Human Smile Distinguishes between Collaborative and Solitary Tasks in Human-Robot Interaction

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ABSTRACT

In this paper, the smiling behavior of participants when they instruct a robot to assist them assembling a wooden toolbox is analyzed. The results show that participants smile more when interacting with the robot than when they assemble the box. Thus, human tutors' smiling behavior can be used as an indicator to distinguish between collaborative and solitary phases during human-robot collaborative work.

Categories and Subject Descriptors

H.1.2 [User/Machine Systems]: human factors

General Terms

Human Factors

Keywords

Smiling; Collaboration; Social Signals

1. INTRODUCTION

The probability that autonomous robots will be used in industrial settings to assist workers is increasing with the advancement of technology. Thrun [1], for instance, suggests that the use of robot co-workers will increase and that robots will assist humans in various different applications, for example, in military, space or construction. Often, these robots will share the same workspace with humans and work closely together with their human partners to perform tasks in their daily work life. In such collaborations, human users may switch between collaborative work and solitary tasks; only the former involve human-robot interaction. In order to design effective robot co-workers, distinguishing between these two types of phases in the work flow may contribute to the robot's understanding of the current activity and thus to design appropriate robot behaviors. In this paper, we address to what extent the human users' smiling behavior can be used to distinguish between solitary and collaborative work phases.

2. PREVIOUS WORK

Even though smiling can be universally found across the world (e.g. [2]), it has been found to be a highly social signal, i.e. it is directly related to social interaction [3,4]. For example, it has been found to depend on social power and gender [5].

To our knowledge, the investigation of smiling in human-robot interaction has only concentrated on the effects of robots smiling (e.g. [6]).

3. EMPIRICAL STUDY

The data were elicited on a collaborative assembly task during which naïve human users were asked to instruct a robot to hand over the appropriate parts for the assembly of a wooden toolbox, which the user then had to assemble him- or herself. The experiments were carried out using a robot torso at the Institute of Computer Science at the University of Innsbruck within the frame of the 3rd-Hand project [7].

3.1 Robot

The robot torso comprises two Kuka robot arms, each equipped with Schunk hands, yet during this experiment, the robot executed the tasks with its left hand only. The robot's KIT head has cameras mounted in eyeballs and one Kinect camera on top. Other cameras were placed around the robot's workspace to record the sessions for later analysis and for the wizard to control the robot. The workspace of the robot is a table in front of the robot with a foam layer on top. For this experiment, the six pieces of the wooden box were placed on the table. The pieces were placed in a holding system so that the robot could easily grasp them. The participants stood at the other side of the table, opposite the robot. To the participants' left, the tools (drill, screws and instruction manual) to assemble the box were placed. Behind the participants, an engineer ensured everyone's safety. Another engineer, not visible to the participants, controlled the robot from behind a screen.

3.2 Participants

36 university students and university employees (aged 18-38), who had no previous experience with industrial robots, took part in the study. The first two participants were part of the piloting and are therefore disregarded in the following. Four more participants are excluded from the data analysis because interacting with the facilitators or visitors in the room influenced their smiling behavior. All in all, 30 participants were included in the analysis, 8 female and 22 male. Participants were recruited by word-of-mouth and rewarded with a bar of chocolate for their time.

3.3 Procedure

Before participants started the task, they were briefly informed on the experiment procedure and were asked to fill out a consent form. After this, they were introduced to the robot platform and the tools and instructed about their task. The task was to guide the robot to assist them in assembling a wooden toolbox. All

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participants received the same introduction and had to find out themselves how they could instruct the robot to fetch the parts. After introducing the participants to the task, the facilitators did not intervene except when assisting users with the drill. The robot reacted based on the users' gestures (not, for instance, their speech). The participants' interactions with the robot were video recorded. After participants completed the task, they filled out a questionnaire about their interaction with the robot.

3.4 Data Analysis

The recorded sessions were analyzed concerning the participants' smiling behavior when they interacted with the robot compared to when they assembled the wooden box themselves. Interactions of the participants with the facilitators were disregarded from the analysis. For every situation, the number and length of participants' smiles was counted. The participants' interaction with the robot was further divided into two kinds of situations: situations in which participants instructed the robot to fetch the parts and situations in which the robot handed the parts over to the participants. Since the assembly involved six parts, there are six instruction and six handover situations per participant. The participants' behavior before and after they smiled was analyzed to determine the contexts in which smiling occurred.

4. RESULTS

The analyses reveal that participants smile more when interacting with the robot than when assembling the toolbox. All in all, participants smiled around five times more when interacting with the robot (236 times) than when assembling the wooden box (42 times).

Table 1: Mean (standard deviation) for number and length of smiles

	instructions	handovers	assembly
# smiling instances	5.067 (2.703)	4.300 (2.261)	1.400 (1.714)
length of smiles in sec	0.382 (0.275)	0.470 (0.395)	0.0493 (0.080)

The quantitative analysis shows that in both phases in which participants interact with the robot, instructing and handovers, participants smile more often and for a longer time than during assembly. T-testing reveals that the solitary assembly phases differ significantly from both other conditions:

Table 2: Comparison of situations using t-testing (Statistica)

	t	p
assembly–instruction: # smiles	7.34742	0.000000
assembly–instruction: smile length	-6.58567	0.000000
assembly–handover: # smiles	-6.71742	0.000000
assembly–handover: smile length	-5.96712	0.000002

The qualitative analysis concerning the contexts in which users smiled reveals the following reasons for smiling when interacting with the robot:

- when the robot does not react (in the beginning, because they cannot find out how to instruct the robot) *(19 participants)*
- when the robot first reacts to users' movements *(11 participants)*
- when the robot does not react in ways they think it would or should *(8 participants)*
- when the robot makes a mistake (e.g. drops a piece) *(8 participants)*
- because it is too slow/ does not react immediately to their instructions *(17 participants)*

Contexts in which users smile when they assemble the toolbox comprise

- situations in which users made a mistake when assembling the box *(16 participants)*.

Moreover, some users seem to smile randomly in the assembly situations *(4 participants)*.

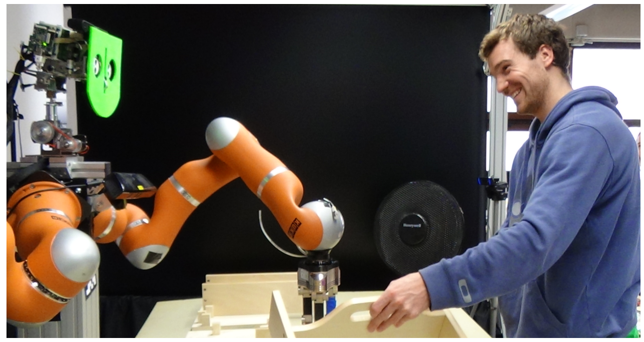

Figure 1. Participant smiles when robot does not react the way he thinks it should.

5. DISCUSSION

A statistically significant difference between collaborations and solitary tasks could be identified with respect to the human tutors' smiling behavior. That is, tutors smile more when interacting with the robot than when working alone. This is not only interesting with respect to the users' understanding of the interactions as social; participants' consistent use of smile as a social signal supports the hypothesis that users understand the robot as a social actor (cf. [8]). Moreover, the results have also very interesting design implications, since the analyses of users' mimics can contribute to the recognition of robot-directed actions and thus to the recognition of the current relevant activity.

6. ACKNOWLEDGMENTS

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