A SERIES OF STUDENT DESIGN PROJECTS FOR IMPROVING AND MODERNIZING SAFETY HELMETS

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ABSTRACT
The Saxion Research Centre for Design and Technology employs many students during research projects. This paper discusses a series of student design projects on safety helmets in the Safety@Work project. At construction sites workers are required to wear personal protective equipment during their work. However, there is often a lack of intrinsic motivation for wearing them. The series of projects focus on raising intrinsic motivation to wear safety helmets by adding features, and making the safety helmet more comfortable to wear. Co-design principles were used for five consecutive projects. The first projects got a clear view of the problems while wearing safety helmets. Later projects focused on designing prototypes, constructing prototypes, and eventually conducting usability studies with construction site workers. Students are given the opportunity to familiarize themselves with companies, research groups at the university, and test their ideas in the real world. A reflection of the process is described.

Keywords: Safety helmet, safety by design, co-design, usability studies, industrial environments, sensory influences

1 INTRODUCTION

How can we improve safety at work by using Ambient Intelligence? A safe working environment is not always obvious. A factor influencing safety is human behaviour [1]. People disobey, or are unfamiliar with safety rules. A big issue in the field is that workers dislike wearing personal protective safety equipment (like safety helmets, safety goggles, and boots). Reasons are a personal lack of motivation, uncomfortable designs, and lack of sense of necessity and dangers.
The basic principle behind the Safety@Work project is how to encourage safe behaviour in industrial environments with support of ambient intelligence. Students have the opportunity to use learned knowledge in research-based projects, based on industrial problems. Several consecutive internships and graduation projects eventually work towards a modern, future-proof, and ready-to-market safety helmet. Projects have a small overlay, so students learn from their predecessor. All students present their work to participating companies during consortium meetings. This paper describes the on-going series of these student design projects. The two main directions in the projects were: 1) Finding out into what extent there is a limited intrinsic motivation to wear the safety helmet. 2) How to increase intrinsic motivation of construction site workers to always wear their safety helmet on construction sites.

2 PROJECT OUTLINE

The project series developed following an empirical approach. Main goal of the Safety@Work project is to identify different ways to create safe working environments. Therefore the first project of the series started with analysing different possibilities to influence safe behaviour.
The series started with a small study on sensory influence and emotional design [2]. The second study explored theories from marketing psychology [3]. Work by Cialdini [4]–[6] deepened the knowledge on subconscious influencing behaviour and human senses. The study looked into how our different senses are usable to influence safe behaviour [3]. Results showed that both these ways could be

constructive. Simultaneously, we learned that constructions sites are confronted with workers who have a limited motivation to wear their safety helmet. Therefore, the findings of both these studies were used in the preparation for a workshop focusing on first steps towards the design of a motivational safety helmet. 15 participants were involved during the workshop in April 2012. All participants studied Industrial Product Design at the Life Science, Engineering & Design department of a Dutch University for Applied Sciences. The two topics chosen for the workshop were the psychology of persuasion, and influencing human senses. The workshop focused on inventing safety solutions based on these topics during several brainstorms.
Regarding the first topics, Cialdini [4]–[6] studied the psychology of persuasion. He discussed six principles of persuasion to influence behaviour in his research. The principles work as shortcuts for decision making in our sub consciousness. According to Cialdini, we created these shortcuts because when we would have to spend time and energy to consciously consider every decision, we would quickly become paralyzed. These principles, preliminary studies for marketing purposed, a starting point for the workshop. During the workshop we explored the possibilities on how to use these principles for safety purposes.
Analysing the design concepts, we see that some concepts improve safety directly. These concepts added safety-improving elements to the helmet: For example the added safety glasses to the helmet. Other design concepts focused on improving safety indirectly, by increasing the motivation and pleasure to wear the helmet. For example, one concept introduced fashionable safety glasses. Focusing on fashion might motivate the workers to wear their glasses more often, resulting in a safer working environment. Other concepts focused on rewarding the wearer in different way, or in improving the comfort by regulating heat
The second topic covered in the workshop was the influence of human senses. In an explorative study, Bondrager [2] discussed several ways to influence behaviour by our senses. Participants of the brainstorm were challenged to use the ideas of sensory influence in their concepts. In some concepts, improving safety was taken to a higher level. In the case of the lemon smell, the helmet was used as a mean to get a cleaner construction site as lemon smell induces cleaning behaviour. Table 1 shows how the different concepts mentioned during the workshop contribute to safe behaviour, based on the categories comfort, safety, and reward.

Table 1. Summary of concepts invented during workshop [7]

	Comfort	Safety		Reward
		Indirect	Direct	
Music	X			
Lemon smell		X		
Wearer of the month				X
Design glasses	X			
Integrated safety glasses			X	
BAM girls				X
Hearing protection			X	
Personalisation	X			

The workshop led to a further focus on improving safety and improving motivation to increase safety indirectly.

2.1 Motivation for safe behaviour

The two studies mentioned earlier [2], [3], in combination with the workshop, were input for a project that studied the influence of primary benefits on the motivation for safe behaviour [8]. From the wide range of design concepts in the workshop, Wanders chose to focus his internship on direct safety solutions. To gain more in-depth insight into safety issues and safe behaviour, an overview of accident causes was used. This was the basis for new concept design study. The top 10 categories with the most incidents are mentioned in Table 2, based on a report from the Ministry of Social Affairs and Employment [9].

Table 2. Incident rates in the Netherlands 1998-2004

Type of incidents	Per year, in numbers	Percentage
Fall from heights	98	21%
Fall from ladder	73	16%
Fall from scaffolding	60	13%
Contact with falling objects (various)	45	10%
Contact with moving parts of a machine	36	8%
Contact falling object from cranes	16	3%
Contact with flying objects	13	3%
Contact with wielding objects / hanging loads	13	3%
Contact with electricity	12	3%
Collision with vehicle	10	2%

Based on the earlier studies, literature, interviews, and a brainstorm with design students, seven concepts were developed. These concepts benefit to safety by increasing the motivation to wear a helmet. The beneficial part in this case was adding functionalities that construction site workers would appreciate and benefit from in a helmet. The seven concepts integrated in safety helmets are briefly described in Figure 1. Four of the concepts added a warning system in the helmet for potential dangers. The other three concepts added work time registration, integrated two-way radio, and machine lock when the helmet was not worn.

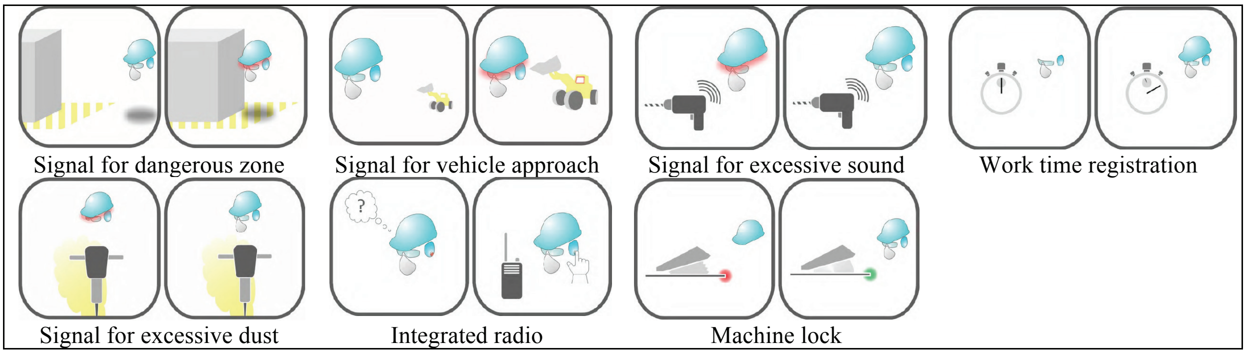

Figure 1. Concepts for added functionalities in safety helmets. (Wanders [8]*)*

In order to reflect these designs with construction site workers, three prototypes (see Figure 2) were built. In these prototypes all concepts were integrated. The functionalities in the prototypes were tested with a wizard of Oz method. 8 construction site workers participated in interviews during a workshop. They took part in a demo wearing the prototypes and reacted to work simulations. Interviews were planned to discuss the prototypes, and were conducted by the succeeding grad student.

Light signal for excessive amount of dust & dust mask

Signal for excessive sound & integrated ear protection

Machine lock (deactivated when wearing helmet), dangerous zone, and approaching vehicle detection

Figure 2. Prototypes with added functionalities

2.2 Usability study for a functional modal

Starting point for the next student project was a usability study to test the concepts of Wanders [8]. This study was conducted in February 2013, with ten construction site workers. These workers got an extra break of 30 minutes during their work to participate in the study. The prototypes were used for a PowerPoint-based simulation with 10 participants. Participants of the study got several assignments, related to workplace safety. The assignments were alternated with pictures of the prototypes. Afterwards a questionnaire was handed out to the participants.

The results of this conducted usability study by Lemmens [10] showed that not all problems found by Wanders were equally relevant. Also, some issues were discovered that were not included in the earlier studies. E.g. Construction site workers tend to bump their heads more often when wearing safety helmets, because of a lack of sense. Most workers indicated that they wore their helmets because it increased their safety, and because it was expected of them. However, part of the workers did not show any intrinsic motivation for wearing the helmet. For example, 1) a helmet was demonstratively thrown onto the ground; 2) a helmet was broken and still not replaced for a new safe one; 3) sun vision protection was sown off, to create better sight. Construction site workers reacted positively on the concept of an integrated smart system. Lighting signals or warning sounds were seen as unusable as they could hardly be seen in daylight or heard on site. Based on the findings during the interviews a new integrated concept was designed (see Figure 3).

Figure 3. Integrated conceptual safety helmet

Lemmens [10] elaborated on the focus of Wanders [8] by stating that feeling safe results in being and doing more safe. More information from literature was gathered to get to know more about safety and motivation. Motivation can be both intrinsic and extrinsic, safety both directly and indirectly, but also has a design component. Designs with a safe appearance might induce a higher motivation. This does not mean it the design is safer as is, but it may add to a safer feeling. For further clarification see Figure 4, based on [10], [11].

Lemmens' concept focused on multiple aspects of the safety helmet mentioned in the earlier studies. In the concept the comfort factor played a huge role. A photo chromatic sunshade was build-in, and in addition a Velcro (inspired) neck strap prevented the helmet from sliding of the head. The second aspect was an early warning system for nearby objects. This warning system used ultrasonic sensors (distance sensing) and vibration motors (like in smartphones) to alert the wearer of nearby objects. In addition, the outside of the helmet is made of soft materials. The soft shell gives the helmet an additional barrier that prevents damage to the hard shell when the wearer bumps his head [12].

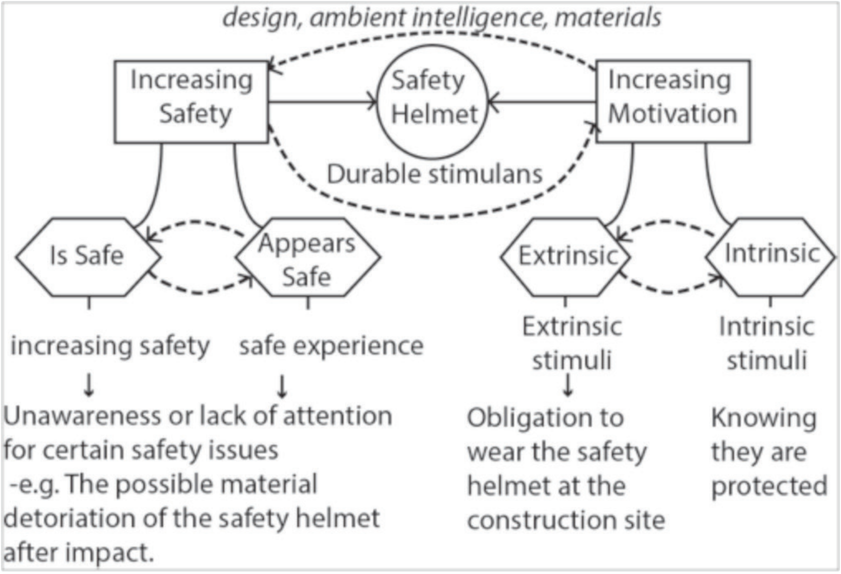

Figure 4. Aspects of motivation and increased safety for safety helmets [11]

2.3 Integrated prototype and usability study

With the design of the integrated conceptual safety helmet of Lemmens [10] a new project was started. Goal of the project was to build a prototype and test it with construction site workers. The project started with a feedback session with construction site workers. The same setup as the previous usability studies was used. A total of 8 construction site workers participated. The project studied specifically in which ways the new design could contribute to the personal motivation of construction site workers to wear the helmet [13]. Two prototypes were made: 1) A functional prototype that encompassed all functionalities from the design, and 2) A sight model that had the look and feel of the design. The design is based on motivational theories such as by Deci & Ryan [14]. Integrating both prototypes into one was not possible because of time and cost constrains.

As a next step, Beldman [13] developed a model to encourage long lasting motivation. Starting point were three kinds of stimuli: 1) internal stimuli (competence, autonomy, and connectedness), 2) autonomous stimuli (values and aspirations), and 3) external stimuli (appreciation). Based on the prototypes and theories, a usability study was conducted. After evaluation of the usability study with construction site workers [13], it appeared that the prototype was appreciated, but not in its current form. Most comments on the design regarded comfort related aspects, which relate to current safety helmets as well (such as heat generation). Other comments regarded the (perceived) heavy weight of the safety helmet and the (un) comfortable fitting of the helmet on the head. Moreover, from a technical point of view, embedding sensors through the shell is possibly not accepted due to strength qualifications. However, a helmet with high comfort and added functionalities can contribute to the intrinsic motivation for wearing the helmet.

Based on these results, first steps were taken to develop a new helmet from a constructive point of view. However, these ideas are still in a preliminary phase.

3 THE PROCESS / REFLECTION

The Safety@Work project enables students to connect education and applied sciences, in order to improve their skills. Researchers coordinating the projects guide the student through several design steps, and force quality control for the series of projects.

For students, it gives them the opportunity to familiarize themselves with companies, applied research, and test their ideas in the real world. A main advantage of using a series projects is the ability to shift according to the developments in the parent project. The approach takes advantage of the availability of students with diverse skillsets, and the embedment of research in their curriculum. A main advantage for the students is that they learn to elaborate on recent, earlier work. Knowing that their work is used immediately for the next phase of the project ensures the quality of their research. For the project it ensures a high probability of succession for the next phase. However the essence of the series is an avoidance of one specific focus throughout all the projects. While the project evolves, the series changes accordingly. Different perspectives of the students can be used in each phase. A drawback of the method used is that research from one student project is not always used in later phases. For example: The first studies looked into the work of Cialdini [4], [6], while later studies completely neglected that knowledge and focused on motivational theories [14].

For researchers, student projects enable them to get more in-depth work done parallel to their own research. The multidisciplinary backgrounds of students add to the variety in outcomes of the project. Beforehand, the end goal of the series was determined as 'the design of a new, modern safety helmet'. The route towards that goal, and the precise final product were not determined. The project was not divided in subprojects focussing on a phase of the production and design process. At the end of each student project result are evaluated, and decision were made for the focus of the next student project. The research line throughout the different projects had an empirical character. Reactions from construction site workers and management staff of construction sites underlie the need for improved and modernised safety helmets.

4 FURTHER WORK

A final and ready-to-market design is still a few steps away. However, a continuation of consecutive student research projects will work towards that goal. During the remainder of the Safety@Work project, there will be a focus on two topics. The first topic is the integration of the sensor system in the helmet with a separately developed sensor shirt. The shirt uses a platform of wireless sensors. The sensors in the helmet could be connected to the same platform to share collected data.

The second topic for further developments is on the used materials in the new helmet design. From the area of smart textiles a study will be conducted that focuses on the used textiles, and the protectiveness of different types of rubber.

For the future we expect a further development of projects in this field, especially in combination with Living Technology program currently developed at our university. New opportunities arise in this because of the program's interdisciplinary approach for research projects.

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