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Graphical Signage Decreases Negative Attitudes towards Robots and Robot Anxiety in Human-Robot Co-working

Abstract. To achieve full potential of collaborative robots, human operators need confidence in robotic co-worker technologies and their capacities. We compare the impact of dynamic signage with static signage on the human-robot collaboration task performance. The results provide evidence that dynamic signage participants had higher accuracy rates compared to static signage ones. Furthermore, dynamic signage resulted in a significant decrease of NARS scores and static signage in a decrease of RAS scores after the interaction with the robot.

Keywords: Human–Robot Collaboration · Static and Dynamic Graphical Signage · Negative Attitudes towards Robots · Robot Anxiety Scale · Manufacturing · Efficiency

Introduction

The UK's manufacturing sector is the 8th largest in the world. It accounts for 44% of UK exports, contributes 10% to GVA, and employs 2.6m people[1], yet the sector is poised to undergo considerable change with Industry 4.0. One of the biggest changes will be to automation, with emergence of collaborative robotics [1], which will transform the way people work with machines. To be successfully integrated, this new technology will have to gain trust and acceptance of the human workforce.

Industrial robots, although not a new phenomenon, can still feel threatening to human workers, which can lead to higher stress levels [2, 3]. This is of particular significance to collaborative robots where workers will be required to work with, and around, active uncaged robots. Acceptance and trust have both been identified by industry partners as major challenges facing deployment of collaborative robots, and the issues are exacerbated if users feel they do not have enough information or training on the technology. Effective information communication can aid human–robot interaction, graphical signage, in particular, has benefits for manufacturing including: not requiring individuals to have prior experience in signage [4, 5], being language invariant [6], not being impeded by noisy environments, and reducing cognitive load [7].

Previous results from the studies conducted by our lab show that the presence of signage can increase efficiency and participant well-being [8–10]. In this paper we present preliminary results comparing the effects of static and dynamic signage on participants' negative attitudes and anxiety towards robots.

Methods

Participants and graphical signage. The current analysis concerns two groups of participants: The first group of participants (University of Sheffield students and staff (N = 30)) were presented with static signage developed in accordance to ISO conventions [11]. The signs illustrated human–robot interaction events, such as the force required to manually manipulate the robot, and the robot's speed. The second group, containing shop-floor workers from an industrial partner (N = 20), were presented with screen-based dynamic graphical signage, which had been refined from the static signage during co-creation workshops with a separate group of industry employees. This signage provided real-time information about robot operational processes, i.e. when to manually manipulate the robot and when not to touch it. The work was approved by the University of Sheffield Ethics Committee.

Procedure, task and measures. Static signage trials were conducted in a laboratory setting designed to resemble an industrial work cell, whilst dynamic signage trials were conducted in a factory environment. The procedure and task for both groups were identical.

Prior to the task, participants signed a consent form, and filled in: a questionnaire measuring their demographic information, a sub-scale measuring anxiety towards the behavioural characteristics of robots from the Robot Anxiety Scale (RAS, [12]), and a subscale of attitudes towards interaction with robots from the Negative Attitudes towards Robots Scale (NARS, [13]). Participants then interacted with a robot on a collaborative task. The task consisted of 16 narrow tubes positioned vertically on a workbench, with 6 containing M5 bolts. The tubes were too narrow to extract bolts by hand, instead requiring use of the robot

[1] www.eef.org.uk/ukmfgfacts

(a KUKA LBR iiwa 7 R800) with an attached magnetic probe. The robot had been pre-programmed with the location of the tubes, but had no means of sensing the locations of the 6 bolts. Therefore, in order to complete the task, participants needed to co-work with the robot by manually positioning the end effector near a tube containing a bolt; the robot would then refine its position, based on the closest tube position, and extract the bolt. Participants were provided with no other verbal information on the robot's operational abilities, and their accuracy (collected bolts/number of trials) was measured during the interaction with the robot. After having completed the task (or after 10 minutes if not) participants once again filled in RAS and NARS scales. The whole experiment lasted around 30 minutes.

Results

To compare whether static and dynamic signage affects participants' accuracy differently, independent t-test were performed. Participants with dynamic signage had a higher accuracy rate compared to those with static signage, $t(96.7) = 2.48$, $p = .015$, Fig 1 A.

Further analysis investigated the effects of the two types of signage on the attitudes (NARS) and anxiety towards robots (RAS). The change in the NARS and RAS scores were calculated by subtracting pre-interaction from post-interaction scores.

Moderated regression with an outcome of NARS Change, predictor of Accuracy, and moderator of Signage (dynamic vs. static) showed that this model was significant in predicting NARS Change ($F(3, 47) = 3.90$, $p = .014$, $R^2 = .20$). Examination of moderators showed a significant effect of interaction NARS Change by Accuracy for dynamic signage ($t = -2.76$, $p = .008$, $b = -7.77$; Fig 1 B). The same interaction with static signage was not significant ($t = -1.71$, $p = .094$, $b = -2.87$). Further analysis with a predictor of Accuracy, outcome RAS Change, and moderator of Signage showed the model was approaching significance ($F(3, 47) = 2.70$, $p = .056$, $R^2 = .15$). Static signage as a moderator showed a significant interaction of RAS Change by Accuracy ($t = -2.69$, $p = .010$, $b = -6.22$; Fig 1 C) while with dynamic signage RAS Change was not affected by the Accuracy ($t = -0.91$, $p = .366$, $b = -3.54$).

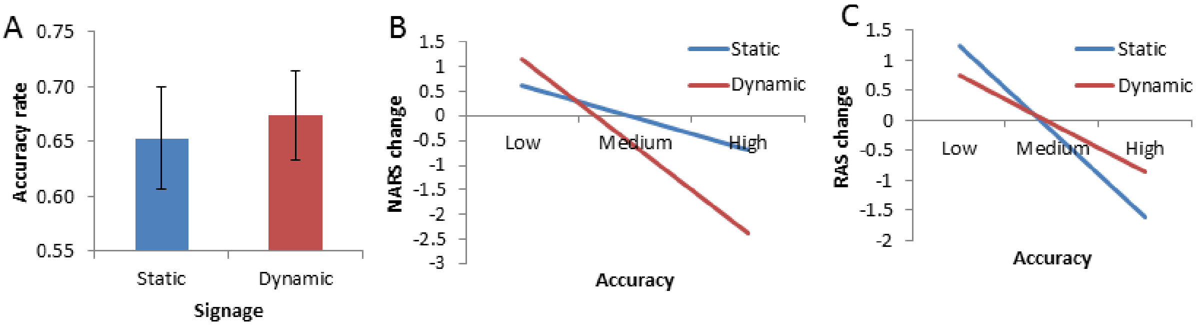

Figure 1: (A) Accuracy rates in static signage and dynamic signage participant groups; (B) Change in Negative Attitudes towards Robots (NARS) scores as a function of Accuracy moderated by the Signage; (C) Change in Robots Anxiety Scale (RAS) scores as a function of Accuracy moderated by the Signage.

Discussion

This work investigated the differences between static and dynamic graphical signage on participants' negative attitudes and anxiety towards robots in a collaborative task. The findings suggest that participants presented with dynamic signage had higher accuracy rates compared to those with static signage. This can be explained by the dynamic signage providing real-time information about the process (such as when manual or autonomous modes are active). Furthermore, moderated regression analysis suggested that signage can decrease negative attitudes and anxiety towards robots after the interaction as a function of increasing accuracy. This is crucially important while working to increase trust and acceptance of robots in manufacturing. While NARS and RAS scores are known to correlate [14], the differential effects of signage on these scales need to be investigated further.

"Social" aspects of human-robot collaboration in manufacturing are still largely understudied, and, even then, the majority of these studies concentrate on trained robotics users. Our study is contributing to the existing literature by investigating low skilled workforce. Further strength lies in higher ecological validity as work was conducted in factory environment. Taken together, the results indicate that, by involving workforce in the technology development and integration in the workplace, we increase their acceptance of new processes, and by communicating information about robot we have improved robot user's comfort.

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