Deep Vision Shield: Assessing the Use of HMD and Wearable Sensors in a Smart Safety Device

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ABSTRACT

Miniaturized and wearable technologies have the potential to augment human senses and capabilities when embedded into everyday objects. We investigate how such technologies can impact workers' health and safety in the energy industry through the design, prototyping and evaluation of a smart safety device. Deep Vision Shield is a protective helmet that embeds gas and noise sensors, head-mounted display and communication systems. The prototype has been evaluated through a user study involving 13 workers in the energy industry. We collected feedback about improved functionalities, user experience, and ergonomics of the proposed system, as well as the risks connected to the use of such technologies in the field of health and safety, such as overconfidence, loss of human skills, and distraction. Overall, the device was assessed very positively, although the need to balance advantages and potential risks stemming from the adoption of new technologies emerged as an essential element to consider while developing similar solutions.

CCS CONCEPTS

• **Human-centered computing** → Interaction design; user centered design • **Ubiquitous and mobile computing** → ubiquitous computing; ambient intelligence

KEYWORDS

Smart Safety Devices, Safety Helmet, Health and Safety, Head-mounted Display, Wearable Sensors, Personal Protective Equipment, User Experience, Energy Industry.

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1 INTRODUCTION

Companies operating in different industries are starting to adopt wearable technologies such as augmented reality, miniaturized sensors, and IoT devices to improve workers' efficiency, shorten the production time, and provide more support to workers in their daily activities, such as remote assistance or training. Such technologies are beginning to appear also in other applications, for instance in the field of health and safety [1]. Although augmented safety systems and devices are gradually being adopted by different industries, their deployment in real contexts remains difficult. Indeed, it requires changes at the systemic level (e.g. connectivity infrastructures, data management platforms, etc.), as well as revised approaches and practices (e.g. new procedures addressing smart safety devices and their functionalities) [1]. In addition to it, technologies embedded into safety devices demand new interaction modalities to users and may arise concerns such as the privacy of collected data [2], thus making their acceptability less obvious. For these reasons, the user experience of such systems should be taken into great consideration.

Despite the great effort to increase safety at work, incidents and fatalities still occur at a high rate. In the mining and oil and gas extraction industry, fatality rates increased from 89 to 112 between 2016 and 2017 in the US [3]. Among the major causes are falls, slips and trips, exposure to harmful substances and environments, and fires and explosions [3]. Because technology poses a number of problems to its implementation, health and safety practices and procedures still heavily rely on humans' compliance to standard, well-rooted safety procedures. However, technology shows great potential to solve some of the main health and safety problems [4], such as exposure to chemical and physical hazards [5], lack of safety compliance [6], insufficient Personal Protective Equipment (PPE) usage [2], or time-consuming procedures for hazard reports in plants. [7].

This paper investigates the use of emerging technologies such as embedded computing, wearable sensors and head-mounted displays in a smart safety device to address specific health and safety problems. It describes the Deep Vision Shield (DVS), an augmented safety helmet that has been designed, prototyped and evaluated with workers through a user study.

When adopted in the workplace, especially in hazardous environments such as oil and gas plants, such smart safety devices can create distributed sensing ecosystems, connect workers, and improve their communication. We tested these functions through our prototype and we collected feedback in order to support future research and applications in this field.

1.1 Objectives

This paper aims at providing a case study supporting the discussion about pros and cons of adopting some emerging technologies in the field of health and safety. We intended to evaluate the design of a smart safety helmet embedding hazard (gas and noise) sensors, alert systems, and a head-mounted display (HMD), to assess the acceptability of those technologies and to discuss the advantages and risks of the adoption of such a device in real contexts.

The results can inform the design of similar systems as well as a broader discussion on the positive and negative effects of new technologies on safety practices in the energy field. Such results can potentially be applied to related industries, such as the construction and manufacturing ones.

2 RELATED WORK

Some examples of connected safety equipment have been developed and tested in the form of research prototypes and commercial products. In a previous research project [8], we designed and prototyped an ecosystem of smart PPE for the energy industry. Preliminary user tests were conducted, although they were not specifically focused on investigating long-term consequences of deploying these systems in real contexts. [2] develop and test a wearable system that continuously monitors the use of PPE by workers. During the study, it emerged that users felt very uncomfortable about the idea of being watched and monitored through wearable technologies. Other uses of wearable computing feature an RFID portal for checking the PPE compliance of personnel [9], or PPE embedded with proximity sensors to avoid struck-by from heavy equipment [10].

Vandrico Solutions prototyped a smart safety helmet clip for miners that allow LED-based communication and embeds four sensors to detect gas and radiation levels. Daqri (daqri.com) developed a prototype of a safety helmet equipped with an augmented reality (AR) visor. The original project has turned into AR protective glasses currently available for companies. Vuzix (vuzix.com) proposes AR glasses and HMDs that can be attached to safety glasses or helmets and feature different industrial applications, from warehouse logistics to training. Realwear (realwear.com) has developed an Android-based micro-display that can be mounted on safety helmets. Many leading manufacturing industries are developing applications for AR systems such as Microsoft HoloLens, to bring AR in the workplace [11]. In most of these cases, the main industrial applications being developed include remote assistance, real-

time information on machine status or parameters, and the possibility to visualize instructions to operate machines. None of the above-mentioned AR systems or HMDs is specifically focused on occupational safety applications.

3 THE DEEP VISION SHIELD

3.1 From vision to prototype

The Deep Vision Shield was originally conceived within the *Augmented Health and Safety: Future Vision* project [12], developed by the MIT Design Lab in collaboration with Eni, a worldwide energy company (www.eni.com). The concept was part of a future vision composed of an ecosystem of digital and physical solutions aimed at advancing health and safety practices in the energy industry through emerging and future technologies. The DVS concept generated in that project was subsequently redesigned and prototyped through currently-available technologies, in order to create a working device that could be evaluated both in terms of feasibility and acceptability.

3.2 Design

Starting from the results of the previous *Future Vision* project, the design of the second version of the DVS followed a process composed of secondary research, design brief generation, and concept refinement.

3.2.1 Research. The initial research phase consisted in the selection and deepening of a number of relevant safety issues that were to be translated into features of the smart safety helmet. Compared to the previously-envisioned solution [12], the safety issues to address in the new version of the concept were selected on the basis of the company's input and priorities. They included acute and long-term exposure to noise and chemicals, lack of procedure compliance, poor use of PPE, and scarce communication between teammates and among stakeholders in the plant.

3.2.2 Design Brief. On the basis of the research outcome, a design brief was generated. The Deep Vision Shield system should i) monitor workers' real-time acute and long-term exposure to environmental hazards (gases, noise) and make this information available to relevant stakeholders (e.g. supervisors or medical doctors), ii) provide workers with contextual and detailed alerts on acute exposure, iii) facilitate communication amongst actors in the plant, and iv) incentivize the use of PPE.

3.2.3 Concept refinement. Starting from the identified requirements, we designed and refined a new concept for the smart safety helmet through multiple iterations. We actively involved stakeholders from the company throughout the whole design process, in order to collect feedback and to guarantee that the designed system complied with their safety requirements and processes.

3.2.4 Features. The main features of the resulting DVS concept are reported below.

Gas and noise sensors. The helmet embeds sensors that constantly measure the worker's exposure to hazardous gases (CO, SO₂ and H₂S) and noise. Sensors collect data on exposure levels both in real time (acute exposure) and over time (long-term exposure). In addition to notifying the worker about any real-time health or safety hazards, the helmet collects exposure data that can be used at a systemic level. Once this information is paired with the worker's position, it can help safety managers to immediately identify any gas leak in the plant, and to map dangerous areas for long-term exposure. Moreover, the exposure history of each worker can help medical doctors to diagnose specific pathologies connected to exposure to physical or chemical hazards.

Head-mounted display. A HMD was embedded in the helmet in order to provide workers with:

- detailed alerts on safety issues and hazards in the plant (e.g. exposure to gas, environmental hazards);
- a system to perform real-time, hands-free reports of safety problems, hazards, and near miss in the plant, which would replace the current paper forms, in order to improve procedure compliance;
- a video/audio communication system connecting the worker to the control room and to teammates;

Passive protections. Different kinds of passive protections (helmet, visor, hearing protections) were integrated in the DVS and were designed as a unique product. The presence of the visor and hearing protections on the helmet intends to incentivize their use, as they were designed as part of the product, and not as additional components like in the solutions that are currently available on the market.

Communication system. The helmet is equipped with a microphone and speakers embedded in the hearing protections, which allow a real-time, hands-free communication among teammates and with the control room.

3.3 Prototype

Once the concept was defined, we implemented the final design into a working prototype (Fig. 1). The prototype was entirely built from the research group, by merging commercial off-the-shelf components and 3D-printed elements. The main components of the prototype are described below.

3.3.1 Control Board. An ARM 32-bit processor was used as the main microcontroller connected to both the noise and gas sensors and the HMD. The board communicated with an external database through Wi-Fi.

3.3.2 Gas sensors module. Off-the-shelf CO, SO₂ and H₂S sensors were embedded into a removable module and connected to the control board.

3.3.3 Head-mounted display. We selected Vuzix 300 as the HMD to integrate in the DVS. This device was selected on the basis of a

number of criteria, including the availability of SDK, the possibility to develop custom Android applications, and additional features such as a proprietary voice recognition platform. Vuzix 300 are equipped with a small lateral screen and an embedded microphone, which can be used to interact with the interface by voice. When connected to our custom database, the HMD was able to receive and display alerts every time the sensors detected the presence of gas or noise above the safety thresholds (Fig. 4). The screen distance from the eye and its inclination could be adjusted through a rail and a sphere joint.

We considered the possibility to use HoloLens instead of a side-screen device, which would provide a smoother AR experience by being integrated directly in the visor. However, HoloLens were too heavy and large to be integrated in a safety helmet that should be worn 8 hours a day.

Figure 1: The DVS prototype includes gas sensors embedded into a removable module.

3.3.4 Hearing protections and visor. The hearing protections and the visor were designed as an integral part of the device. The visor can be manually removed if necessary, e.g. when operating machines that generate steam, which may condense on the visor and impede vision. Moreover, although the visor should replace protective glasses, it was made removable to allow users to wear special glasses for certain activities (e.g. soldering).

The hearing protections can be opened but cannot be completely removed. They feature speakers, which are used both to allow communication with other workers and to notify the user about safety issues (e.g. gas exposure) through sound alerts.

3.3.5 Database. The database collects data from noise and gas sensors. Safety thresholds were set, corresponding to the acute (STEL)¹ exposure thresholds for CO, SO₂ and H₂S [13]. When the sensors data exceeds such thresholds, the database sends an input to the helmet control board, which conveys the alert by visual and sound signals.

3.3.6 Alert system. When the database detects exposure to toxic gases or noise, a visual alert appears on the HMD, synched with a sound alert provided through the speakers embedded in the hearing protections. The alert is also visualized on the back of the helmet through a LED strip. The color of the light emitted is coded to communicate two different levels of alert (orange for warnings and red for emergency alerts). (Fig. 2)

Figure 2: Rear view of the DVS with a visual LED-based alert system for nearby workers.

3.3.7 Control room and medical doctor interfaces. A desktop interface was developed to simulate the helmet data visualized by the control room. Indeed, plant supervisors should be able to monitor the exposure of workers to gas and noise, as well as to receive alerts in case of hazards, therefore using the helmet as distributed sensing points in the plant. Data on acute and long-term exposure were also embedded in a mockup interface for medical doctors, who could see the workers' exposure history.

The helmet features a removable battery that can be extracted to be rapidly swapped or charged wirelessly (Fig. 3).

3.4 Use cases

We performed four semi-structured interviews with workers and site managers at two Eni plants in Southern Italy (a power plant and an upstream site), in order to identify specific health and safety use cases for the helmet. As a result, the following three use cases were selected:

- Use Case 1: Exposure tracking;
- Use Case 2: Hazard report;
- Use Case 3: Plant Navigation and Lockout areas.

¹ STEL: short-term exposure limit. STEL is the acceptable average exposure over a short period of time, usually 15 minutes.

Figure 3: The helmet has a removable battery pack for rapid extraction and wireless charging.

Such use cases guided the design and implementation of both the database and the desktop/HMD applications for the Deep Vision Shield. They were used both to demonstrate the DVS functionalities to the company and as support material to storytell and exemplify the helmet use during the user study we performed.

The selected use cases are presented in the following sections.

3.4.1 Use Case 1: Exposure tracking. Workers' exposure to gas and noise is currently monitored by ambient sensors and by personal sensors that users are required to wear. Such systems alert workers when safety exposure thresholds are trespassed, typically by emitting sound alarms.

The Deep Vision Shield tracks the worker's exposure to noise and hazardous gases in real time and sends data through Wi-Fi to an external database for analysis and record. Visual and sound alerts are triggered when the helmet sensors detect CO / SO₂ / H₂S or noise levels above set thresholds. Visual alerts are displayed on the helmet HMD (Fig. 4).

Figure 4: Workers are alerted by both visual and auditory notifications when hazardous gas is detected.

Two types of gas alerts can be displayed:

- a warning, or pre-alert (orange background) is triggered when the sensors detected an amount of gas corresponding to half of the safety threshold;
- an alarm (red background) is triggered when the gas safety threshold is reached.

The helmet back light blinks reproducing the color corresponding to the emergency level (orange or red), every time an alert is displayed on the worker's helmet. This way, the helmet acts as an ambient display that notifies nearby workers of a dangerous situation on the site.

When an exposure alert is triggered, the control room operators are also notified by an alert appearing on their dashboard. (Fig. 5)

Figure 5: The control room dashboard showing a notification for hazardous gas detection.

3.4.2 Use Case 2: Hazard report. Workers are currently required to report any unsafe condition, unsafe act or near miss they encounter in the plant, by filling in paper forms. We designed and developed a software application for the HMD that allows to report unsafe conditions hands free, by voice interaction only, through a guided procedure (Fig. 6).

The app also features QR code detection, which is used to automatically recognize machines and equipment, when the unsafe condition is connected to a faulty machine. It also allows to take pictures of the scene by the camera embedded in the HMD.

Figure 6: Hazard report can be performed by the HMD app, which features QR code scanning and voice interaction.

3.4.3 Use Case 3: Plant Navigation and Lockout area. The Deep Vision Shield improves the communication between the worker and the control room, especially when the control room detects a problem on a machine that requires immediate intervention from a worker on site. Through the helmet HMD, the control room operator can indicate the faulty equipment and its position on a live map. The map guides the worker to the specific machine that needs to be fixed.

The navigation app also notifies the worker about restrained zones in the plant such as lockout areas or machines that should not be operated. Such areas trigger a visual warning on the HMD when the worker approaches them, along with an auditory alert (Fig. 7).

Figure 7: The DVS displays live location of the worker in relation to the overall space of the plant, as well as visual alerts for lockout machines and restrained zones.

4 USER STUDY

We assessed the potential benefits and risks of using an augmented safety device in real workplaces through a user study. We performed semi-structured interviews with 13 users in order to collect feedback on the advantages and difficulties connected to the Deep Vision Shield prototype. On a more general level, interviews were also aimed at discussing the consequences of adopting technologies such as HMD and wearable sensors in the field of health and safety, together with their impact on existing practices.

4.1 Participants

13 users were involved in the interviews (Fig. 8). They were all Eni employees, selected on the basis of their roles and expertise. Participants had to have at least one year of field experience and had to be familiar with safety devices worn in plants.

We involved both operative workers and safety managers in order to obtain feedback from users with different experience and perspectives on health and safety practices. Participants included:

- 5 HSEQ (Health, Safety, Environment and Quality) managers
- 2 production managers with field experience
- 5 operative workers from sites (1 shift supervisor, 2 site supervisors, 2 HSEQ supervisors)
- 1 medical doctor

Users were recruited through emails and were invited to partake in the study on a voluntary basis.

Figure 8: Participants were asked to provide feedback on the helmet features as well as its usability in different scenarios.

4.2 Method

Prior to the beginning of the interviews, participants were asked to sign a consent form. The moderator presented them with the objectives of the study and gave an introduction on the functionalities of the helmet. The three DVS use cases were presented through video scenarios, which reproduced the use of the helmet in the plant (Fig. 4, 6 and 7).

The interview was divided into two sections. The first one aimed at collecting:

1. General comments;
2. Perceived advantages and foreseen problems in the use of the helmet on site;
3. Usefulness of the system compared to solutions currently adopted in plants, for what concerns:
 - Exposure to hazardous gases and loud noise
 - Hazard report
 - Plant navigation
 - On-site communication;
4. User experience in terms of positive and negative emotional response to the helmet.

Items 1 and 2 were explored through semi-structured interviews. For item 3, we asked users to express their levels of agreement on a 5-point Likert scale. Point 4 was evaluated through PrEmo [14], a non-verbal method used to assess user's emotional reactions to a product in its early-development phases [15]. In PrEmo, cartoon-like expressions showing 7 positive and 7 negative emotions are shown to the user, who is asked to select the expressions that better reproduce how they feel towards the product.

In the second part of the interview, participants were asked to wear the helmet, test the passive protections and interact with the HMD system showing alerts and navigation screens, and comment on the following features:

- Comfort/physical ergonomics (i.e. is the helmet comfortable?)
- Cognitive ergonomics (i.e. are screen-based messages and visual/auditory alerts clear enough?)
- Intuitiveness and ease of use (i.e. is it intuitive/easy to interact with?)

In the first part of the study, users were not allowed to try on the helmet, because the goal was to collect feedback on the features of the system and its perceived usefulness in real contexts. In this phase, users' assessment should not be affected by ergonomic factors or possible malfunctions of the prototype.

4.3 Results

Results will be presented in two sections, focused on the foreseen benefits and risks of this solution for what concerns its functionalities, experience and ergonomics.

4.3.1 Potential Benefits. In general, we collected very positive feedback from all users. All subjects stated they would wear the DVS instead of their current safety helmets if they were given the opportunity to use it.

Functionalities. According to users, the augmented helmet improves exposure monitoring and alert, communication, hazard report and plant navigation, compared to current solutions (Fig. 9).

Figure 9: Responses from users' assessment of the Deep Vision Shield functionalities.

Real-time notification of exposure to hazardous gases and noise was assessed as the most improved scenario, while the possibility to be assisted in the plant navigation was the less convincing one. This might be due to the fact that navigation

was not perceived as an issue by more than half of users, it largely depending on the size and the complexity of the plant.

The hands-free communication system was perceived as extremely beneficial especially when workers have their hands occupied by operating on equipment. Moreover, such a system allows users to communicate with each other also while climbing stairs, which requires to hold the stair handrail, or while working at height, with no risk to drop the radio.

The system was interpreted as a platform open to multiple uses. Indeed, both the HMD, the communication system, and the alert system (including speakers and backlight), can be utilized in different contexts and to different goals. This feature was very much appreciated.

When asked for additional applications they envisioned for the DVS, participants provided a wide number of alternative uses. For instance, the HMD could be used to navigate users out of the plant in case of emergencies, directing them through the safest route, which can change from case to case. Additional suggested uses include training, remote assistance, or the use of the alert system to warn workers who try to access restricted areas, such as offshore platforms or scaffoldings, without the required training certificates. These use cases are not all connected to health and safety procedures, but still confirm the usefulness of a similar system for different applications in the workplace.

User Experience. In terms of user experience, the emotional reactions to the product were very positive. Only 2 negative emotions were expressed against 20 positive ones.

Positive emotions associated with the DVS were fascination (5), pleasant surprise (4), joy (4), desire (3), satisfaction (2), pride (1) and hope (1).

Some users mentioned that the integration of emerging technology into safety devices can make the system more interesting and therefore incentivize the use of PPE. Introducing new technologies “generates enthusiasm and motivates users” to comply with safety practices.

Comfort and Ergonomics. The ergonomics and usability of the helmet were positively assessed. Comfort was described as high by all users, but for two elements - the HMD adaptability and the weight of the system. They will be explained in detail in the following section.

One of the main benefits mentioned by users was the integration of different PPE in a single device. Users declared that embedding gas and noise detectors, as well as the visor and hearing protections in the helmet would make it impossible to forget or lose them, thus reducing cognitive effort and stress.

4.3.2 Anticipated risks. Some foreseen difficulties and risks connected to the Deep Vision Shield, and the technology it embeds, emerged during the interviews.

Functionalities. Difficulties connected to the DVS functionalities mainly concern the effort required for their

implementation, including the creation of Wi-Fi infrastructures or the generation of digital maps for entire plants.

Certain risks were associated with specific technologies. Some users pointed out that HMD applications could lead to distraction if not designed and used properly. For instance, delicate operations on certain machines need full attention; other tasks, such as moving in the plant, require the user to be aware of the surroundings (slip, trips and falls are the main causes for incidents in the workplace). In such cases, messages and alerts visualized on the HMD should not distract the user. Designers have to pay attention to this aspect, by finding the right balance between providing relevant information when needed and avoiding disruption or distraction during specific operations.

Another concern we collected regards the potential loss of human skills connected to the use of certain technologies. For instance, providing instructions on how to operate a machine through the HMD unburdens the worker on the one side, but it also prevents them from learning skills that would be essential in case of an emergency, when there is no time to retrieve the relevant information on the HMD. This aspect is connected to other two themes that emerged, i.e. responsibility offload and risk of overconfidence. When technology takes on some tasks, procedures, and operations once performed by humans, users can feel less responsible and safer, and can start to be less attentive to risky situations. This represents one of the most relevant concerns for the introduction of new technologies in the safety field. Technology should not replace human skills, rather it should empower workers and augment their abilities, still making them stay alert and feel responsible for the operations being performed.

User Experience. Regarding the emotional response to the DVS, none of the negative emotions presented in the PrEmo tool were mentioned by the participants. However, two users expressed doubt in response to the augmented helmet. Doubt was mainly connected to the foreseen difficulties in the system implementation and to the uncertainty about the possibility to pass all the required certifications (especially the ones concerning explosion risk). The DVS itself, however, did not elicit any negative emotion.

Comfort and Ergonomics. Two elements of discomfort were identified in the DVS. The first one concerns the adaptability of the HMD. For a few subjects, the display was hard to adjust and people having sight problems had difficulties in reading the information visualized on the small screen.

The second, and most important concern, refers to the weight of the system. All participants mentioned weight as an extremely important factor. Workers wearing PPE on a daily basis stated that they expected the system to be heavier than it actually felt and that, compared to the current set of helmet and hearing protections, the DVS was lighter. They also stated that this impression might be due to a higher comfort of the system. However, people with past field experience, who currently perform office work and do not wear safety equipment

frequently, stated that the helmet was too heavy to be worn for eight hours.

Although it was not possible to have a final response on the suitability of the DVS in terms of weight, it clearly emerged how this element plays a crucial role in the acceptability of the system. Users repeatedly stated that discomfort due to excessive weight would likely prevent workers from wearing such a PPE.

The inability to completely remove the hearing protections was addressed as another critical point by a few users. While the integration of such protections in the helmet incentivizes their use, it can also generate discomfort if the DVS is worn in hot climates, and that might lead not to use the PPE entirely.

Users stressed the need to balance technology advancements with the comfort that PPE requires. According to all of users' responses, improved functionalities and facilitated procedures could not justify a loss of comfort (e.g. additional weight). This was one of the main issues identified.

5. DISCUSSION

The use of the Deep Vision Shield in real contexts was assessed as potentially very beneficial. The most interesting features mentioned by users were the possibility to i) receive real-time exposure alerts, ii) communicate with teammates hands-free, and iii) report problems in the plant in real time, which free workers from the need to remember details and fill in paper reports subsequently. The integration of different safety devices in the same wearable system was also assessed as extremely positive, as it made it impossible for workers to forget to wear PPE.

The possibility to receive contextual information in the form of text-based messages was another mentioned advantage. Indeed, through the HMD, users can receive explicit and clear information, which replaces or reinforces current visual or sound ambient alerts. This was highlighted as a benefit, because in case of an emergency it might be difficult to remember the meaning of the light/sound codifications, which correspond to specific hazards or types of emergencies. We also proved that HMD, and augmented reality in general, can have more applications than only training, remote assistance, or real-time instructions, which are the use cases usually addressed by AR systems for manufacturing.

The collected feedback demonstrates that the integration of different technologies in a safety device opens new opportunities and scenarios that were assessed as very advantageous.

However, the adoption of wearable computing and technology in health and safety applications can also generate some risks and potential criticalities. The main one refers to the risk of prioritizing new functionalities over ergonomics and comfort, which would prevent workers from wearing the augmented device. This confirms the results of previous studies, where lack of comfort is mentioned as one of the main reasons for not wearing PPE [16], [17]. Doubts also concerned the effort required to implement smart and connected solutions in the workplace, as well as the risk of losing human skills. The current

approach to safety and the procedures employed so far necessitate workers to be fully aware of risks and to be able to respond to emergencies by relying on their own knowledge, experience, and training.

The helmet was meant to be coupled with other systems monitoring the workers' position, which were being deployed by the company. For this reason, privacy-related issues were not addressed in the discussion, although they proved to be relevant in previous studies [2].

6. CONCLUSION

We designed the Deep Vision Shield, a smart safety device integrating passive protection, HMD and wearable sensors. We prototyped the device and tested it with 13 users. We collected positive feedback in terms of improved functionalities and experience, although a few doubts about its ergonomics and comfort arose, together with some foreseen implementation difficulties and risks connected to the adoption of new technologies in the field of health and safety.

As a conclusion, the integration of emerging technologies in safety devices has to take into great consideration the user experience in terms of comfort, perceived advantages of new functionalities, and emotional response. A balance should be sought between technological advancements on the one side, and the risk of decreasing comfort, losing human skills and reducing alertness on the other one. It is difficult to predict if and to what extent the current human-based approach to safety will be transformed over time thanks to the introduction of new technologies. However, it is worth investigating what opportunities and risks such a transformation would carry, as new technologies emerge and become available to companies.

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