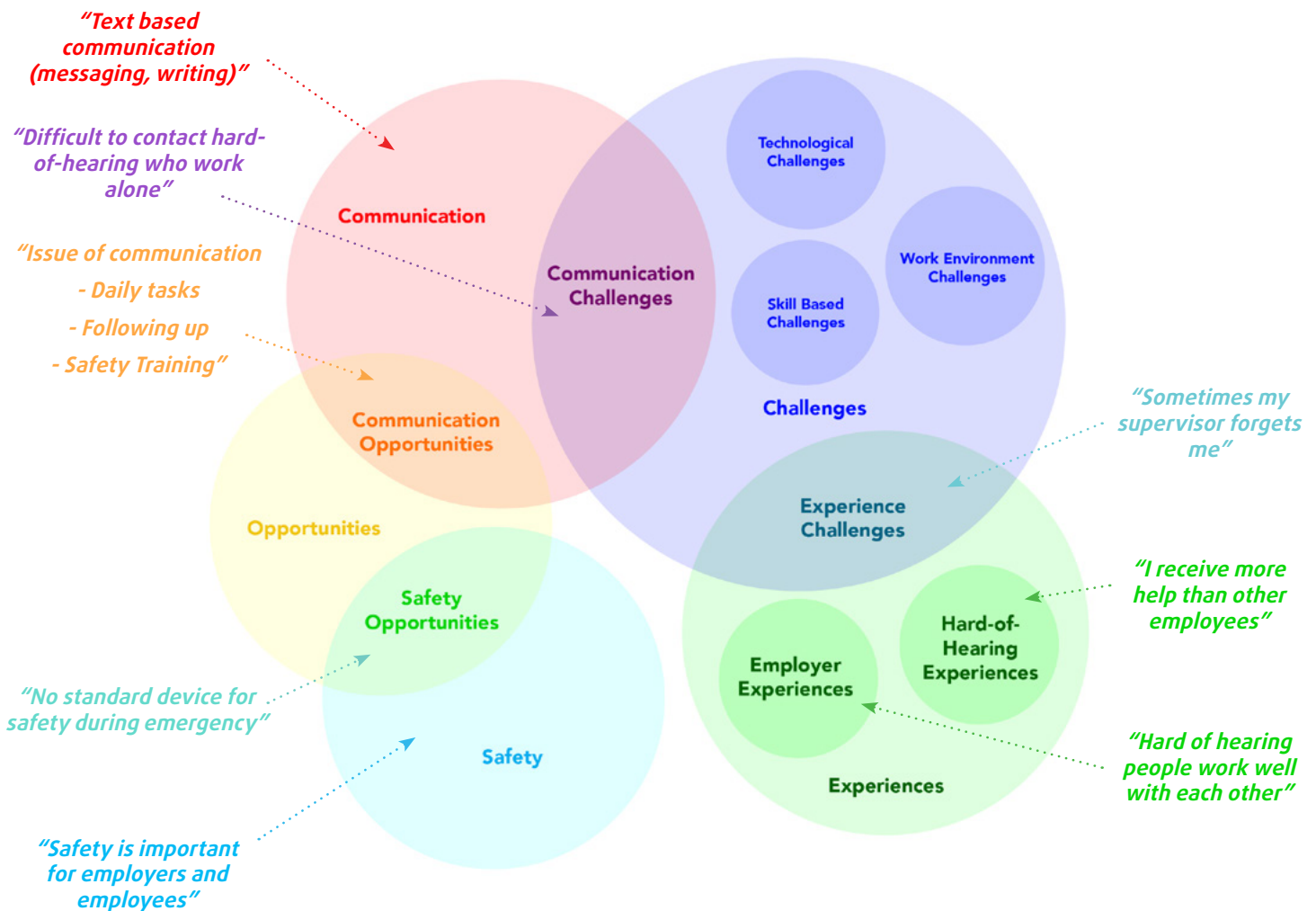
Figure 5.5- Main Themes
The main themes generated after the initial holistic coding of the data and focused coding for the categorization of those themes

The themes of challenges and opportunities helped in understanding what the difficulties currently faced by the employers and the hard-of-hearing employees and various opportunities to tackle them are. After organizing the data in the themes, it was essential to determine which were the crucial pain points which can pave the path for the design intervention. The researcher did 'what's on your radar' activity with the collected data. The exercise helped in prioritizing the critical finding with the center being the most vital, middle being the important and the last circle being the peripheral data.

Figure 5.6- What's on your Radar
This activity helped in determining the important issues those are critical and needed to be solved with a design intervention. The center circle has most critical issues and the outer circle has the peripheral ones.

SUGGESTIONS FOR FUTURE RESEARCH

Due to the limitation of the time as it was done for a degree requirement, the researcher was only able to visit the single distribution center in Windsor, CT. With more field visits and more interviews with the hard-of-hearing employees may reveal more issues and different problems than those found by the researcher. Also, the researcher interviewed the SMEs of the most reputed companies in the USA. It will be interesting to know what steps have been taken in the countries other than the USA for hard-of-hearing employees becoming part of the warehouse workforce. Especially the ones who are facing the issue of skilled labor shortage like the USA. One of the other things which will be necessary for future research is that hard-of-hearing employees often have speech challenge and it can also create research opportunities on how to solve the communication problem for the mute as well as speech challenged employees.
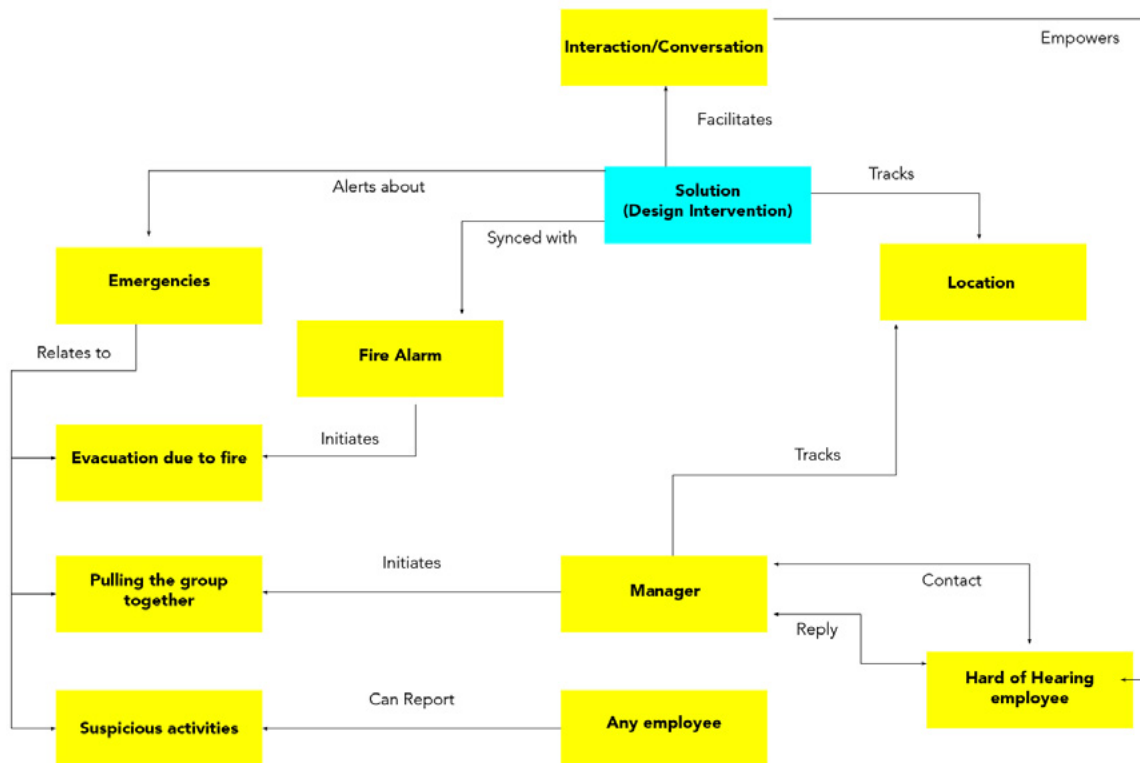

Figure 5.7- Concept Map
Based on the themes generated and the critical opportunities and challenges found in the data, a concept map within the warehouse communication & safety system

RECOMMENDATIONS FOR POSSIBLE DESIGN INTERVENTIONS

Based on the themes generated and the critical opportunities and challenges found in the data, a concept map with the system was generated. The concept map of the system helped in addressing the several issues and the opportunities. It helped the researcher in understanding what design intervention should do to fit into the scheme of warehouses and enhance the experience of the hard-of-hearing employees in becoming part of it. The concept map also includes all the stakeholders associated with other employees and managers/supervisors. The design intervention aims to be a universal design which will not only help the hearing impaired employees but also help the rest of employees enhancing their experience and reduce the differences.

With the crucial issues like safety and communication, the design intervention aims in alerting the emergencies, help manager in tracking the location and create an interaction opportunity for the hard of hearing employee empowering him/her. Considering this concept map of the system, the possible design intervention would be:

1. A mass communication unit in the warehouse which addresses these issues using the haptics or vibrotactile technology.

2. A cell-phone safety notification service.

3. A wearable device which can be used by the employees and the supervisors in the warehouse.

DESIGN INTERVENTION

INTRODUCTION

After conducting the research and analyzing the data, it concluded that the employee safety was the most prominent concern among the employers as well as the hard-of-hearing employees themselves. Among the three possible design interventions, the researcher decided to proceed with cell-phone safety push-notification service. The solution was designed, and the researcher conducted a dummy mock-test of the solution. This chapter encapsulates not only the process of generating the prototype for the design intervention and testing it but also suggestions for future research, testing, and design.

RATIONALE FOR INTERVENTION DESIGN

All the three SMEs interviewed stressed on the fact that safety is the most important thing they consider when hiring someone and distribute the task the employees according to it. Each of the companies they work for, security was given the utmost importance and never compromised. Currently, the hard-of-hearing employee has to be dependent on their peers or supervisors to alert them about any emergency situation as employees get warned through use of alarms. 5 out of 7 hard-of-hearing employees mentioned that they would like to have some indicators for the emergency situations. It was evident that

safety is the most significant concern and hurdle for the hard-of-hearing to be part of warehouse workforce for their employers as well as themselves. By targeting this issue, the system of push-notification was decided to be an intelligent design intervention. This design intervention not only aligned with the interests of hard-of-hiring users who will feel more independent and confident about their safety but also the clients (warehouses and companies) as it is easy to implement cheaply from existing technologies available at the warehouses.

DESIGN FORM AND OPERATION

The Design intervention of push notification system will use the cell phones of the employees. A push notification is a message that pops up on a mobile device. App publishers can send them at any time; users don't have to be in the app or using their mobile phones to receive them. Push notifications are a way to speak directly to a user. They don't get caught in spam filters, or forgotten in an inbox — click-through rates can be twice as high as email (Push Notifications Explained, 2018). From 2013, Push notifications were also called as Rich notifications as they can contain images, as well as action buttons. Action buttons let users take immediate action from a warning. Publishers or back-end app can deliver more relevant messages by using location

data and it will be an excellent source for the warehouse as all the employees on the location of the warehouse can be notified or detected using GPS service in their cell phones to send the safety alerts.

PROTOTYPE DEVELOPMENT PROCESS

With safety issue to be targeted, it was essential to understand what kind of safety emergencies can an employee face in a warehouse environment. Based on the conversation with all the SMEs and Field visit in Windsor CT, there are three main types of emergency situations:
1. Evacuating the warehouse in case of Fire.

2. Gathering in a Safe room in case of weather emergencies like Tornados.

3. Safety alert to hide and be safe during suspicious activity like a shootout.

There was a need to create push notifications for each emergency and action buttons to notify backend or supervisors about their safety.
Considering the panic during the emergency situation, it was essential to have a cell phone accessible to the users rather than having it in a pocket or somewhere hidden. So the cell phone was attached to an armband in the biceps area so that the screen is always accessible. The notification will be alerted to the user through vibration native to their cell phone.

Push notification screens were designed for each kind of emergency separately.
The screen orientation of the notification is landscape to facilitate the ease of use in the way the cell phone is attached to the arm.

Figure 6.1- Armband with cell phone
For the testing purposes, the cell phone was tied to the biceps area using the arm band which made mobile screen always accessible during the emergency.
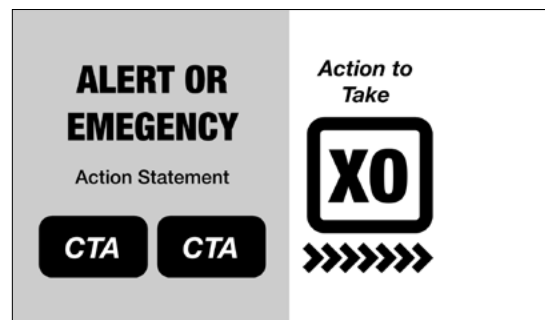
Figure 6.2- Wireframe of the notification
The wireframe for the notification was designed to have the alert and action persistent to view on the screen and 'Call to Action' (buttons) were large to prevent wrong interaction.

Figure 6.3- Push Notification Screens

The screens designed for testing of each emergency situation- Fire Alarm, Tornado Alert &
Suspicious activity.

Figure 6.4- Push Notification in action

The application distributer or publisher empowers their application with an Operating System
Push Notification Service (OSPNS) connected to the backend server and can send the push
notification to the enlisted devices in the particular location.

USER TESTING
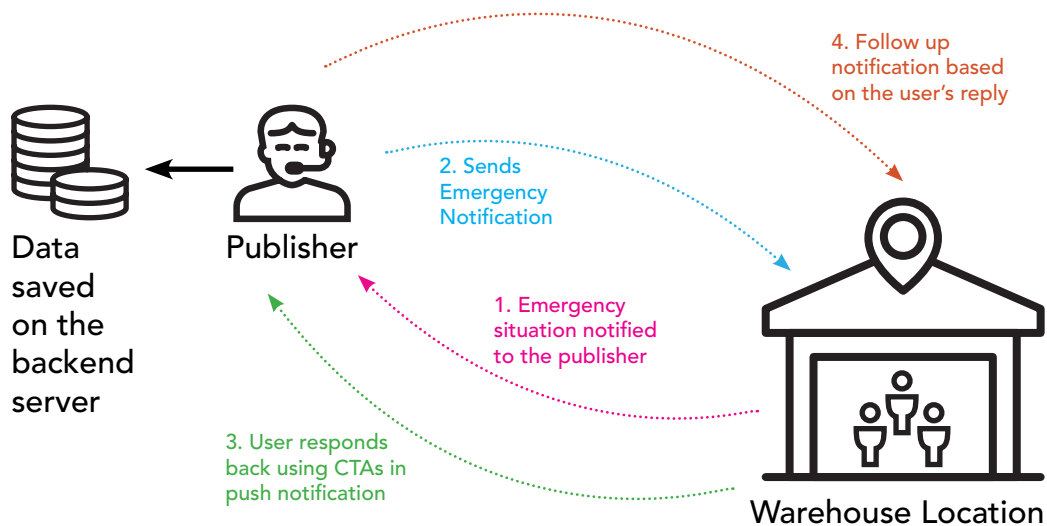
After designing the prototype, a user testing was conducted in a building floor to resemble warehouse setting. The subjects were not hard-of-hearing, but they were made to wear noise-cancellation headphones with music which hampered their sense of hearing.

1. Before starting the test, the researcher explained different types of alarm sounds, how push notification system worked and how the participants should react when they receive the notification.

2. The researcher asked subjects to put an armband around the biceps area in a comfortable position and asked the subjects to do an engaging task just like how employees would in the warehouse environment.

3. Doing an engaging duty made the subjects to not worry about getting a safety alert but would make them concentrate on the work.

4. The subjects with the noise cancellation headphones couldn't hear the loud alarm.

5. They were notified about the alarm through vibrations in the cell phones which popped up the push notifications of either tornado scenario or fire alarm scenario on which the subjects acted accordingly. With the fire alarm, the subjects had to exit and evacuate via a particular staircase, and in case of the tornado, the subjects had to go to another room on the floor which needed RFID card to unlock as most of the places in a warehouse are accessible through employee ID card.

6. Four subjects participated in the study and all the subjects completed the test successfully.

FINDINGS & CONCLUSIONS

After performing the usability test with the prototype on the subjects, the researcher conducted a short interview with each of the subjects to understand their experiences. Based on the experiences of the subjects, all four felt safe having an emergency alert at their disposal and made them more independent as they won't be dependent on any of their peers to save them during these situations.

All 4 subjects got notified about emergency successfully using the haptics during the testing

All 4 subjects felt safe having an emergency alert at their disposal and made them feel more independent

One of the subjects had a valid concern over what if someone wears a lot of layers, will he/she experience the haptics?
"What if we have more layers of clothes. Will we be able to feel vibrations?"

Other findings were related to the design of push notifications. One of the subject gave a feedback-
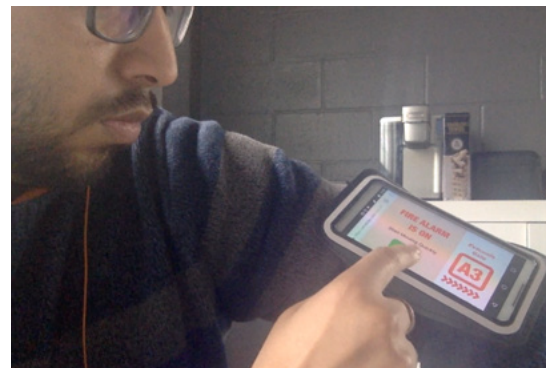

Figure 6.5- Interacting with Push Notification

"Use of Green & Red color might be an issue for someone who is color blind."

A version of color-blind friendly push notifications can help in making this design more universal.

A couple of subjects found that type can be difficult to read if it is smaller phone screen than the one tested on 5.5 in screen size

"If it is smaller phone screen, it might be an issue."

Here are some of the other feedback and questions from the subjects:

"Can there be different vibrations for different emergencies?"

Yes, there can be different vibration patterns and strength for different emergencies which can assist the users to identify different alarms.

"I have to move the armband towards me to look at it."

Because of the armband position on the biceps area, the users have to pull the screen towards themselves. It might be an extra effort but still keeps the mobile screen in the sight for a quick response from the user.

Findings from the testing phase suggest that haptics could be effective, especially when located on the arm because vibrations here were noticed very quickly. This will benefit the hard of hearing immensely and can help them become confident, independent and safe.

SUGGESTIONS FOR FUTURE RESEARCH, TESTING, AND DESIGN

This test was conducted in a dummy environment and not the real warehouses and the hard of hearing employees. There is an opportunity to conduct this testing in a real situation and hard-of-hearing employees themselves. Also, when the experiment was performed, the participants were aware that they aren't under any danger as it was conducted in a safe environment. It will be interesting to test the solution on the participants who are in that mode of panic of an emergency situation. There is also an opportunity to check on the workers who have limited literacy of English used in the solution.

DESIGN RESEARCH
CONCLUSIONS & DISCUSIONS

INTRODUCTION

This research aimed at understanding different avenues on how hard-of-hearing can be a part of fast diminishing skilled warehouse workforce. Based on a review of existing literature, there is no standard solution or a universal platform where the effort is being made to design inclusive devices through the technology for the hard-of-hearing. Once the primary research of interviews with the SMEs, the field visit to the Walgreens DC in Windsor CT and interviews with the hard-of-hearing employees, it was evident that safety was the most prominent factor that affects the hard-of-hearing people's experience in becoming a warehouse employee. This research planed at helping the businesses who are struggling for skilled labor. The proposed design intervention of push notification system for an emergency system using haptics targets the safety issues enhancing the experience of hard-of-hearing employees working in the warehouses and feeling more independent and safe.

SUMMARY OF PROJECT FINDINGS

The research planned at understanding the most critical issues that hinder the experience of hard-of-hearing warehouse employees. After the interview with the SMEs, the field visit to Walgreens distribution center in Windsor CT and another set of interviews with hard-of-hearing employees themselves, communication and safety were the most important aspects which can make it difficult for the hard-of-hearing to work in the warehouses. All the three SMEs highlighted that employers are very particular about the safety of their warehouse and employees including the ones that are hard-of-hearing. Also, the 5 out of 7 hard-of-hearing employees stressed on the fact that they would like to feel safer as they can't hear any safety alarms. Also, all the hard-of-hearing employees had used haptics or used to vibrotactile technology in different occasions in a day to day life. The prototype of the design intervention of cell-phone safety push-notification service was generated to tackle the issue of safety in the house. This test was conducted in a dummy environment and not the real warehouses and the hard of hearing employees. The prototype was tested on the four subjects.

The subjects were not hard-of-hearing, but they were made to wear noise-cancellation headphones with music which hampered their sense of hearing. All the four subjects felt more safe and independent during the emergency situations. There is an opportunity to conduct this test in the real environment and hard-of-hearing employees themselves in real emergency situations which will yield more accurate results and reveal further issues that need to be tackled.

CONCLUSIONS

The research provides an opportunity to the industries who own warehouses and distribution centers to think about the haptics to integrate hard-of-hearing employees and enhance their experience by making them more self-reliant and assure more safety. This will not only benefit these companies to tackle the issue of scarce skilled labor but also help the hard-of-hearing people by opening various avenues for them to earn their living and support their families. The proposed solution is a universal design and can benefit not only hard-of-hearing employees but all the associated employees with the warehouses. This solution was mainly designed for the warehouses; there is an opportunity to test this solution to benefit hard-of-hearing in different environments like corporate offices, schools, and colleges, hospitals, etc.

DISCUSSION & FUTURE SCOPE

This research and project were motivated by the social innovation for design. The researcher tried to address the issues of hard-of-hearing and provide a universal design intervention for the reducing the problems for the hard-of-hearing employees

in becoming the part of the warehouse workforce.

Being an experience designer, it is important to consider the accessibility issues for the communities that have been deprived of it in various environments like schools, offices, public transportation etc. It's not just about working on the accessibility aspects of the design but also the experience and usability aspect of it which will ensure an optimum use and understanding of the product or service.

The design intervention generated to solve the issue uses the current technologies in the warehouses and something which won't cost too much to the warehouse owners. There is a great opportunities for the researchers to conduct similar research across different environments and for different disabilities to promote more inclusion through experience design and design research.

The research was conducted with the reputed companies of the USA and different countries with different types of warehouses will have different challenges which might include difference of culture, tasks and warehouse functioning.

The literature review and the research established that the haptics are the best form of communication for the hard-of-hearing and safety and communication are the biggest challenges for them to be a part of warehouse workforce. It will be fascinating to know what might be the different considerations in the different environments, cultures, and disabilities which can generate a great scope for the future researchers to work on.

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APPENDICES

CONSENT FORM FOR SMES

This study examines Hard-of-hearing people and they becoming part of warehouse workforce. You are not required to participate in this study; it is entirely voluntary. Participants must be at least 18 years of age to participate. If you decline to participate in the study, it will not affect your employment or academic standing in any way.

If you choose to participate, here are some important things to know about your involvement in the study:

The researcher will request for a skype interview lasting approximately 30 minutes. This interview will occur at a date and time of your choosing. The interview will be audio-recorded.

The researcher will request basic demographic information about you, but your confidentiality is protected. The researcher will not use your name or any identifying information about you in their reports about the study.

Only lead researcher will have access to the confidential data which will be stored on a password protected flash drive which will be locked in a file cabinet that only lead researcher have access to.

You are free to decline to be interviewed or to end your participation in the interview at any time.

The researcher does not share any relation with your employer and If you decline to participate in the interview or answer any question it will not affect your employment standing in any way.

You have rights as a participant in this study. If you have questions about the study, please contact the lead researcher, Yashodhan Mandke, by phone (XOX) XOX-XOXO; or e-mail xoxox@miamioh.edu.

Miami University's Research Ethics & Integrity Program has reviewed and approved this study. For questions or concerns about your rights as a research subject please contact the Research Compliance Office at Miami University: (XOX) XOX-XOXO or xoxoxs@miamioh.edu.

I _____ agree to participate in this study for purposes outlined above. I give my permission to be interviewed and for the interview to be audio-recorded.

Date _____

CONSENT FORM FOR HARD-OF-HEARING EMPLOYEES

This study examines Hard-of-hearing people and they becoming part of warehouse workforce. You are not required to participate in this study; it is entirely voluntary. Participants must be at least 18 years of age to participate. If you decline to participate in the study, it will not affect your employment or academic standing in any way.

If you choose to participate, here are some important things to know about your involvement in the study:

The researcher will request to meet with you in-person for an interview lasting approximately 20 minutes. This interview will occur in the break-room or a lounge of the warehouse . The interview will be audio-recorded.

Your participation will have no effect at all on your daily activities. Participants are allowed to do the things they usually do during break while participating like eat or drink, go to the bathroom etc.

The researcher will request basic demographic information about you, but your confidentiality is protected. The researcher will not use your name or any identifying information about you in their reports about the study.

Only lead researcher will have access to the confidential data which will be stored on a password protected flash drive which will be locked in a file cabinet that only lead researcher have access to.

During the interview, there is a chance that you can remember something that might be a hard memory and can make you uncomfortable or emotional. Please let the lead researcher know about it. You are free to decline to be interviewed or to end your participation in the interview at any time.

The researcher does not share any relation with your employer and If you decline to participate in the interview or answer any question it will not affect your employment standing in any way.

You have rights as a participant in this study. If you have questions about the study, please contact the lead researcher, Yashodhan Mandke, by phone (XOX) XOX-XOXO; or e-mail xoxox@miamioh.edu.

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I _____ agree to participate in this study for purposes outlined above. I give my permission to be interviewed and for the interview to be audio-recorded.

Date _____

ASSENT SCRIPT (SUBJECT MATTER EXPERTS)

Greetings! I am Yashodhan Mandke and I am a student at Miami University in the Master of Fine Arts in Experience Design program. My faculty advisor for this research project is Dennis Cheatham. Thank you for choosing to participate in the interview. This study is being done by researchers from Miami University, who are interested in learning more about Hard-of-hearing people and they become a part of warehouse workforce.

The purpose of the study is to more clearly understand how we can mitigate the obstacles for the hard-of-hearing employees working in the warehouse environment with the use of Haptics or Vibro-tactile technology. You are being asked to participate because you have been working as an employee for *** company in the warehouse environment. Your thoughts and experience will be valuable for this research.

Questions will be about your perspective and insights on your experience as a trainer/recruiter for hard-of-hearing employees to work in the warehouses. There are no wrong answers. We want to learn about your experiences and viewpoint as a hearing-impaired employee.

If you decline to participate in the interview or the activity, it will not affect your employment standing in any way. You may decline to answer any questions for any reason.

We believe the results of this study will provide important information that will help hard-of-hearing warehouse workers for themselves and their loved ones.

All the audio recording for this interview will be stored on one researcher-owned laptop whose contents are encrypted and access protected by a password known only by the researcher. Your identity and information is secured and will not be revealed to anyone. Please let me know if you have any questions.

If it's fine with you, I would like to start the audio recording and proceed with the questions.

ASSENT SCRIPT (HARD OF HEARING EMPLOYEES)

Greetings! I am Yashodhan Mandke and I am a student at Miami University in the Master of Fine Arts in Experience Design program. My faculty advisor for this research project is Dennis Cheatham. Thank you for choosing to participate in the interview. This study is being done by researchers from Miami University, who are interested in learning more about hard-of-hearing people and they become a part of warehouse workforce.

The purpose of the study is to more clearly understand how we can mitigate the obstacles for the hard-of-hearing employees working in the warehouse environment with the use of Haptics or Vibro-tactile technology. You are being asked to participate because you have been working as an employee for *** company in the warehouse environment. Your thoughts and experience will be valuable for this research.

There are no wrong answers. We want to learn about your experiences and viewpoint as a hearing-impaired employee.

If you decline to participate in the interview or the activity, it will not affect your employment standing in any way. You may decline to answer any questions for any reason.

We believe the results of this study will provide important information that will help hard-of-hearing warehouse workers for themselves and their loved ones.

All the audio recording for this interview will be stored on one researcher-owned laptop whose contents are encrypted and access protected by a password known only by the researcher. Your identity and information is secured and will not be revealed to anyone. Please let me know if you have any questions.

If it's fine with you, I would like to start the audio recording and proceed with the questions.

INTERVIEW QUESTIONS FOR THE SMES:

I would like to know more about your work experience.

How long have you been associated with the hard-of-hearing (or other disability) training/recruitment?

What are some of the most challenging parts of hiring/training differently abled employees in the warehouse?
　　　Particularly with hiring/training hard-of-hearing employees?
　　　　　The lack of opportunities?
　　　　　The skills of the employees?
　　　　　The warehouses are not adapted to fit hearing impaired?

What assistive devices or technology is currently being used in the hiring/training of hard-of-hearing?

What are the common complaints from the hard-of-hearing employees after the training/hiring about something not working for them?

Based on the difficulties and complaints like *** you mentioned, if we could improve one of them to make work for the hard-of-hearing employee in the warehouse easier, which would you like to see improved?

Is there anything that we missed speaking about in this interview which you would like to share which can be important for this research?

INTERVIEW QUESTIONS FOR THE HARD-OF-HEARING WAREHOUSE EMPLOYEES:

I would like to know more about your work experience.

How long have you been working with *** company?
　　　Is this your first job?
　　　　　Where have you worked before?
　　　　　What type of work did you do?

I'd like to learn what a typical day of work is like for you.
　　　What are some of the more difficult parts of your job?
　　　If you use assistive devices to help you do your work, what are they?
　　　Do they do a good job helping you get work done?
　　　　　For the ones that aren't very helpful, where do they fall short?

Do you think the vibrators in your cell phone makes using your cell phone easier?
　　　So you use any other devices with vibrators?
　　　　　(if so) What kind of devices do you use with the vibrators? E.g. alarm clocks, wearables etc.

Now I'd like to learn about your experience working with other employees.
　　　Do you get fair treatment as a hard-of-hearing employee?
　　　Have you faced any discrimination?
　　　Do you feel that you receive more help than other employees?

What are some of the most challenging parts of being a hard-of-hearing employee?

Based on the difficulties like *** you mentioned, if we could improve one of them to make your work in the warehouse easier, which would you like to see improved?-

RECRUITMENT MATERIALS- EMAIL TO THE SMES WITH FAQS

Dear XXX,

Hope you are doing well. I am Yashodhan Mandke, a graduate student studying Master of Fine Arts in Experience Design at Miami University in Oxford, OH.

I received your contact from XXX, working for XXX. I got your contact in reference to my thesis project research. The purpose of the study is to understand how we can mitigate the obstacles for the hard-of-hearing employees working in the warehouse environment with the use of Haptics or Vibro-tactile technology.

XXX mentioned that you have worked on the training of hard-of-hearing employees in the warehouses.

It would be great to talk with you and get some information about it. Your experience and exposure in the topic will be valuable for this research.

I would really appreciate if you take out some time from your busy schedule for a short skype interview. It will be great if you can mention some dates and time that you are free. Participation in the study is voluntary. In particular, we anticipate your participation will have no effect at all on your daily activities. If you decline to participate in the interview or the activity, it will not affect your employment standing in any way.

Please find more information about the research project and the interviews below:

What kinds of questions will be asked?
Questions will be about your perspective and insights on your experience on the training of hard-of-hearing warehouse employees. There are no wrong answers.

Do I have to participate?
Participation in the study is voluntary. In particular, we anticipate your participation will have no effect at all on your daily activities. If you decline to participate in the interview or the activity, it will not affect your employment standing in any way.

How long will it take?
The researcher would like to have skype interview with you that will take approximately 30 minutes.

How will my answers be used?
The study results will be written into a report which will be shared with other researchers, professionals who expertise in differently-abled employment in warehouses and in academic magazines. The results will also be shared with those who participated in the study. We believe the results of this study will provide important information that will help hard-of-hearing warehouse workers for themselves and their loved ones.

Are my answers confidential?
Yes. Your answers will never be used in any way that would identify you. They will be combined with answers from other people who participate in the study to make a report.

How will my information be protected?
All the audio recording for this interview will be stored on one researcher-owned laptop whose contents are encrypted and access protected by a password known only by the researcher. Later your audio recording will be transferred and saved in a password protected flash drive.

Also, please don't hesitate to ask if you have any questions.
I look forward to hearing from you. Thanks in advance for your consideration.

Sincerely,
Yashodhan Mandke

YOUR VOICE MATTERS!

Come & share your thoughts about being a hard-of-hearing employee working in a warehouse

Participate in a 15 minute interview during your break or change of shifts.

The participation is voluntary, but employees who consider themselves hard-of-hearing are requested to participate.**

Your participation in the interviews will have no effect at all on your daily activities and work schedule.

You can do usual stuff like eat or drink, go to the bathroom etc. while you participate in the activity

Any answers provided during the interview are confidential and won't be used in any way to identify you

**Not participating in this research or denying to answer any of the questions will not affect their employment status in any way.

♥ *Your participation will benefit hard-of-hearing employees like yourselves in becoming part of the warehouse workforce and it will assist warehouses to accommodate hard-of-hearing employees in a better way.*

Contact your supervisor for more information

INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL EMAIL

MIAMI UNIVERSITY
OXFORD, OH · EST. 1809

OFFICE FOR THE ADVANCEMENT OF RESEARCH AND SCHOLARSHIP (OARS)
Institutional Review Board for Human Subjects Research
102 Roudebush Hall
Oxford, OH 45056
513-529-3600

To: Yashodhan Mandke and Dennis Cheatham

From: Dr. Ann Bainbridge Frymier
        Institutional Review Board for Human Subjects Research

Date: February 23, 2018

RE: IRB Revision Request for 01573r, Mitigating the obstacles for the hearing impaired employees in becoming the part of warehouse workforce though Haptics and Vibro-tactile technology

Thank you for submitting the application referenced above to the Institutional Review Board (IRB).

The board has reviewed and approved your proposal through the regulatory Expedited Review procedure.

Your protocol approval number is: 01573r

Approval of this project is in effect until: February 22, 2019

If you complete your project before the date listed above, please send an email message indicating so to humansubjects@miamiOH.edu and we will close your file.

Regulations require periodic review of all ongoing human subjects research projects. If your project will continue beyond the approval date shown above, you will need to submit an Application for Continuing Review and status update for review before the expiration date.

Please submit your next application for continuing review by: January 22, 2019

Should you wish to change your procedures relating to the use of human subjects or personnel having access to the data, you must obtain approval from the IRB **prior** to instituting any changes.

On behalf of the committee and the University, I thank you for your efforts to conduct your research in compliance with the federal regulations that have been established for the protection of human subjects. Thank you for your attention to this matter, and best wishes for the success of your project.

OBSERVATION STUDY- DISTRIBUTION CENTER IN WINDSOR, CT

SORTING FLOOR- DISTRIBUTION CENTER IN WINDSOR, CT

CATEGORIZING THE CODED DATA