Persuasive assistance for safe behaviour in human-robot collaboration

Matthias Hartwig, Vanessa Budde, Alissa Platte, & Sascha Wischniewski
Federal Institute for Occupational Safety and Health
Germany

Abstract

In a working context, conflicts between working safe and working fast can lead to deliberate violations of safety rules. Modern computer-human interfaces can create new opportunities to reduce these violations by influencing the user. Technologies deliberately used to influence attitudes and/or behaviour of users are called persuasive technologies and often make use of nudging strategies. In a randomized experiment, 90 participants had the task to collaborate with an industrial robot in a conflict between meeting the safety instructions and monetary incentives for working fast. An intervention group received emotional computer generated feedback on their safety behaviour, while a control group did not. Violations committed by the participant during and after the intervention were measured as well as intention towards the safety behaviour. Results show that participants receiving feedback on their behaviour committed only half as many violations as participants in the control group, a tendency that was also visible after the intervention ceased. Interestingly, subjective behaviour intention was nearly identical between the groups, which hint to a less deliberate form of behaviour impact of the feedback. Results suggest considering nudges as complementary action to promote safe behaviour at work besides giving information and penalising.

Introduction

Concerning occupational safety and health, there is a gap between extensive knowledge about hazards, regulations to minimize these and their implementation in operational practice. One level, where safety regulations are to be applied, is the individual level, where the reasons for safety violations are divergent.

Reason (2008) classifies "unsafe acts" in unintentional errors, like slips and mistakes, and intentional violations, which are based on a conscious decision to act against the regulation. These conscious deviations often pose an especially high risk, because they commonly form a habit and will most likely be repeated in every similar situation.

In D. de Waard, F. Di Nocera, D. Coelho, J. Edworthy, K. Brookhuis, F. Ferlazzo, T. Franke, and A. Toffetti (Eds.) (2018). Proceedings of the Human Factors and Ergonomics Society Europe Chapter 2017 Annual Conference. ISSN 2333-4959 (online). Available from http://hfes-europe.org

Modern man-machine systems, especially in the area of man-robot interaction, create an increasing degree of direct collaboration with interlocking working steps between user and machine. Therefore, on the one hand these interfaces evoke new demands for safe individual behaviour, while on the other hand they may have the potential to provide assistance by facilitating safe behaviour.

The second aspect is especially true for those oriented to the technology vision of ambient intelligence, characterized by Aarts and De Buyter (2009) by the central features of context awareness, personalization, adaptive behaviour and anticipation. In a working environment, these systems are called adaptive work assisting systems (AWAS; Windel & Hartwig, 2012). These features possibly enable the system to reduce violations by (1) being aware of the behaviour of the user, (2) evaluating it autonomously regarding violations and (3) presenting evaluative feedback or reminder that change the user’s behaviour. Such computer interfaces, purposely designed to change the behaviour of the user, can be subsumed under the term persuasive technology (Fogg, 2002).

Persuasive technology is a technology-based form of nudging. This concept by Thaler and Sunstein (2009) encompasses any form of choice architecture that changes the behaviour of a person in a predictable way without forcing choice or economic incentives. The concept relies on the assumption that human decision-making is influenced by cognitive biases based on cognitive boundaries, routines and habits. Nudges use these mechanisms to influence decisions in an intended direction (Hansen, Skov, & Skov, 2016).

In a predecessor study on work assistance systems (Hartwig & Windel, 2013), a manually triggered anthropomorphic agent was proved to be effective to influence user’s behaviour, using different emotional facial expressions. In the present study, the same virtual agent is implemented in a work assistance system to autonomously improve individual safety behaviour in a man-robot-collaboration setting. To gain insights into the best form of assistance, different types of persuasive strategies were applied: persuasive feedback that reacts to the participants’ behaviour and a persuasive reminder that occurs at the moment the target behaviour becomes relevant. Therefore, we first hypothisized these forms of persuasive interventions to reduce safety violations when working in a man-robot interaction simulation compared to a control group that receives no persuasive assistance. Furthermore, the study aims at identifying the psychological mechanisms of the intended behaviour changes by investigating attitude towards behaviour and subjective social norm concerning the safety behaviour as two key sources for behaviour decisions in the theory of planned behaviour (TPB; Ajzen, 1991).

Method

The study sample included 90 participants, 45 men and 45 women. The participants were on average 24.5 (SD = 3.33, range 20-34 years) years old at the time of the investigation. All participants were students, recruited at nearby universities. In a randomized experiment the work task to assemble circuits in collaboration with an industrial robot was given to all participants. This task required the positioning of empty plug boards and the corresponding components in specific holders (Figure 1).

Afterwards, the participants started the robot, which autonomously connected the individual parts and then tested the assembled electric circuit for operability. This procedure was repeated 14 times, assembling one operational plug board each.

The behaviour of the participants during the working phase of the robot was the primary dependent variable. All subjects were instructed to wait after starting the robot until it finished the assembling and the testing. Then the participants received a safety clearance message and are allowed to proceed with the next plug board.

Figure 1. Participant placing the components.

Working within the robots reach prior to the security clearance is recorded by a light barrier installed in the workplace and counted as a safety violation. The recording is done unnoticed by the participants. The instruction explains this working sequence as a necessary safety procedure to avoid collisions with the moving robot. In fact, the implemented work system is designed for direct collaboration with the user, so there is no actual threat, regardless of the participant's behaviour. However, constituting a credible threat in the experimental setup is crucial to simulate a realistic decision for or against safety behaviour. To simulate the surrounding that often leads to safety violations in operational practice, a financial bonus of €10 for fast task completion is promised the participants.

Since violating the waiting process and prematurely working on the subsequent board was speeding up the working task substantially, a conflict between profitable and safe behaviour was created, as it exists in operational practice as well. Participant's safety behaviour as the primary dependent variable was measured by recording the number of plug boards on which safety violations were committed. Safety violations were operationalised as reaching into the work area of the robot before the safety clearance. This action was recorded automatically by a laser barrier installed in the experimental set-up.

Participants were able to commit safety violations on all 14 plug boards at most. Furthermore, the variables "Attitude towards Behaviour" and "Perceived Social Norm" were measured as two of the deterministic antecedents for behaviour according to the TPB to gain first insights into the psychological mechanisms of behaviour change. A questionnaire was created according to Ajzen's (2002) guidelines, the wording of the items matching the specific behaviour.

As independent variables, the participants received different interactive assistant systems that should animate them to wait for the safety clearance. The control group worked on the task without any assisting system. The group "Reminder" was reminded by an anthropomorphic virtual agent (see Figure 2) to wait for safety clearance each time they start the robot. In the group "Feedback" the same agent giving negative feedback was presented every time the participant worked prior to the security clearance of the active robot. In addition, positive feedback was presented to participants after the fourth and tenth plug board, if they had not committed any violation until that point. Positive Feedback was given by the same virtual agent, showing a friendly emotion, underlined by an affirmative text message "Very good! You complied with the safety clearance."

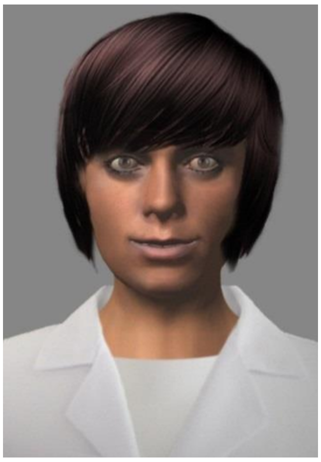

Figure 2. Anthropomorphic agent.

Results

The first hypothesis assumed a difference in the number of safety violations/premature intrusions between the different experimental conditions. Figure 3 shows the mean number of boards in which safety violations were committed. The mean value in the "Feedback" condition was $M = 2.69$ ($SD = 3.17$), in the "Reminder" condition $M = 4.71$ ($SD = 5.65$) and in the "Control Group" $M = 4.91$ ($SD = 5.12$) violations. The results of the one-factorial analysis of variance showed no significant differences between the number of boards with violations and the experimental groups $F(2, 65) = 1.59$ $p > .05$. Therefore, Hypothesis 1 was declined.

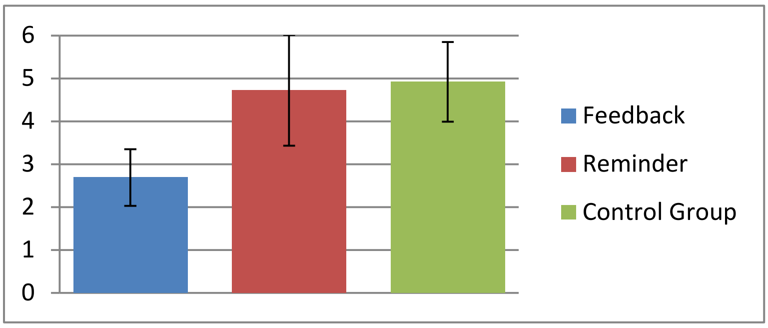

Figure 3. Number of violations in the different groups. Error bars reflect Standard Error of the mean.

Hypothesis 2 investigated differences between the experimental groups concerning the attitude and perceived social norm towards the safety behaviour. The average attitude towards safety behaviour of the feedback group was M = 17.13 (SD = 4.19), of the reminder group M = 19.86 (SD = 3.84) and of the control group M = 16.96 (SD = 4.42), see Figure 4.

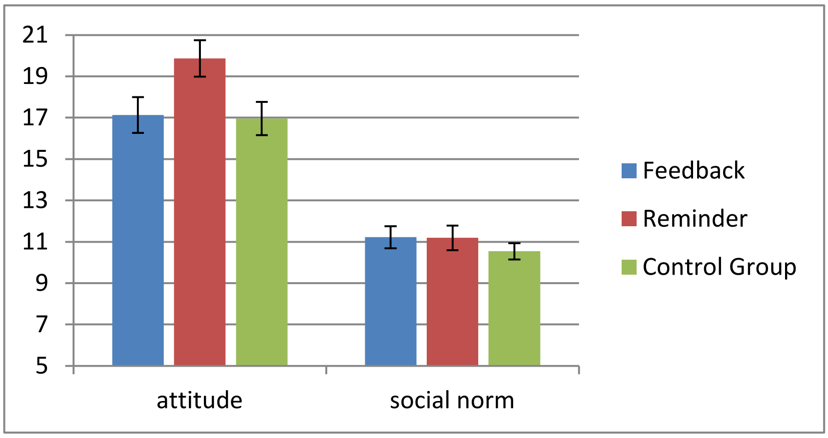

Figure 4. Average attitude and social norm towards safety behaviour. Error bars reflect Standard Error of the mean.

With regard to social norm towards safety behaviour, average score of the feedback group was M = 11.22 (SD = 2.52), of the reminder group M = 11.19 (SD = 2.62) and of the control group M = 10.54 (SD = 2.12).

To examine this hypothesis, two one-way analyses of variance were performed. The results show there was no significant difference between the three tested experimental groups with regard to the setting concerning attitude towards behaviour $F(2, 65) = .04$, $p > .05$ and concerning social norm $F(2, 65) = .58$, $p > .05$. Thus, hypothesis 2 showed no differences between the experimental groups regarding attitude towards safety behaviour or corresponding social norms.

Discussion

The presented experiment investigated the effects of different persuasive techniques on safety behaviour and subjective attitudes. The results show a substantially higher number of violations in the control group than in the two intervention groups where behaviour was assisted by different persuasive strategies. However, the statistical inference shows no significant result of the Anova concerning the safety violations, which indicates that the treatment had no effect on participant's behaviour. This result is in contrast to a predecessor study (Hartwig & Windel, 2013) and therefore hints more at a failure of the experimental setup rather than an overall ineffectiveness of the persuasive strategies which were used in both studies. Finally, there is also a probability of an existing systematic difference between the groups that the anova failed to detect (2nd type error), which is here neglected for the benefit of conservative hypothesis testing.

The different results of the two studies may partly be caused by the different test setting including a more realistic working task and the industrial robot. Looking at the absolute numbers, even the control group committed only a third of all possible safety violations, creating a ceiling effect. The low number of violations might be caused by the participants' unfamiliarity with industrial robots, resulting in a quite cautious behaviour. This could have been counteracted by a more intense training or recruiting participants experienced in working with robots. This, however, was not possible without exposing the cover story, as even moderate expertise in working with collaborative robots would reveal that there was no real danger because of the robot's integrated safety measures. Regarding future studies, the conflict between safe behaviour and the incentive for quick work should therefore be intensified by realistic conditions regarding the time constraints in everyday work, causing less cautious behaviour and more safety violations without the persuasive intervention.

A surprising finding is the discrepancy between the subjective personal perceptions towards safety behaviour and the actual behaviour. The numerical lowest violations occur in the feedback group, while the most positive attitude towards the behaviour is measured in the reminder group. Our initial assumption was that the persuasive techniques would change the subjective attitude and social norm, which in turn leads to less safety violations, but the data show no indication for this causal chain. The psychological mechanisms remain unknown for the time; subsequent studies should therefore put great attention to the psychological mechanisms that cause the intended behaviour change. Only by understanding why persuasive technology works, it will be possible to identify potential applications and limits of persuasive assistance systems that may contribute in safer behaviour at work.

References

Aarts, E., & De Buyter, B. (2009). New research perspectives on Ambient Intelligence. *Environments, 1*, 5-14.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179–211.

Ajzen, I. (2002). *Constructing a TPB questionnaire: Conceptual and methodological considerations.* (Working Paper). Amherst: University of Massachusetts. (available online at
http://www-unix.oit.umass.edu/~aizen/pdf/tpb.measurement.pdf).

Fogg, B. J. (1998). Persuasive computers: perspectives and research directions. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 225-232). New York, USA: ACM Press/Addison-Wesley Publishing Co.

Fogg, B.J. (2002). Persuasive technology: using computers to change what we think and do. *Ubiquity, 2002 (December),* 5.

Hansen, P. G., Skov, L. R., & Skov, K. L. (2016). Making healthy choices easier: regulation versus nudging. *Annual review of public health*, *37*, 237-251.

Hartwig, M., & Windel, A. (2013). Safety and health at work through persuasive assistance systems. In V.G. Duffy (Ed.) *Digital Human Modeling and Applications in Health, Safety, Ergonomics, and Risk Management. Human Body Modeling and Ergonomics (*pp. 40-49). Heidelberg, Germany: Springer.

Reason, J.T. (2008). *The Human Contribution. Unsafe Acts, Accidents and Heroic Recoveries*. Farnham, UK: Ashgate Publishing.

Thaler, R. H., & C. R. Sunstein (2009). *Nudge: Improving Decisions About Health, Wealth, and Happiness*. London, UK: Penguin.

Windel, A., & Hartwig, M. (2012). New Forms of Work Assistance by Ambient Intelligence. In F. Paternò, B. de Ruyter, P. Markopoulos, C. Santoro, E. van Loenen, and K. Luyten (Eds.) *Ambient Intelligence* (pp. 348-355). Heidelberg Germany: Springer.