Applying the Behavior Grid for Improving Safety in Industrial Environments

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1 Introduction

The Saxion University of Applied Sciences recently started its "Safety at Work" project. Its objective is to increase safety in the workplace by combining and applying state-of-the-art factors from Ambient Intelligence, Industrial & Product Design and Smart Materials [1].

The human factor plays a significant role in safety. Safety is related to incidents happening to people who get injured or even die. 97% of the cases in which an injury occurs [2] concerns something that happens is within someone's control. Many incidents at work are often the result of human behavior: how people interact with each other, and how people cope with risks and guidelines. Industrial environments need to be organized in such a way that people behave safely in an automatic way and that safety becomes a habit. Encouraging safe behavior starts with safe products. However, in many cases this is not sufficient, and incidents still occur. Therefore, communication is often an effective medium that target people's conscious mind. One cost-effective, asynchronous, and persistent way of communicating with people is through ICT. The approach to changing behavior through ICT is termed Persuasive Technology. We focus on ambient aspects of safety: influencing people in an invisible (unconscious) way so as to make industrial environments safer.

Literature distinguishes between individual aspects of safety (attitudes, individual differences) on one end, and environmental aspects of safety (safety climate, supervision, work design) on the other end [3, 4]. Depending on several factors, like the safety culture of a company, type of workers, and management involvement, these aspects contribute to safe behavior. Looking at these factors, we argue that a right mix of them contributes to improving safe behavior. Hence, our main research question is:

In which ways can people in work environments be influenced to behave more safe, with the use of technology?

2 Model

When listing the previously mentioned factors, two axes are clearly distinguishable: influencing people versus adapting environments, and influencing directly versus influencing indirectly. On the direct side, the mechanisms are more conscious, and task-oriented. And on the indirect side, the mechanisms are more unconscious, and attitude-oriented. However, both sides are not necessarily exclusively targeting the conscious or unconscious mind.

The factors are combined into a model that systematically selects measures to influence behavior, and so improve safety (see figure 1). Currently, the model is a rudimentary framework that still needs to be further developed, which is the focus of our research projects.

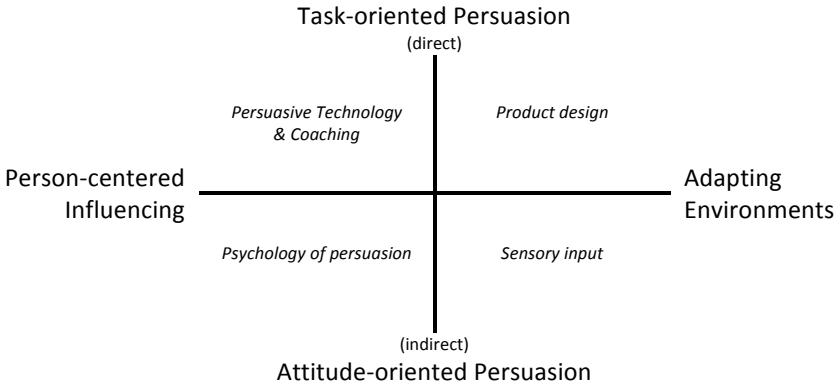

Fig. 1. Framework for Industrial Safety

Based on the rudimentary framework in Fig. 1., we distinguish four quadrants in which behavior can be influenced. Those quadrants are: Task-oriented Persuasion & Person-centered Influencing, Task-oriented Persuasion & Adapting Environments, Attitude-oriented Persuasion & Person-centered Influencing, and Attitude-oriented Persuasion & Adapting Environments. For each of these quadrants, relevant scientific disciplines were studied. In the following paragraphs, we give a brief overview on the state of the art in these disciplines.

2.1 Task-oriented Persuasion & Adapting environments

A safe industrial environment starts with the use of safe products. Product designers know that the safety of a product depends on its physical properties, operation and function, and on how the product is used and perceived by users [4–7]. For example, if doors to an unsafe area are blocked, no accidents can happen there. This concept is well known as CPTED (Crime Prevention Through Environmental Design), or also as safety by design.

2.2 Attitude-oriented Persuasion & Adapting Environments

Research shows that people are often triggered to act based on environmental conditions [8, 9] while operating a product (for example, the environment is noisy or crowded). The environment is closely related to sensory input. Humans perceive the world around them with their eyes, ears, nose, mouth, and skin. Input from the senses is important for their emotional state, and influence their daily decisions.

Neuroscience has shown that we have very little insight into our motivations and, consequently, are poor at predicting our own behavior [10]. It seems emotions are an important predictor of our behavior. Input from our senses is important for our emotional state, and therefore influence our behavior in an invisible way. First, the most trusted-on sense: sight, gives people the ability to perceive (the lack of) light. A high light level positively affects the concentration levels [8, 9] of students. The color of light, and color in general also influence peoples feelings [8, 11–13]. Second, our hearing has two important functions: spatial ability and orientation [14, 15], and an alarm and warning system for dangerous situations.

In respect to safety, all our somatic senses are sensitive to dangerous situation. However, depending on the situation (noisy, filthy, hot, smelly, dark) not all our senses are equally accessible all the time.

2.3 Attitude-oriented Persuasion & Person-centered Influencing

In terms of influencing behavior, we also looked at how other industries try to achieve this. The most promising sector – and that with the published most studies – is marketing psychology. Subconsciously, we have created shortcuts to help us to 'automatically' deal with choices. In his book "Influence, the psychology of persuasion", Robert Cialdini discusses six principles for influencing behavior for marketing purposes [16]. Cialdini states that if we have to think about every decision, life would become impossible because it would take too much time and energy to consciously consider every decision we make. We would quickly become frozen. Therefore, we have created shortcuts to help us to 'automatically' deal with choices.

The principles of Cialdini are general and examples are easy to imagine and apply. 1) Persuade the tough guy in the factory to behave safe and others will conform to his behavior (social proof). 2) A worker may complete a safety checklist before he starts with his work of the day. On the checklist he commits to keeping certain safety related matters in mind. While doing his job that day, he is likely to honor his commitment and to keep safety matters in mind (commitment and consistency).

People use their shortcuts every day to deal with such choices. It is interesting to gain more insight into how we can use such shortcuts to encourage people behave more safely.

2.4 Task-oriented Persuasion & Person-centered Influencing

Beyond invisible influencing of people, ICT can be used to explicitly coach industrial workers [17]. Persuasive Technology is defined as any interactive computing system

designed to change people's attitudes or behaviors. Fogg [18] distinguishes three kinds of persuasive technology. The first kind is Persuasive Technology as a tool. For example, a heart rate monitor is an exercise device that gives an auditory alarm when the user's heart rate falls outside a pre-set range. The second kind is Persuasive Technology as a medium, like a mirror to show how you will look like if you continue with your unhealthy habits. The third kind is Persuasive Technology as a social actor, for example using chatter robots or chat-bots.

2.5 Framework for Industrial Safety

From the previous sections we conclude that so far at least four mechanisms are suitable to influence behavior. Two mechanisms focus on adaptive environments – product design, sensory input – and two focus on the person-centered influencing – psychology of persuasion and persuasive technology. Also, two aim at indirect ways to influence behavior (Cialdini's measures based on marketing psychology, sensory input based on neuropsychology), and two are concerned with the more direct ways to influence behavior (persuasive technology, product design). Depending on several factors, like the safety culture of a company, type of workers, and management involvement. We argue that for every behavioral safety problem, there is an ideal position on these axes to solve the problem.

Studies conducted by the Captology group at Stanford [18] show that when you want to change behavior, it is necessary to specify the duration of the required behavior change (once only, span of time, or on-going), and the type of change (flavor) you want to accomplish. By flavor, we mean whether new behavior is introduced, or if familiar behavior is maintained, increased, decreased, or stopped.

As we need the to know the direction and duration of the intended behavior change, we use Fogg's Behavior grid to determine the intervention for the behavioral safety problem.

3 Expected Results

Now that our understanding of behavior change is formed into framework, the next step is to see how – and in which direction – to change behavior. For each behavioral safety problem, we want to assess which of the quadrants in the framework is most suitable, depending on previously mentioned factors, like safety culture, type of workers, and management involvement.

Based on literature, interviews, and experiments, validation of the model will be effectuated. Hence, for influencing safe behavior in industrial environments, our model consist of a further development of Fogg's Behavior Grid [19–23]. We aim towards a workable toolset to improve safety at workplaces, usable by both practitioners and academics. The toolset gives suggestions on how to target a behavior problem, depending on the location of the problem in the framework.

4 Future work

The foundation of our framework is described in the literature from several relevant disciplines. Currently, experiments are being conducted to start validation of the framework. Therefore we encourage research into this field that will form a bridge between academics, organizations from the industry, and education.

A deeper understanding of the way we can address human senses in industrial environments is needed. Because of the nature of this industry, the opportunities for reaching and triggering senses will be limited. From this point of view, an observation study will be conducted to achieve a good overview of the opportunities for triggering human senses – and the limits.

Furthermore, we need to come up with experiments for interventions that fill our framework. These experiments will be conducted in real life settings.

The first experiment, planned for the winter of 2012-2013, focuses on one-time behavior change. When walking into or out of a building, people have the habit to consequently take a same entrance or exit. These habits are changeable by using light/dark or red/green conditions (sensory input), changing the environment, and using authoritative figures. New habits will stay active in the sub-consciousness for an extended time after the intervention. Such new habits can be used to evacuate a building more efficiently, for example in the event of fire. During this experiment all visitors of an office will be counted with camera-systems, and lightning and environmental conditions are varied between entrances. Our hypothesis is that lightning and environmental conditions can change how people enter and exit buildings.

With the second set of experiments, we try to answer the question of how we can persuade constructions site workers to clean up their workplaces. Wandering dirt at construction sites is a high-risk factor for accidents. These experiments are set-up at a large construction site in the Netherlands, and are based on interviews held with construction site workers. From the interviews, a list of 20 factors regarding safety problems has been gathered. The factors were used as input for a brainstorm session, which resulted in several intervention possibilities. One of these interventions is a SMS safety awareness game. Participants in this game receive a daily SMS with a specific question (How many time did you throw something in the dust-bin? How many times did you take off you helmet? Did you end up in a dangerous situation?) Answers are saved to a database, and anonymously returned to users with photo frames at their workplaces.

A third experiment, currently being conducted in a machine factory, looks into the differences between light, smell, and sound effects on stress and fatigue. Stress and fatigue are huge contributors to accidents at workplaces. During the experiment, participants are exposed to different flavors, lightning conditions and music, while their heartbeat is being monitored. In addition, 3 times a day, participants fill in a questionnaire in which they indicate their level of stress and fatigue. The next step in this experiment is to expose participants to these conditions, only when their heartbeat rises to a critical level. In this way participants get feedback during their workday.

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