Reducing Anxiety while Interacting with Industrial Robots

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ABSTRACT
Studies in the field of human-robot collaboration have shown that the direct cooperation of humans and robots can lead to increased anxiety feelings of workers. Previous studies realize either a collaboration with lightweight robots or a temporal and spatial separation of humans and robots. We use a robot with a load capacity greater than 200 kg with a temporal and spatial overlap of the working areas. Three different prototypes for Google Glass render the current state of the system in the form of text, icons or a traffic light. The evaluation in a comparative field study shows that when using any of the three prototypes, the perceived state anxiety is low.

Author Keywords
human-robot collaboration; head mounted displays; trust;

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous; H.1.2 Models and Priciples: User/Machine Systems

INTRODUCTION
The working areas of robots and humans are physically and temporally strictly separated from each other for safety reasons. Protective fences or light fences reliably prevent violation of the protected area during the robot's automatic mode. Any intrusion in today's production lines results in an immediate emergency stop of the robot and subsequently, if necessary, of an entire production line. Because of new variants of human-robot collaboration, the aim is to merge the workplaces of humans and robots. Recent studies, introduced in the next section, have shown that this can have a negative impact on the human. The proximity to the robot produces a subjectively higher workload reflected in the form of stress and anxiety. Our work deals with the question of whether the use of head mounted displays (HMD) can possibly reduce this fear and lower the workload through targeted information delivery. In a field study, we evaluated three prototypes against each other to work out whether the subjects could experience a reduced workload during the collaboration when using a Head-Mounted display.

RELATED WORK
Currently breaking this barrier between humans and robots for direct cooperation (human-robot collaboration) is a matter of research driven by the manufacturing industry ([5], [3]). The international standard of ISO 10218 [2] suggests that there are four different types of human-robot collaboration: Safety Monitored Stop, Hand Guiding, Speed and Separation Monitoring, Power and Force Limiting. Naber et al. [6] have shown that performance and risk cognition of a worker depends on the speed of the robot and distance to it. Furthermore the size and speed of a robot have influence on the perception of subjective occupational safety of people [7] and robots moving physically close to humans have an influence on the mental stress of workers according to Arai et al. [1]. They recommend informing the worker about movements of the robot in their vicinity.

EXPERIMENTAL METHODOLOGY
In a field study, we realized the human robot collaboration according to the principle of separation speed and monitoring. By retrieving and evaluating the context information in real time human-robot collaboration was implemented. The system localizes the worker within the work cell using laser scanners and retrieves position data of the robot through a robot interface.
For the field study, we simulate an assembly task of a heavy car engine as taken from a real use case. The robot grasps an engine block and presents it to the worker. The worker inserts four pairs of screws. Afterwards the robot proceeds with its program. In the meantime the worker assembles an oil pan outside the reach of the robot. In between the tasks, the worker can rest.
Our system continously informs the worker about his next task. The resulting action we display on the HMD. This has several advantages over conventional techniques such as acoustics or displays for two reasons: (1) The use of acoustic warnings continuously informing the worker is impractical due to the noisy environment. (2) Stationary erected traffic lights or monitors are as well not suited, because the worker is not working on a fixed position.
We developed three user interfaces for the presentation of work instructions. One interface is based on text, one is based

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Figure 1. Icon-based interface

traffic light symbols and the third is based on icons (see figure 1) representing the current state of the system. The first state stands for the execution of the activity within the robot's reach with the robot halting in secured position. The second state indicates that the worker has to carry out an unsupervised activity outside of the robot's reach. The third state directs the worker to leave the danger zone of the robot.

In a field study, we evaluated the three different user interfaces using a "within subjects" set-up for a direct comparison. For testing we recruited 12 subjects (2 females and 10 male) between 20 and 35 years of age. Each of the three user interfaces the subjects used in sequence. With the STAI questionnaire [4], we determined the State and Trait Anxiety.

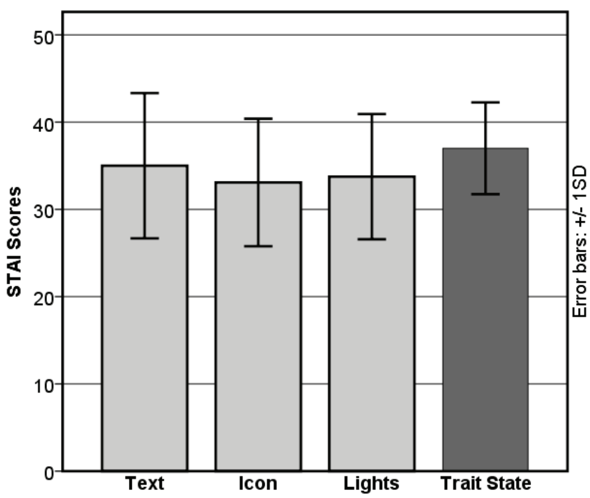

Figure 2. STAI

RESULTS AND ANALYSIS

Generally, all subjects have become accustomed to the use of the various prototypes and they could use them correctly without problems. The focus was mostly on the secured activities. During the study the subjects concentrated not only on the instructions on the HMD but often took the current position or motion of the robot as a visual guide. Consequently, a total of 17 times the subjects started the unsupervised activity too early.

The values determined with regard to the perceived state anxiety were between 21 and 53. Figure 2 shows the average values sorted by prototype (Text: 35.00, SD = 8.32; Icon: 33.08, SD = 7.30; Lights: 33.75, SD = 7.17). In addition, the anxiety as a personality trait we applied here (trait anxiety: 37.00, SD: 5.26). Regarding the anxiety as a personality trait, a similar image as in the anxiety states arises: the values range from 30 to 47. Generally, one should note that the anxiety state was low independent of the used prototype. In a direct comparison between state anxiety and anxiety as a personality trait, we found no abnormalities. A one-way analysis of variance with repeated measures ($F_{2;22} = 3.797$, $p = 0.019$) shows statistical significance. Sidak-corrected pairwise analysis confirms significant differences for comparing the icon-based interface and the anxiety as a personal trait ($p = 0.027$).

DISCUSSION AN FUTURE WORK

We presented an evaluation of three prototypical implementations on a Google Glass, supposed to reduce anxiety in human-robot collaboration at the workplace. In a field study, we compared icon-, text-, and light-based prototypes. We could show that the state anxiety of the worker does not increase regardless of the used interface prototype. Overall, the results and the statistical analysis suggest the icon-based system is favored over the other prototypes. Future work may include extensions of the user interface such as displaying a countdown. It is also possible to take further advantage of additional context information, e.g. visually informing the operator of the next steps in the robot program.

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