Demonstrating actions to a robot: How naïve users adapt to a robot's replication of goal and manner-oriented actions

Anna-Lisa Vollmer[1], **Manuel Mühlig**[2], **Katharina J. Rohlfing**[3], **Britta Wrede**[4], **Angelo Cangelosi**[1]
[1] School of Computing and Mathematics, Plymouth University, Plymouth, United Kingdom
{anna-lisa.vollmer, a.cangelosi}@plymouth.ac.uk
[2] Honda Research Institute Europe GmbH, Offenbach/Main, Germany
manuel.muehlig@honda-ri.de
[3] CITEC, [4] Applied Informatics Group, Bielefeld University, Bielefeld, Germany
kjr@uni-bielefeld.de, bwrede@techfak.uni-bielefeld.de

Abstract

Subscribing to an interactive view on robot action learning, we conducted a human-robot interaction experiment with inexperienced users. This paper describes an analysis on how the robot's replications influence participants' following demonstrations. Detailed results will be presented on the poster.

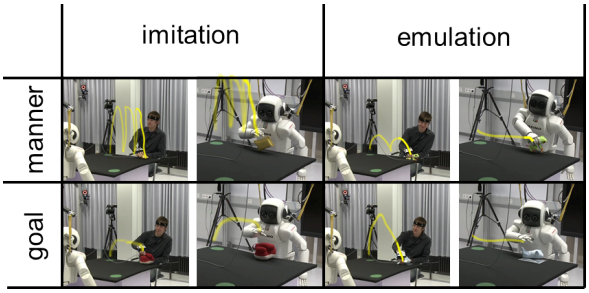

Figure 1: Experimental conditions.

1 Introduction

Imitation learning in robotics aims at developing mechanisms for robots to learn from a human tutor's demonstrations (Schaal, 1999). In order to replicate an action correctly, the robot needs to understand a demonstrated action which implies knowing what is important about it. But how do tutors convey this information about an action? Recent research has proposed that in action learning the learner's mental states are aligned to those of the tutor in a bi-directional process (Thibault, 2011; De Jaegher et al., 2010). Subscribing to this view, tutoring a robot should really be a bi-directional endeavor in which the robot not merely observes the tutor's demonstrations, but actively takes part by giving feedback. In adult-infant tutoring interactions, the infant learner's feedback reveals information about his/her state of attention and understanding and has been found to influence the adult tutor's action demonstrations (Pitsch et al., in press). Analyzing data from a human-robot interaction study where human tutor and robot learner take turns in demonstrating and replicating actions, we investigate how naïve users modify their action demonstrations, when the robot replicates the action correctly or incorrectly.

2 Experiment

The experiment was conducted with 59 participants (28 m, 31 f). Participants had no prior experience with robots and interacted with the robot for the first time.

Participants were seated at a table across from a standing humanoid robot and were asked to teach the robot eight different actions. The actions were chosen to be either goal-oriented (the end position of the involved object is the important main feature, e.g. the action 'to hang up the phone') or manner-oriented (the path is most important, e.g. the action 'to clean the window with a sponge') and the robot replicated the actions via imitation (copying the movement of the involved object as exactly as possible) or emulation (transporting the object straight to its end position) yielding correct and incorrect replication attempts. Additionally, each participant was presented with one of three robot gaze behaviors (a social gaze consisting in appropriately following the action demonstration (imitation) or anticipating the goal position (emulation condition), a random gaze consisting in various alternating gaze targets independent of the tutor's conduct and a static gaze condition in which the robot only showed a fixed gaze to the overall scene).

For each action, the participant and robot took turns in executing the action. After the participant demonstrated the action, the robot replicated it and the participant had the chance to correct the robot by demonstrating the same action again followed by another robot replication turn (for one specific action, the robot replicated the action in the same

condition and did not change its behavior) and so on. After each robot repetition, the participant decided if it was necessary to demonstrate the action again or to stop and carry on to the next action.
In this analysis, we focus on the very first action each participant demonstrated to the robot because demonstrations of subsequent actions incorporated potential modifications based on experiences from previous turns. The order of actions was randomized for each participant and also if the robot imitated or emulated this action. Because goal and manner-oriented actions have very different properties, we examined the data separately for the two types of action. The analysis sets out to compare the tutor's first demonstration of the first action and the second demonstration of the same action (after the robot's replication turn). Not all participants deemed it necessary to show a second demonstration of the action leaving us with 26 participants who demonstrated a goal-oriented action (which the robot imitated in 10 and emulated in 16 cases) and 26 participants who demonstrated a manner-oriented action (which the robot imitated in 6 and emulated in 20 cases). The data used for the analysis consisted of 3D object trajectory data obtained from a magnetic-field based Polhemus Liberty System which was attached to the objects involved in the actions and tracked their movements. To compare the characteristics of the demonstrations, we computed a set of objective measures on the obtained trajectories, please refer to (Rohlfing et al., 2006; Vollmer et al.,).

3 Results and Discussion

We investigated goal-oriented and manner-oriented actions individually and conducted separate two-way mixed ANOVAs with demonstration (first, second) as within-subjects variable and robot replication condition (imitation, emulation) as between-subjects variable.

3.1 Goal-oriented actions

For goal-oriented actions, they revealed significant main effects of the demonstration for *acceleration*, and marginally significant main effects for *velocity*, *average length of motion pauses*, and *range*. Participants demonstrated the action slower in the second demonstration than in the first demonstration, and with longer motion pauses. The second demonstration was shown with less range than the first one. In summary, goal-oriented actions were shown slower and with less detail when they were repeated.
Additionally the tests revealed a marginally significant interaction effect for *action length*. T-tests as post hoc comparisons showed a marginally significant difference between the length of the first demonstration of a subsequently imitated action and the length of the first demonstration of a subsequently emulated action. One possible explanation for this finding could involve the robot gaze during the demonstrations. Indeed, when conducting follow-up tests for the three robot gaze conditions separately, we found this difference alone in the social gaze condition, which thus seems to account for the finding. Thus, the anticipating gaze of the robot in the emulation condition during the participant's action demonstration, led participants to perform the demonstration in a shorter time frame than when the robot followed the movements with its gaze in the imitation condition.

3.2 Manner-oriented actions

For manner-oriented actions, the tests revealed a marginally significant main effect of the demonstration for *width*. Participants demonstrated the action less wide at the second demonstration compared to the first one. Additionally they showed significant interaction effects for *height*, *velocity*, and *acceleration*. T-tests as post hoc comparisons showed that the second demonstration of a previously imitated action was significantly higher than the first demonstration. Results suggest that when the action was emulated by the robot, the second demonstration was of similar or even lower height than the first one. For the demonstration speed, the tests revealed that the second demonstrations of previously emulated actions were performed with less velocity and acceleration than the first ones and slower than the second demonstrations of a previously imitated action. A possible explanation for these findings is that participants exaggerate their following demonstrations to emphasize the manner of the action, when the robot successfully replicated (imitated) it. When the robot failed to replicate (emulated) the shown action, the participant showed a simpler and easier subsequent demonstration. Thus, participants adjusted their subsequent demonstrations according to the robot's capabilities and understanding witnessed in its replication as a turn-based feedback.

Acknowledgments

This research was supported by the Honda Research Institute Europe and the EU project RobotDoC (235065) from the FP7 Marie Curie Actions ITN.

References

Hanne De Jaegher, Ezequiel Di Paolo, and Shaun Gallagher. 2010. Can social interaction constitute social cognition? *Trends in cognitive sciences*, 14(10):441–447.

Karola Pitsch, Anna-Lisa Vollmer, Katharina J. Rohlfing, Jannik Fritsch, and Britta Wrede. in press. Tutoring in adult-child interaction. on the loop of the tutor's action modification and the recipient's gaze. *Interaction Studies*.

Katharina J. Rohlfing, Jannik Fritsch, Britta Wrede, and Tanja Jungmann. 2006. How can multimodal cues from child-directed interaction reduce learning complexity in robots? *Advanced Robotics*, 20(10):1183–1199.

Stefan Schaal. 1999. Is imitation learning the route to humanoid robots? *Trends in cognitive sciences*, 3(6):233–242.

Paul J. Thibault. 2011. First-order languaging dynamics and second-order language: the distributed language view. *Ecological Psychology*, 23(3):210–245.

Anna-Lisa Vollmer, Manuel Mühlig, Jochen J. Steil, Karola Pitsch, Jannik Fritsch, Katharina J. Rohlfing, and Britta Wrede. Robots show us how to teach them: Feedback from robots shapes tutoring behavior during action learning. *Manuscript submitted for publication.*