Robotic Mirror Game for Movement Rehabilitation

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***Abstract*— We present findings on applying the Mirror Game, a technique borrowed from Improvisational Theater, to human-robot interaction, with the ultimate goal of using this game in a rehabilitative physical therapy setting. In our study, participants played the mirror game with a collocated embodied physical robot, the Kinova Mico robotic arm, or with a video projection of the robot. We expected to find a strong preference for interacting with the embodied robot vs. with its screen projection. While our findings do show a preference for the physical robot condition, the virtual rendition of the robotic arm also received positive feedback from the participants. The results suggest that a virtual environment may be a reasonable substitute for an embodied system under certain conditions. Given the significant costs of using actual robots in therapy, we believe it is important to identify where simulations are sufficient and real robots may not be needed.**

Keywords—Robotic Therapy, Socially Assistive Robots (SAR), Human-Robot Interaction, The Mirror Game

I. Introduction

It is well known that repetitive movement practice is a cornerstone of rehabilitation [1]. Drawing inspiration from human-robot interaction (HRI) and drama acting methods [2] we explore possible mappings between the mirror game improvisational drama exercise [3] and physical therapy. In the mirror game two players face each other, and attempt to mirror the other person's movements, with one of the players possibly designated as the leader. We suggest that this technique can be adapted to robotics in physical therapy, in order to increase engagement with a prescribed exercise program, with the robot playing the role of one of the partners.

Socially Assistive Robots (SARs) are forming a relatively new category of assistive robots. Incorporating concepts from social robotics into physical therapy treatment may improve patients' attitude towards physical therapy exercises. Here, we propose to build on positive attitudes found towards social robots, and on their demonstrated success in engaging people in performing tasks [4], and specifically investigate the motivation of participants to continue a movement-based interaction with an embodied robotic arm, compared to interacting with its screen projection.

We present a realization of a robotic mirror game prototype implemented using a robotic arm. We also generated a virtual version of the robotic actor, via a video projection of it, to study the importance of embodiment in the context of the robotic mirror game.

*Funding was provided by the Leir and Bronfman Foundations; The Israeli Science Foundation (grants # 535/16 and 2166/16); and by the Helmsley Charitable Trust through the Agricultural Biological and Cognitive Robotics Center of the Ben-Gurion University of the Negev.

II. Methods

A. Participants

Twenty three individuals (13 female), ages 18–29 participated in this experiment. They all signed informed consent, as stipulated by the Ben Gurion University's Ethics Committee.

B. Experimental setup

The experimental set-up consisted of two mirror-game "partners": a robotic arm, and a screen projection of the robotic arm. In the "robot" condition, participants played the game with a Kinova Mico robotic arm. In the "screen" condition, they played the game with a video of the robotic arm projected on a smart-board. Participants stood between 1.4-2.2m from the partner. The video projection of the robot's movements was presented onto the smart-board at the same height and in the same scale as the physical robot.

Robotic movements The movements performed by the robot were created by asking four volunteers, prior to the experiment's initiation, to move their right arm freely while facing the Microsoft Kinect v2 camera, for 40 seconds. Their movements were recorded and fed into the robotic motion path.

C. Procedure

In each condition (robot/screen), participants performed a brief training session, consisting of two movement trials followed by three semi-randomized repetitions of each of the four pre-recorded movements. At the beginning and at the end of each trial the robot (either embodied or projected on the screen) would move from a home position to the starting location, and then open its hand for the duration of the trial. This signaled to the participant when the robot was performing the movement that should be tracked (robotic hand is open), and not simply relocating to the start of the next movement (robotic hand is closed). Approximately half of the participants started with the robot as their partner, and the others half with the screen as their first partner.

The experiments were recorded by an RGB camcorder, and the participants' movements were tracked from the front using an adapted version the Microsoft Kinect v2 skeleton tracker. Each trial started with the participant opening and closing their right hand.

Participants were asked to fill out the Godspeed questionnaire [5] after each condition. In addition, at the end of the experiment, they were asked to answer a questionnaire comprised of 7 questions: (1) You have two trials remaining, which partner would you prefer to perform them with? (2) Which partner did you enjoy more? (3) Which partner did you find more engaging? (4) Which partner did you feel you tracked better? (5) Do you feel fatigued? (6) What did you enjoy? (7) What did you not enjoy?

III. Results

A. *Godspeed questionnaire*

The responses to the Godspeed questionnaire for the two conditions (robot vs. screen) were overall similar, with a slight advantage for the embodied robot. The responses for the two conditions were significantly different, in favor of the embodied robot, on the questions of whether the system is perceived as machinelike or humanlike ($p=0.007$), and whether it was liked or disliked by the participants ($p=0.03$). On the question of how friendly or unfriendly they found the system to be, there was an advantage for the embodied robot, with a borderline p-value of 0.05.

B. *Participants' preferences*

In response to question number 1 on the end-of-experiment questionnaire, 43.5% of the participants opted to play the next two trials with the robot, 30.5% chose to play the next two trials with the screen, and 26% chose to play one trial with the robot and one with the screen.

The average score on questions 2, 3 and 4 (listed above) was 2.3, 2.4 and 2.4, respectively, on a Likert scale of 1-5 showing a slight advantage towards the embodied robot. In question 5, 1 denoted "not at all fatigued" and 5 denoted "very fatigued". The average report was 3.4, indicating this interaction with their arm held up presented a challenge over time.

In response to question number 6 ('what did you enjoy?'), most participants said that they had never done something like that, and that they enjoyed the novelty, and found it enjoyably challenging to adjust their movements to the robot's movements. Additionally, they enjoyed seeing how the robot moved, and imitating it. This was particularly the case when they perceived the movement to be humanlike. However, there was one participant who said she found the screen condition to be more interesting.

In response to question number 7 ('what did you not enjoy?'), most participants said it was difficult to concentrate during the experiment, and to hold up their hand in the air for so long. Some participants reported feeling bored because they felt it was a monotonous assignment, following the robotic movements. Some reported they did not enjoy the screen condition because it was difficult for them to exactly discern the robotic movement. Some reported that they did not like the movements that were fast and small in amplitude, as at times it was difficult for them to follow these.

IV. Discussion

Previous work with socially assistive robots primarily included social agents that were encouraging and friendly [e.g., 4], though they did not directly participate in collaboratively achieving the task with the participants. We present a prototype for a socially assistive robotic interaction that incorporates the robot as a partner in performing the desired movement task. Ultimately, we envision using this framework to motivate participants to perform a range of movements as part of their physical rehabilitation routine.

Participants overall reported that they enjoyed the novelty of the interaction, and that they found the robot to be pleasant and responsive. We found a preference in favor of the robotic condition in participants' responses to both questionnaires. However, the scores for the virtual projection were not very different from those of the embodied system, suggesting people enjoyed interacting with both systems.

This preliminary study demonstrates that embodied robots do not always offer a strong advantage over virtual interactions, and highlights the importance of the interaction design for motivating participants. For example, perhaps the benefits of embodiment are apparent at close proximity to the robot, and not when standing far from it.

Acknowledgments

Our thanks to Shir Kashi for help with data analysis and to Yoav Raanan for help with the technical setup.

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