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Playing the Mirror Game with a Humanoid: Probing the Social Aspects of Switching Interaction Roles

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Abstract— **Individuals can easily change interaction roles during everyday tasks, for example by shifting from following someone's lead, to leading the task themselves. We are interested in how these existing social experiences scale to human-robot interaction (HRI). How would robots change their interaction roles when working with people? Would changes in interaction roles pose a challenge unique to robots? In this paper, we propose a testbed for changing interaction roles in HRI based on a drama exercise known as the Mirror Game. The Mirror Game enables close collaboration between two individuals with each closely following the other's movements. Utilizing the Mirror Game with a large humanoid robot allowed us to examine people's reactions to changes in the humanoid interaction roles. We contribute: 1) the design of a human-robot interaction role-switching testbed based on the Mirror Game 2) a prototype of our testbed realized with Rethink Robotic's humanoid, Baxter, and 3) the results of a preliminary study examining people's reactions to the robot changing interaction roles to verify the design of the testbed.**

Keywords— Applications of social robots; cooperation and collaboration in human-robot teams; human-robot relationships; switch of social roles; social acceptance; mirror game; research design

I. Introduction

Social interactions serve a significant role in human development and interpersonal bonding [7]. Accordingly, the importance on affective human-robot interaction has been investigated in the recent years. Discovering the most appropriate solution for implementing aspects of social cues, roles and potentially adopting human behavior onto humanoid robots has then become a popular topic of interest [5, 16]. Distinguishing roles within society is known to develop automatically in situations of human social structure [16]. Consequently, the concept of switching between leader or follower lies at the core of this aspect.

We argue this social phenomenon is at least partially valid beyond the human social structure and can be extended into the region of human-robot interaction. However, the boundaries are still unclear on where our common knowledge and understanding towards role assignment should be distinguished in human-robot interaction. Should social robots be programmed to obey humans? Or will society be able to collaborate with them, leader or follower? Over the progression and efforts towards humanoid robots, effective collaboration has been investigated in many areas of our society. Some of which include integrating such robots into search and rescue, used to demonstrate medical therapy as well as extensively experimented within entertainment and gameplay. However, it is still common to perceive robots as intelligent, helpful and obedient machines whose main purpose is to assist humans [5]. Therefore, robots who may adopt an authoritative role and attain the ability to adopt human behavior is often a more difficult concept for humans to accept. In extreme cases, robots with this capability can then be perceived as a threat and unsafe to collaborate with [7].

On the other hand, the rapid development of autonomous robots makes the concept of implementing robots with the ability to switch between leader and follower roles inevitable. The ability to acquire and maintain situation social status when assigning tasks to robots will be critical to human- robot interaction, while integration of role-shifting between humans and robots still needs to be further investigated. While individuals can easily change interaction roles during everyday tasks, what would this look like when a robot does the same? Understanding the critical requirements for robotics tasks will be important, particularly when operators must work with multiple systems across aerial and ground platforms, and must perform under what will likely be varying levels of system autonomy. Therefore, guidelines for how the social nature of the robot is expressed can be taken from the social literature on human social interaction.

This paper proposes a potential design for exploring leader-follower role-switching in HRI. Investigating people's awareness and reactions upon unexpected robotic behaviors now when a robot switches to lead. In this design, we introduce a modified version of the Mirror Game that allows a human player and the robot to lead, follow or switch between the two and to examine the collaboration and behavioral communication in between. We also report the implementation of our testbed utilizing Rethink Robotic's humanoid, Baxter and the results of a preliminary study. Our main contribution is the simple design of the testing platform, which sets the stage of this less explored research area in HRI that leads to answer the following questions. Can humanoids adopt a leader role and convince the participants to follow along? How would a human react when Baxter starts changing between tasks or switching to an authoritative role? Ultimately, should robots attain aspects of human behavior – especially in a social setting?

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II. Related Work

Effective collaboration for social robots has been investigated in the recent years. Several of these robots are driven by technological advances and install humanistic features in attempt to establish a more natural interaction with humans [2]. By adopting a life-like interaction, they have been intensively studied in various scenarios such as the army [17, 18, 19], medical therapy [10, 13, 20], and gameplay [1, 5, 7, 13]. In addition, studies tie in aspects of psychology and sociology in application to HRI to test social acceptance [5, 7]. Furthermore, the application of drama exercises to test human-robot collaboration has also been an emerging trend [13, 20]. This aimed to study the importance of communication and trust between two entities; namely a human participant and a robotic arm [13, 20]. However, there exists a gap in investigating deeper into what aspects are necessary for effective collaboration between a human and robot [7, 14, 15]. Our experiment design serves to complement these findings and further investigate role-switching utilizing a more human-like robot rather than a robotic arm. In summary, the current state-of-the-art in relation to collaboration glaze over a crucial component; distinguishing a set of appropriate social roles and switching between them in a social setting.

III. Method

Collaboration and communication within human-human relationships are simpler due to existing well-recognized social cues such as body languages and known autonomy. Similarly, to establish an understandable relationship between a human and robot we will need to go down to the basics of such social cues and further apply them into human-robot interaction. In this section, we will discuss a common autonomy of the Mirror Game and instructions which guided our design process.

A. *Mirror Game*

For our research, we adopted the Mirror Game and centered our design around it (Figure 1). Mirror Game, commonly known as a drama or educational exercise, is structured to allow both participants to simultaneously lead and follow. Therefore, switching between the given roles enhances collaboration and communication between the players.

The Mirror Game in theory can have two players pair together and are declared as player A or B. They face each other at approximately arm's length and proceed with the following 3 stages [10]:

- Stage 1 – Player A dictates the body movement while player B mimic's the actions of the other player to be a precise mirror image. For example, if player A lifts his left arm, player B does the same with his right arm.
- Stage 2 – the roles of the players reverse as player B dictates actions while player A copies those movements.
- Stage 3 – there is no designated leader or follower, and the game continues solely on the rule that free movement results in mirrored actions.

The smooth transition of roles between a leader and a follower during a Mirror Game exercise is built on mutual trust and equality between the two human players. Eventually players experience an effortless synchronization, meaning there is no leaders and followers. The common social cue ensures a gradual process of role-switching between human players; however, we would like to test switching between the designated roles when installing a robot in place for one of the participants.

Figure 1. During a human-human Mirror Game exercise, roles switch between the leader and followers, which may become indistinguishable especially from a third-person perspective.

Our aim is to test whether a human participant would be willing to follow a robot when playing the Mirror Game without explicitly stating they may have the ability to lead. Therefore, our application and approach needed to be modified to test our experiment design by excluding Stage 3. Notice that without a set knowledge base of a robot's role within society, it is challenging to determine a Stage 3; where free movement and switching between the leader or follower simultaneously is possible. Therefore, we decided to structure our Mirror Game by executing only Stage 1 and Stage 2.

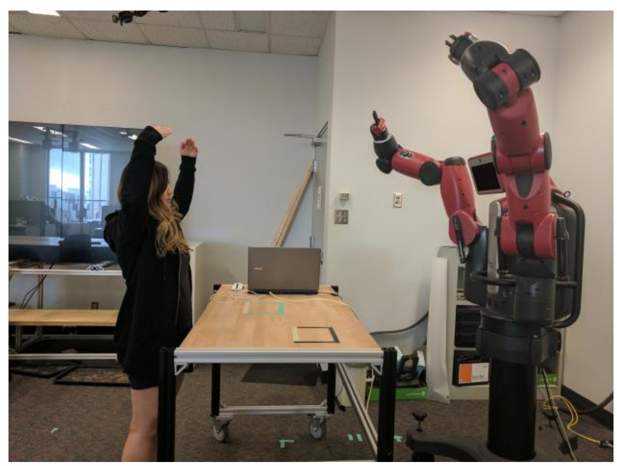

Figure 2. Baxter the humanoid replacing one of the human players in our rendition of the Mirror Game.

Our experiment design begins with Stage 1, namely "Human-Lead", in which the human is designated as the leader while the robot follows their movement. Stage 2 is when the roles switch, namely "Robot-Lead" where the robot attempts to lead the human.

B. *Baxter the Humanoid*

As mentioned previously, collaboration and communication within a human-human relationship have already been predefined by social cues. For our project, we utilized Rethink Robotics Baxter (Figure 3). Baxter is an industrial humanoid robot designed by Rethink Robotics [1], with the ability to perform actions like folding a T-shirt, playing rock paper scissors, and even participating in social events, Baxter is redefining a typical robot's capabilities [1]. This robot can exercise a series of movements by increasing, decreasing or rotating its joints and can be controlled through a set of system commands.

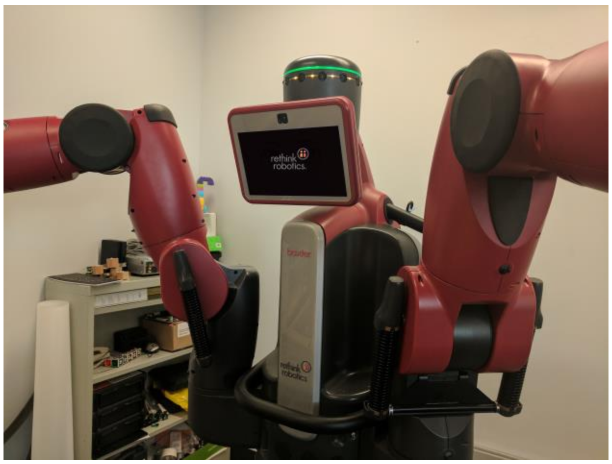

Figure 3. Baxter the humanoid resembles a more realistic and human-like figure as it has a similar joints to the human autonomy.

We chose Baxter as our representation of the humanoid in our study design as it resembles a more realistic and human-like figure as compared to other robots. First, we believe the structure of such a humanoid can reflect basic human anatomy, allowing the robot to perform mirror games with a human. This is not possible for simpler robots without sufficient limbs and joints in order to mimic human postures and actions. Second, though there exists more sophisticated androids, we argue a typical industrial humanoid like Baxter is more likely to collaborate with humans in realistic situations that involve authoritative role-switching.

Figure 4. Baxter's existing joints and the joints we decided to use.

However, it is important to note that Baxter is designed with a larger number of degrees of freedom than a human participant can mimic. Ensuring the robot of choice catered to the same human behavior was crucial to making the movement natural. To reduce the existing complexity, we stripped down to basic arm movements; including the shoulders, elbows and wrists. All of which can either be increased, decreased or rotated; translating to human arm movement.

TABLE I. SELECTED JOINTS

Joint	Increased	Decreased
S1	Shoulder forwards	Shoulder backwards
E0	Shoulder up	Shoulder down
E1	Elbow up	Elbow down
W1	Wrist up	Wrist down

C. *Design of the Baxter Mirror Game*

Here we propose the design of our modified Mirror Game between a human participant and Baxter the humanoid. The goal of the design is to establish a testbed for investigating participants' awareness and reaction when the robot starts to lead in a safe and controlled game environment. The results of the study can then be compared with human-human mirror games, resulting in a better insight and understanding of humans' acknowledgement and response towards authoritative roles from robots.

We carefully design the new Mirror Game in such a way that using the humanoid is the only thing changed from the classic human-human mirror games. We minimized the change so that all the psychological and sociological lessons learnt from the classic mirror games will be preserved. To eliminate any physical risk and emotional pressure caused by the large size robot, we create a safe distance by placing a table between Baxter and the human participant.

Figure 5. The setup of our study design; Baxter plays the Mirror Game with the human participant with role-switching happens during the process. Stage 1, namely Human-Lead begins the experiment

The study starts with an introduction of the concept of the Mirror Game. A human researcher plays the entire mirror game, namely Stage 1 and Stage 2, as presented in the Method section, with the participant to ensure they fully understand the basics of the game. However, we carefully avoid any vocal hint related to Baxter's taking the lead, to prevent participants from mentally preparing for the role-switch.

During the Mirror Game, we let the human participant lead first while Baxter follows. The human-lead stage 1 will proceed for a period upon our judgement on the comfortability of the human and robot interacting, which usually last for about 2-3 minutes. When the human participant appears to be comfortable with the robot, we switch roles, into robot-lead stage 2, without the participant's knowledge. As mentioned before, by doing so, we can aim to observe the human participant's reaction to a humanoid robot leading the movement.

IV. Implementation

We also implemented and conducted a preliminary pilot study and critique sessions to verify the testbed. The aim of our pilot run was to probe on aspects of social acceptance in terms of human-robot interaction. We wanted to take a step closer to answer whether a robot can be socially accepted if it has the ability to switch between leader and follower roles simultaneously. In order to test and refine our design method, we developed a simple Wizard-of-Oz prototype. For the duration of the Mirror Game, Baxter is controlled through keyboard inputs. Each key corresponds to the joints described in our method to either increase, decrease or rotate a joint. In this section, we will discuss the Wizard-of-Oz implementation, followed by the report of the pilot study and its initial findings.

A. Keyboard Controlled Interface

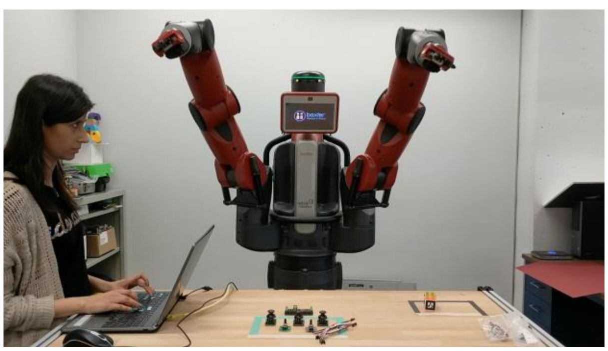

Figure 6. An operator controls the movement of Baxter's joints.

For our Wizard-of-Oz interface, we controlled Baxter by mapping keys to joints on the robot. This interface consisted of 8 buttons for each arm. The buttons were implemented for both arms as follows: shoulder forward rotate, shoulder back rotate, shoulder up, shoulder down, elbow up, elbow down, wrist up, and wrist down. Moreover, the buttons were strategically placed in order to make it intuitive and maintain proximity to make it easier to manipulate movement. (As shown in Figure 7) Keys from the left side of the keyboard were delegated to Baxter's right arm while those from the right were mapped with the robot's left arm. This was done to make it easier for the person controlling the movement as they would be facing the robot, and thus would see the sides as reversed. In efforts to accomplish this refined keyboard console approach as seen in Figure 7, the keys were placed as follows: shoulder rotations horizontally next to each other (keys 1, 2, 9, 0), shoulder up and down vertically next to each other (keys Q, A, P, L), elbow up and down vertically next to each other (keys W, S, O, K), and wrist up and down also vertically next to each other (keys E, D, I, J).

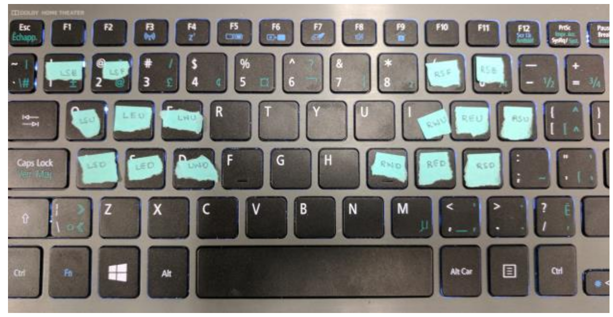

Figure 7. Keystrokes are mapped to Baxter's joints to perform the Mirror Game in a Wizard-of-Oz fashion.

B. Pilot Study Structure

Our sample research consisted of 5 pilot participants. The participants were university students between the ages of 21 and 26 and consisted of two males and three females. When the experiment began, the participants had no knowledge of our implementation, and were aware of only the scope mentioned during debriefing.

It is worth mentioning that during all the trials, participants never noticed that the robot was controlled directly by an operator. Participants assumed that the robot made its own judgement and reacted on human inputs. This is also the reason we think the Wizard-of-Oz method has no impact on the social aspect of the study design.

C. Results

Though the study is preliminary we are still able to collect interesting findings. What surprised us was, regardless participants thought the humanoid looked "intelligent" (P3), "smart" (P5) and played the game "just like a real human player" (P4), they do not view the experience of playing the mirror game with the robot the same as playing it with a human due to assumed technical difficulties - mentioned by all participants - or lack of distinguished social roles - mentioned by 3.

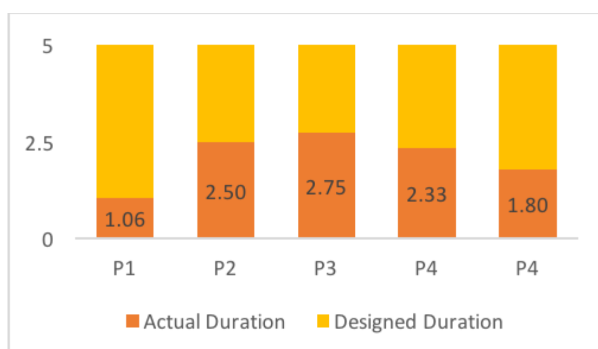

Figure 8. Terminated time of each participant when Baxter starts to lead (Stage 2) in mins.

Interestingly, female participants followed the robot to some extent in efforts to bring back the robot to follow them again and "function properly" (P1). In contrast, male participants were not keen on following the robot for any purpose after they noticed that it had stopped following them. As a whole, we found out that participants concluded that the robot is not a smart entity as compared to humans because it was "malfunctioning" (P3) or at least "something wrong with it" (P4, P5).

The quantitative results strengthen the evidence from another perspective. The parts of the Mirror Game when Baxter was supposed to lead are designed to last for 5 minutes; however, all participants terminated their trials much earlier (Figure 8). On average participants quit after 2.1 mins, with SD = 0.52 mins, after Baxter the humanoid took the leadership. This meant most of the participants gave up during the first half of the session.

I. Discussion and Future Work

This pilot study has provided initial insight into what kind of testbed is best for this kind of a study. The possible design can be foreseen from this. For one thing, it can be noted that humans do not consider the possibility of the robot "thinking for itself". The non-obedient behavior of the robot is seen as a glitch on the part of either the robot (hardware) or the programmer (software). The possibility of role switching where the robot may lead in the Mirror Game does not occur in the participant's train of thought. Secondly, the different ways in which males and females deal with the unexpected behavior of the robot in a social HRI environment is also visible. Despite the assumption that the robot could not make decisions for itself was visible across the genders, both approached the matter differently. Females attempted to track some of the movements of Baxter in attempts to make the robot follow them again while males were quicker to disregard the robot once it stopped following them.

With the introduction of humanistic "beings" that could be integrated in work and collaboration environments with humans, it becomes essential to probe on the perceived role of robots. In the pilot investigation of the Mirror Game between a human and a humanoid robot, it was realized that the perceived possibility of a robot acting on its own becomes unthought of. Our participants believe that Baxter is glitching when it makes moves that are independent from movements that it is supposed to mimic by copying the human. They explain this as a feeling of bias that they had going into the experiment. They claim that being told that the robot would copy them makes them not think of the possibility of the robot being able to lead in this game. They see the entity as a machine that will solely perform the task at hand as programmed.

Based on our findings observed from our pilot study, we see value in refining our approach. In the future, the following recommendations should be considered to improve the Baxter-based Mirror Game in attempt to find a better understanding of role-switching in human-robot collaboration. Some of which include providing a wider range of robot movements with better automation, including an animated face, and considering the impact of priors during experimentation. Enhancing these components will help iron out any "bugs" in Baxter's movement as well as help transition the stages to be more approachable for the human participant to catch on and allow Baxter to lead.

In the current implementation, Baxter was controlled by ourselves in a Wizard-of-Oz method, which requires the operator's consistent performance to ensure a similar experience across all participants. To increase consistency of the humanoid's action and alleviate the operator's effort during future studies, we see value in implementing an automatic system that is able to capture participants' movement, perhaps via motion sensors such as Microsoft Kinect or Vicon Motion System or by utilizing Baxter's existing cameras.

It has been expressed that eye contact or facial expression plays an important role in instilling trust and successful collaboration between partners. Therefore, perhaps taking a step further and displaying a static or dynamic face onto Baxter can fill this void. We assume that since all participants proposed if Baxter was malfunctioning, we could include blinking or smiling throughout the Mirror Game. This way consistency of Baxter's working functionalities would be expressed. Including facial expressions may also enhance knowledge on similar social cues found in human-human interaction.

As seen from our pilot study results, it seems that while the gut reaction of a person was to stop and think about the malfunction, it may be worthwhile to experiment with switching the stages and propose multiple renditions for the same study. For example, one rendition will begin with a robot-lead stage; allowing the human participant to follow the robot first. Furthermore, before transitioning into a human-lead stage, allow the robot to stop and wait for the human to then lead. Another rendition would then have the roles switches, beginning with a human-lead stage followed by the robot-lead stage. The result is influenced by priors, which means that some people assume that robots are followers so they will stop immediately when they see robots leading. But some people assume that robots could be leaders so they won't stop. To eliminate the prior, we could have a random order of treatments for each participant. Some people start with robots as leaders while some start with robots as followers.

II. Conclusion

In general, the pilot study provides a deeper understanding of topics in human-robot interaction such as entertainment, social acceptance, and role-switching. One can see that humans may have an initial perspective on the robot's intelligence in regards to leader or follower roles. Consequently, without proper understanding of a robot's role in society, some tend to consider humanoids to be followers rather than leaders. The role of robots should still be a topic to be explored and further investigated on before integrating such entities into society.

Considering the development of humanoids are still on the rise, when robots are introduced to collaborate with humans, the notion of being superior to the entity is common. The idea of the robot leading is a foreign concept for two reasons. Firstly, being introduced to a robot as an entity that will copy them eliminates their expectations of it being capable of anything else. Secondly, the idea of the robot being able to think on its own is unthought of and far-fetched. The Mirror Game is a fast-track way of visualizing the future of how humans will react to robots becoming more prevalent in society.

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