Smart Hard Hat: Responding to Sound to Protect Your Ear Health

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ABSTRACT

The Smart Hard Hat is an interactive hard hat that aims to protect the hearing health of construction workers by utilising shape shifting technology. The device responds to loud noises by automatically closing earmuffs around the users ears, warning them of the damage that is being caused while taking away the need to consciously protect yourself. Construction workers are particularly vulnerable to noise-induced hearing loss, so this was the target user for this design. Initial testing revealed that the Smart Hard Hat effectively blocks out noise, and that there is potential for expanding the design to new user groups.

CCS CONCEPTS

• **Human-centered computing** → **Usability testing**; **Sound-based input / output**.

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Figure 1: The Smart Hard Hat is adjusted to fit the user's head and so the earmuffs fully cover ears. After this the user has no further interaction apart from simply wearing the hat

Figure 2: If the sensors detect sound above a level of 85dB the earmuffs automatically close over the user's ears

KEYWORDS

Smart Hard Hat, noise-induced hearing loss, shape-shifting technology

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INTRODUCTION

Sounds can be harmful when they are too loud, this can be when they are loud and long-lasting or even for a short time. People of all ages, including children, teens and older people can develop Noise-Induced Hearing Loss. A study in 2012 involving hearing tests and interviews with participants found that it is likely 40 million adults in the U.S. have noise-induced hearing loss in one or both ears from exposure to loud noise [4]. Participants in our preliminary questionnaire indicate they would simply leave an environment in the case of exposure to excessively loud noise. Unfortunately, this is not always possible, especially when it is part of daily work, as it is for construction workers. A study was carried out on construction workers from 2000 to 2010 which showed that prolonged exposure to noise levels above the recommended level of 85db was responsible for hearing loss in workers. Also, most of the damage was done early on in their careers [7]. This shows why it is vital to take measures to protect hearing health early on in construction workers. The Smart Hard Hat aims to solve this problem. Our device comes with a microphone and earmuffs. When the sound detected by the microphone has exceeded the set threshold, motors are activated causing the earmuffs to cover the user's ears. The microphone measures the sound every 5 seconds and if the threshold is still exceeded, the earmuffs keep covering the ears. When the sound is below the threshold, the motors reverse direction and the earmuffs will be moved off the user's ears.

While the device was primarily designed for construction workers, it is possible to use this device in other loud environments. Most of the answers to our questionnaire indicate people do not try to protect their hearing health when exposed to loud noise despite answers suggesting concern about hearing health. Since the process of adjusting the earmuffs is automatic, users do not have to perform any manual action aside from wearing the hat. Users of this device have reported it effectively blocks out noise and would be beneficial to their hearing health. From our questionnaire, people reported recently going to loud places like live concerts, nightclubs, gigs, firework displays, festivals, pubs or workshops. Some participants have even reported environments like weddings, airports or even city sounds as loud. The usability study aims to identify how we can improve the Smart Hard Hat so a similar design can be utilized by people to protect their hearing health.

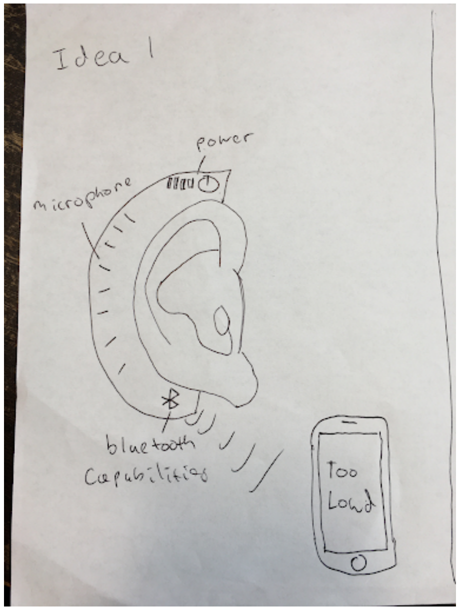

Figure 3: A device similar in look to a hearing aid, which would detect loud sounds and send the data to the users phone in order to alert them of the potential damage

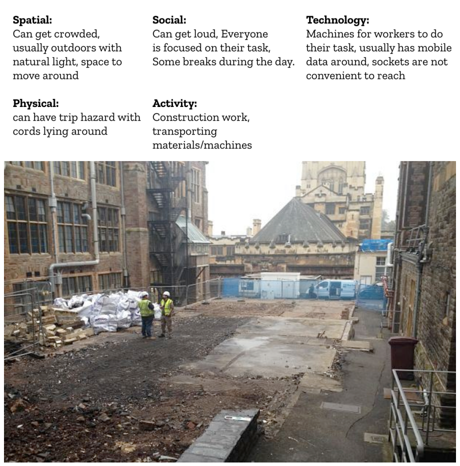

Figure 4: Annotations showing a construction site context, and how this influences the technology used

RELATED WORK

The area of safety surrounding construction workers is very well explored. Many additional safety features are being integrated into hard hats which are already mandatory to wear on construction sites. There are a multitude of devices that focus on providing first aid requirements which can be used on workers after the incidents occur [6], but there are few to prevent accidents or damage from happening in the first place.

Sensors integrated onto hard hats have been used to monitor biometrics [5] of the users as they perform occupational duties. A central processing board is also able to deliver immediate feedback alerts to the worker and their supervisor if dangerous situations have occurred. This takes the first aid hard hat one step further by automatically sending alerts, reducing the time for help to arrive. This idea has been extended to workers in the electric power industry, monitoring the environment to detect hazards, also including GPS tracking to aid rescue attempts [1]. The aim of this device, again, is to protect from further problems; not necessarily prevent the problem from occurring in the first place.

One current device available which does attempt to prevent damage or accidents from occurring is the Arduino Smart Working Helmet [2]. This hat warns the user about various hazards within their environment including sound levels, temperature and gas toxicity. However, it only provides warnings and not physical protection.

This research shows the need for devices to protect workers against these dangers in their environment. Our smart hard hat plans to take these ideas further and create a device that actively protects the user from the dangers that are sensed.

WALKTHROUGH

The product of the smart hard hat should involve minimal interaction of the user with the device, with most of the interaction being from the device on the user. The user will simply secure the hat on their head and adjust the ear protectors to fully cover their ears (Figure 1). After this, no interaction from the user is expected on the device. The device should then automatically cover the user's ears when the surrounding sound has surpassed a set threshold (Figure 2). This threshold has currently been set at 85dB which, according to studies, can lead to Noise Induced Hearing Loss (NIHL) after 2 hours [7]. The devices will also light up one of three LEDs depending on the proximity of objects to the device. These LEDs will indicate which direction this object is approaching from, which in turn should guide the user in moving their head to a safer point.

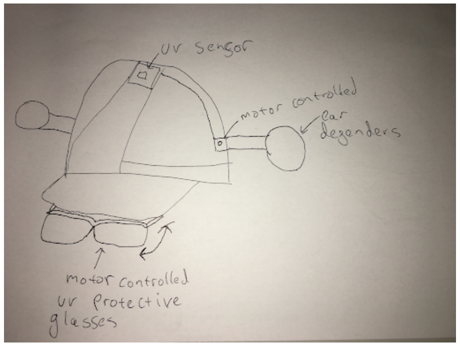

Figure 5: An early design sketch showing different types of sensors that could be useful to a construction environment

Figure 6: The first physical prototype, more layers of sound insulation would cover the ear as the sound became louder

DESIGN

During brainstorming we quickly focused on the issue of hearing health since it is a topic neglected by the general population, despite concerns about hearing loss. The first idea in the design iteration was a small earpiece that would detect sound near your ears. The device would then transmit data through Bluetooth to an app on your phone, for the purposes of alerting the user at times of sounds loud enough to induce hearing loss. This device is illustrated in Figure 3. However, this design had the issue of only warning the user about the loud sounds, but not actually providing physical protection. Also, it was also important to understand the context as part of the process. To do so, many context related pictures were gathered and explanations of the spatial, social or technological impact were given for each picture. From those pictures one of them was a construction site (Figure 4). At this stage of the process, we understood construction workers were going to be our main focus and so we started brainstorming ideas for a hard hat.

Initially the Smart Hard Hat had many different functionalities added to it, as shown in an early design sketch (Figure 5), but the team decided the focus should be on hearing health protection, in order to provide a more optimised design. When considering the different ways of adding the hearing protection to the hard hat, one of the first ideas was to have a well fit frame around the ear and more layers of sound proof material are slowly added on top of it as sound gets louder. To better understand the concept, a very simple prototype was created, shown in Figure 6. This idea was too intrusive as it consisted of having a frame around the ear all the time. Therefore the idea that made the final prototype was to lower earpieces from the hat down on the ear when loud noises were present. Lastly after acquiring an Arduino UNO board together with two servo motors and a noise sensor, the final prototype started to emerge. The Arduino was programmed to turn the servos when the detected noise exceeds a set threshold. The outline of the process is as follows: the noise sensor constantly collects data; if at any point the noise levels pass the predefined threshold, the Arduino sends a signal to the servos to rotate at a position where the earpieces cover the ears. At this stage the Arduino also starts a 5 second timer. Whenever the sensor collects data about a loud sound, that timer is reset. When the timer ends, the servos rotate back thus releasing the earpieces from the ear. As mentioned before there was the idea to add multiple modules to the smart hard hat, therefore the Arduino was also fitted with proximity sensors. This was internally tested for the addition of a proximity module that would alert the user through LED lights if there was something close behind their head. The concept is that the modules will expand and there will be plenty of customizability for the user in the future, with modules such as the proximity alert, UV sensor alert and more.

STUDY

We conducted an informal user study with 8 student participants from the University of Bristol, between the ages of 18 and 25. These participants were asked to wear the Smart Hard Hat and answer a series of basic maths questions in the presence of loud background noise. Afterwards, participants answered a survey of 10 questions rating the ease of use, effectiveness and user satisfaction on a scale of 1-7 based on their level of agreement. The questions asked are shown in Table 1. We chose not to use the standard SUS questions [3] because there is not much user input to the system which the SUS questions focus on.

The Smart Hard Hat scored a 63% score obtained by adding the scores of each question, where each had a contribution of 0 to 6, and multiplying the result by 1.6 for a percentage. On the SUS scale this would be just below average, and although this cannot be directly compared as we did not use the standard questions it gives us an idea of how well the device performs. The responses show that all the participants had no difficulties in using the device (scoring a 6 or a 7), and all participants also scored 5 or above when asked if the device responded to sound effectively. However, 5 of the 8 participants gave the lowest score of 1 when asked if they would wear this device or similar to a festival or gig, and most of the participants thought the device was fragile. These two points could be easily addressed with a more compact, discreet design without exposed hardware.

Additional qualitative feedback was obtained from the same participants including suggestions on how to improve the system. This indicated that users felt the design was appropriate for construction workers, but too clunky and unfashionable to wear elsewhere, one participant said "I would [wear it] in construction sites. It looks too silly for other environments". Users also pointed out that an adjustable size would be beneficial in order to make sure the earmuffs covered the user's ears correctly. Adjustability and a more discreet design would be the focuses for future iterations of improvement.

1. The Hard Hat was comfortable
2. Sound was effectively blocked
3. The noise did not distract me from the task
4. The device could be used by children
5. The earmuffs hurt my ears when they closed
6. I would wear a similar device at a gig or festival
7. The device responded to sound effectively
8. I encountered problems using the device
9. The device felt fragile
10. The device was manufactured with a suitable material

Table 1: Table showing the questions asked to participants of the study. Participants were asked to rank their agreement with the statement from 1-7

FUTURE WORK

There are many directions to explore with further research; our feedback showed that students would prefer a more subtle design and so future iterations of the product could focus on a more compact, stylish design. As the proof of concept has been successful, the feedback showed that the device worked well for its purpose, the hardware can definitely be scaled down to make the final product more wearable.

Further studies and questionnaires will need to be executed in order to get more of a range of feedback. We only asked students in our initial study, which are not our main target audience. Studies involving people in the construction business are essential, and also with parents or children to find out if this concept would be used in other contexts such as fireworks displays where young children's hearing might be damaged.

Another interesting feedback point we received from one participant was that they would prefer the device if "you could control how much sound got through them". This would be an interesting point of research in the future to further enhance the device. There is also the possibility to connect the device to an app to send warnings and information on hearing health to the users phone. This could potentially make the user think about how much sound they are letting through and start to monitor their own interaction with loud sounds. This also ties in with further research into the optimal threshold to set the device to.

Other sensors are already being used in devices such as the Arduino Smart Working Helmet [2] mentioned in the Related Work Section. Further research could be developed in this area, looking at how to utilise the UV sensors into our device to protect from more than just noise, for example. We have already began to look into proximity sensors and how this would be useful for construction workers or workers in tunnels particularly. The proximity sensors would warn the user when their head is getting close to hitting something so the accident can be prevented.

CONCLUSION

In this paper we have introduced the Smart Hard Hat, a device which responds to the noise levels in the environment, changes shape to cover your ears and protects you from damaging your hearing health. With a more sleek and compact design this device could be used in a range of contexts, from construction workers to children watching fireworks. Despite design drawbacks, feedback largely showed that this device works, it blocks sound effectively and is easy to use. This device has great potential for further improvements and can be used to protect against noise-induced hearing loss.

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