Tablet-Based Augmented Reality in the Factory: Influence of Knowledge in Computer Programming on Robot Teaching Tasks

Kevin Kain, Susanne Stadler, Manuel Giuliani,
Nicole Mirnig, Gerald Stollnberger, Manfred Tscheligi
Center for Human-Computer Interaction, Christian Doppler Laboratory "Contextual Interfaces"
Department of Computer Science, University of Salzburg
Sigmund-Haffner-Gasse 18, 5020 Salzburg, Austria
firstname.lastname@sbg.ac.at

ABSTRACT

We investigate whether a user's background in computer programming has an influence on user's mental workload, when using a tablet-based augmented reality robot control interface that visualizes task-based information. For this purpose we conducted a user study, in which participants solved multiple robot control tasks. In the study, the users had to control a Sphero robot ball with the help of a tablet-based augmented reality (AR) interface. The AR interface was used to show task instructions to the user. The results of the study show that users with computer programming background had a higher effort and also report a higher frustration when using the AR interface. Additionally, they rate the usability of the AR interface as "ok", in comparison to naïve users without programming background, who gave it a "good" rating. These results suggest that users with a computer programming background need an AR interface that visualizes more technical information.

Keywords

augmented reality; workload analysis; robot teaching

1. INTRODUCTION

There is a trend in robotics industry that more and more non-professionals are programming robots, for example employees of small and medium-sized enterprises. For effective robot programming, the programmer needs to have the right information, for example the points and paths on which the robot should move along. This information can be quite complex. One way to convey this complex information to unexperienced users is to show it in augmented reality-based (AR) interfaces. When using an AR interface for robot programming, we have to consider that the users have other pre-experiences, that might influence the user experience when using the interface. For example, Davis [2] found that computer programming experience and object-oriented experience can have a positive influence on robot programming.

Therefore, we investigate the influence of a user's background in computer programming experience, while controlling a robot and being supported by an AR interface. We conducted a study, in which naïve users and users with computer programming knowledge had to control a robot with and without support of the AR interface. We measured and analyzed the workload of the users and their rating of the usability of the interface.

HRI '17 Companion March 06-09, 2017, Vienna, Austria

ACM ISBN 978-1-4503-4885-0/17/03...$15.00

DOI: http://dx.doi.org/10.1145/3029798.3038347

Figure 1: Sphero robot ball and testbed

2. EXPERIMENT DESCRIPTION

In our study, users controlled a Sphero robot ball and had to solve three tasks. These tasks were either supported by an AR interface or a paper-based plan This section describes the study setup, procedure, participants and results.

2.1 Study Setup

The hardware for the study setup consisted of a tablet, a Sphero robot ball, and a 1×1 meter testbed. The participants used the tablet to control the robot and to display information. Fig. 1 shows the robot ball and the testbed. For the AR interface, we used a tablet-based (see-through and robot control) AR approach. The whole scenery was shown from the point of view of the hand-held device, and not that of the user (as when wearing AR glasses). A similar study setup was presented by Stadler et al. [5].

2.2 Study Procedure

The study was split in five parts. First, the users got a briefing about the purpose of the study. After that, they filled out an informed consent and a demographic questionnaire. Second, the user had to take a training session. In this session the user had to control the Sphero in three exercises. These three exercises consisted of linear and circular movements on the testbed. The goal of the training session was to give the user a feeling for the basic movements and control over the Sphero. Third, the users had to execute three robot control tasks. During task execution, the participant either got information about the task over the AR interface (condition with-AR) or on a sheet of paper (condition no-AR). All participants experienced both conditions. The order in which they experienced both conditions was randomized. The three tasks were called "TCP", "Trajectory" and "Overlap" teaching. These tasks are derived from typical industrial robot teaching tasks. Fig. 2 shows how the tasks instructions were displayed on the AR interface and on the paper sheet.

The three tasks are described in the following paragraph. *TCP teaching*: The user had to control the Sphero into a shape from given multiple directions, stop in the middle of the shape and then drive outside the shape on the opposite side. *Trajectory teaching*: The user had to control the Sphero along a linear movement pattern over five points. *Overlap teaching*: The user had to control the Sphero from one point to another, by driving an arc. A third point worked as indicator for errors as well as a help for driving the arc.

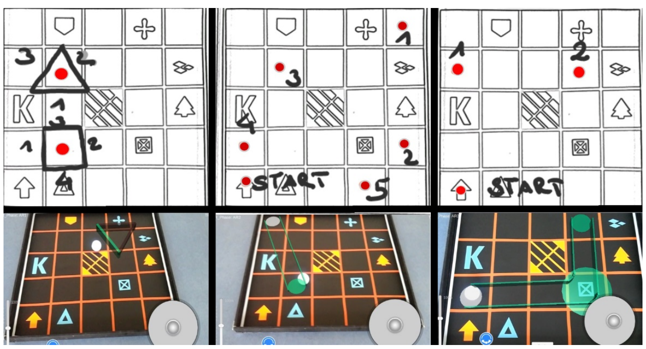

Figure 2: Tasks, the users had to execute. TCP, Trajectory, and Overlap teaching. Top: instructions on paper, bottom: instructions in AR interface

After each of the three major task sessions (training, with-AR, no-AR), the participants had to fill out the SUS and NASA-RTLX questionnaires (Both will be explained in the results section). At the end of the study, we interviewed the users about their experience with the AR interface in a semi-structured interview.

2.3 Participants

In total 20 people aged between 22 and 54 years (M=30.75, SD=10.47) participated in the study. The selection was skill-balanced (10 expert, 10 naïve users) within the experimental condition augmented reality support (with-AR, no-AR). Skill-balanced in this context means, participants were either classified as programmers or as naïve participants. This classification was based on a self-assessment questionnaire, filled out by the users, at the beginning of the study. We refer to participants with beginner level or without computer programming knowledge as naïve participants. All 20 participants had no experience in teaching or programming robots, this was confirmed by the demographic data we collected beforehand.

2.4 Results

We measured the workload of the participants immediately after each session, using the NASA-RTLX questionnaire [3]. The results show that programmers (M=79.00, SD=19.41) had a significant higher effort than naïve participants (M=51.50, SD=30.37) p =0.044, r =0.45. Programmers (M=55.50, SD=25.76) also showed a significant higher frustration than naïve participants (M=31.50, SD=16.00) p =0.044, r =0.45. Significance was determined using the Wilcoxon signed rank test.

The SUS questionnaire consists of ten items that measure the usability of a system. The users had to give a subjective score between one (worst) and five (best). To analyze the system usability score we interpreted the score based on the adjective rating scale by Bangor [1]. Programmers (M=68.50, SD=18.23) therefore rated the system between ok and good while naïve participants (M=73.88, SD=13.56) rated the system between good and excellent. The results are not significantly different, which was again computed by Wilcoxon signed rank test.

3. CONCLUSION AND FUTURE WORK

The results of the NASA-RTLX questionnaire indicate that programmers had a higher workload than naïve user when using our AR interface. We believe that this result might be based on the way the interface displayed information. Our AR interface showed a graphical presentation of the task instruction (see Fig. 2) without any technical details. According to the expertise reversal effect [4], programmers would probably prefer to have an interface that shows precise technical information. The positive results of the SUS questionnaire indicate that the usability of the system was good. The results of naïve users are higher than the programmer's results.

In the interview after the study, 19 of 20 participants reported that they would in general use an AR-based interface to control robots. In a future study we will test augmented reality with end users that have robot programming experience. This study will also make use of an industrial robot instead of the Sphero robot.

4. REFERENCES

[1] A. Bangor, P. Kortum, and J. Miller. Determining what individual sus scores mean: Adding an adjective rating scale. *Journal of usability studies*, 4(3):114–123, 2009.

[2] S. P. Davies, D. J. Gilmore, and T. R. Green. Are objects that important? effects of expertise and familiarity on classification of object-oriented code. *Human–Computer Interaction*, 10(2-3):227–248, 1995.

[3] S. G. Hart. NASA-Task Load Index (NASA-TLX); 20 years later. In *In Proceedings of the Human Factors and Ergonomics Society*, pages 904–908, 2006.

[4] S. Kalyuga, P. Ayres, P. Chandler, and J. Sweller. The expertise reversal effect. *Educational Psychologist*, 38(1):23–31, 2003.

[5] S. Stadler, K. Kain, M. Giuliani, N. Mirnig, G. Stollnberger, and M. Tscheligi. Augmented reality for industrial robot programmers: Workload analysis for task-based, augmented reality-supported robot control. In *Proceedings of the IEEE International Symposium on Robot and Human Interactive Communication, RO-MAN '16*, 2016.