It Gets Worse Before it Gets Better

Timing of Instructions in Close Human-Robot Collaboration

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ABSTRACT

A micro-analysis of the timing of people's actions in close human-robot collaborations shows that people expect robots to attend to interactional achievements in the same way as humans do; that is, they expect that in a repeated task, the robot builds on the common ground acquired in the previous interaction. This expectation is revealed through increased response times by the human users, which leads to less fluent interactions; however, users recover over the course of the next actions, orienting at the principle of least collaborative effort. The paper thus illustrates a) how a qualitative micro-analysis provides a methodological tool for uncovering users' expectations online (in comparison to post hoc by means of questionnaires, for instance), and b) what exactly it is that users expect.

Keywords

timing; contingency; uncanny valley; common ground; human-robot collaboration

1. INTRODUCTION

In this paper, we investigate mutual adaptation processes in repeated tasks during human-robot collaboration. In the joint action scenario under consideration, human and robot have to fulfill the same task four times in order to complete the whole task, and we study the ways in which the human users adjust to the robot. However, while interactions generally become more fluent in each repetition, most interactions exhibit a novel problem in the second task, which disappears in further iterations. We argue that this problem indicates that human users take interactional achievement for granted, which characterizes human, but not human-robot interaction.

2. PREVIOUS WORK

Much previous work on human interaction shows that interaction partners adjust to each other over the course of interactions, and that particularly in repeated tasks they develop shared representations, for instance concerning the lexical material used [1], but also concerning interactional procedures [2], leading to increasingly tight coordination.

Human interaction is characterized by considerable interactional coordination [3, 4, 5]. In general, interaction partners respond to each other in a time frame of about 300-500 msecs, which requires the successful prediction of next action [3, 6]. Thus, in iterative tasks, with the next action becoming more predictable, interactions between humans become increasingly fluent and tightly coupled. Similar observations have been made for human-robot interaction; for instance, [7] describes how people adjust to robotic communication partners over time. Based on these findings, it can be expected that human-robot interactions become increasingly coordinated; that an interaction that is running smoothly should become less smooth in a repetition is thus rather unexpected.

3. DATA

36 participants interacted with an industrial robot to collaborate on the construction of a piece of furniture. 11 were female and 25 were male (age range 19-39). Interactions lasted about 5 minutes on average. The data analyzed is the video footage from 3 goPro cameras placed at different locations in the work space.

3.1 Procedure

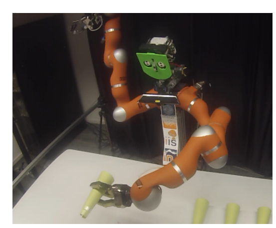

Figure 1: Robot

In the experiment, participants were told to assemble an IKEA children's stool with the assistance of the robot. Their task was to instruct the robot to fetch the legs of the stool, while the participants themselves had to perform the actual assembly. It was left open to the participants exactly how to instruct the robot. The instruction consisted of two phases: a fetching phase, in which participants had to indicate to the robot which of the four legs they wanted, and a handover phase in which the participant had to let the robot know where to to deliver the leg. The participants then connected the leg to the seat.

3.2 Robot

The robot comprises two KuKa arms, each equipped with a Schunk 3-finger gripper. However, for this study the robot made only use of its left arm, and a KIT head. The robot acted semi-autonomously during the experiments, needing only a confirmation for the planner to execute.

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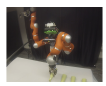
4. METHOD

The method for the analysis is ethnomethodological conversation analysis [3], which proceeds sequentially by reconstructing each participant's interpretation of the respective partner's turn; the underlying assumption is that people in interaction need to signal to each other constantly how they understand each others' actions, which then provides a methodological resource for the analyst. One of the main principles of conversation analysis is therefore 'order at all points', i.e. the idea that every detail of the interaction may be meaningful [8].

5. ANALYSIS

The analysis shows that while participants indeed adjusted to the robot over time and became increasingly savvy about how to interact with the robot best, they are less fluent in the second execution of the task than they are in the first. Initially, when the robot stops after it has lifted the first leg, participants initiate the next action after a short delay, which indicates that they cannot predict the robot's next action. However, in round 2, they hesitate even longer, indicating that they expect the robot to carry out its task autonomously:



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                     First Handover
1.    Robot:   lifts arm with stool leg
2.             (0.9)
3.    Human:   reaches for the stool leg
                     Second Handover
4.    Robot:   lifts arm with stool leg
5.             (5.9)
6.    Human:   holds out hand
               (waiting for robot)
                     Third Handover
7.    Robot:   lifts arm with stool leg
8.             (1.7)
9.    Human:   holds out hand
               (waiting for robot)
                     Fourth Handover
10.   Robot:   lifts arm with stool leg
11.            (1.7)
12.   Human:   holds out hand
               (waiting for robot)
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Example 1

Thus, participants assume that the robot understands that the current task is a repetition of the previous one and that it has successfully learned from the previous interaction what the next step will be, namely to hand over the leg after it has picked it up, without being explicitly signalled to do so again.

6. DISCUSSION

As illustrated above, human-robot collaborations do not simply become more fluent over time, as previous work would suggest; instead, people's expectations that the robot will build on previous interactions results in longer response times and hence less fluent interaction. Participants recover from this erroneous assumption relatively quickly - within 5.9 seconds in the example above; nevertheless, the fact that almost all participants in our interactions make this error indicates that this is an expectation that may need to be accounted for in human-robot interactions (see also [9]). After all, interactional achievement is generally two-sided, even though people can also take over increased interactional load in asymmetric interactions [10], orienting at the principle of least collaborative effort [1].

7. CONCLUSIONS AND IMPLICATIONS

Our analyses have illustrated the use of a qualitative microanalysis to uncover people's expectations as they carry them into the interaction online and in the moment. This methodology thus provides an alternative to the more common post hoc analyses, which use post-experimental questionaires to identify users' expectations, for instance. The analyses furthermore serve to show what aspects of human interactions people may transfer to human-robot interactions ([11]); as the example above illustrates, common response times of 300-500 msecs are not necessarily targeted, whereas the assumption that the robot learns from previous interactions is indeed transferred and presupposed. While robot designers may try to implement all human behavior into robots, it may actually suffice to implement those that people expect the robot to have, and the current study has identified one such expectation that should be considered in robot design for all repetitive collaborative tasks.

Finally, from a more general perspective, the results of this study show that while people may carry expectations into human-robot interactions, they also recover quickly from the violation of these expectations; this finding has consequences for concepts like the 'uncanny valley', which might be overcome very quickly in interaction (cf. [12]).

8. ACKNOWLEDGMENT

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