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Playing the 'Trust Game' with Robots: Social Strategies and Experiences

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Abstract— **We present the results of a pilot study that investigates if and how people judge the trustworthiness of a robot during social Human-Robot Interaction (sHRI). Current research in sHRI has observed that people tend to interact with robots socially. However, results from neuroscience suggests people use different cognitive mechanisms interacting with robots than they do with humans, leading to a debate about whether people truly perceive robots as social entities. Our paper focuses on one aspect of this debate, by examining trustworthiness between people and robots using behavioral economics' 'Trust Game' scenario. Our pilot study replicates a trust game scenario, where a person invests money with a robot trustee in hopes they will receive a larger sum (trusting the robot to give more back), then gets a chance to invest once more. Our qualitative analysis of investing behavior and interviews with participants suggests that people may follow a human-robot (h-r) trust model that is quite similar to the human-human trust model. Our results also suggest a possible resolution to the sHRI and Neuroscience debate: people try to interact socially with robots, but due to lack of common social cues, they draw from social experience, or create new experiences by actively exploring the robot behavior.**

I. Introduction

In recent years, the worldwide number of autonomous robots that interact socially with humans has increased [1]. As these robots become more advanced, they are also becoming more capable of doing jobs that require people to trust them, for example, a robot in a hospital may be entrusted to deliver medications correctly. Trust is an important factor in social interaction between humans that relies on many social cues [2]–[5], however there are open questions on how people build or lose trust when interacting with robots. This paper evaluates human trust towards robots in the context of a common behavioral economics trust experiment called the trust game (or the investment game) [6]. In this context, *trust*, in the context of the trust game, is a mutual trust that can be defined as the action of one party (trustor) to rely on the actions of another party (trustee) in order to improve the outcome for both parties.

Neuroscience, psychology, and economics have used 'The Trust Game' to study the initial evaluation and building of trust in an investment scenario [6]. The game is a turn based scenario where one person, the investor, can invest (trust) some amount of money to another, the trustee, hoping to make money from a return on investment. The trustee receives the money invested multiplied by a factor, allowing them to pay back the investor while still gaining from the transaction. However, the trustee is may also keep the entire amount, returning nothing to the investor. The game requires the investor to make a judgement call about the trustworthiness of the other person – how likely is it that the trustee will return a profit on the investment?

When it comes to trust between humans and computers, there is a contrast between the neuroscience-based approach and findings, and between the Computers as Social Actors (CASA) [7] approach. Studies in neuroscience noted that apparently different areas of the brain are used to judge trustworthiness when the trustee is more human versus more machine-like [8]. In contrast to this judgment, the CASA paradigm had demonstrated that people respond to computers in the same manner as they would toward other people [7], at least at a behavioral level. Our work is attempting to investigate this contrast, asking whether people would build social trust with robots on a behavioral level similarly to the way they would build trust with another person, or differently. As our experimental pilot test-bed we choose the trust game.

We adapted the trust game from its original human-human context to a social human-robot interaction setting using a Baxter humanoid robot. Our findings suggest that people playing the sHRI trust game may follow a human-robot (h-r) trust model that is quite similar to the human-human trust mode. In addition, our results showed players trying to build new social experiences with Baxter to explore and fill in gaps in their existing trust model, providing one possible solution for the discrepancy between the neurological and CASA results.

II. Related Work

Research has been devoted to evaluate human trust towards robots [9]–[12]. This past work addressed trust as a measure of the human belief in the effectiveness of the robot for performing collaborative tasks reflecting on robots in hospitals [13], military [8], urban search and rescue [14], and other situations where people may be required to trust information and orders from robots on a regular basis in dynamic and stressful environments (e.g. a robot telling an elder to take prescribed medication in a hospital every day). Importantly, what these works have in common is the perception of sHRI trust as the human conviction in the robot to do its job efficiently, reliably and consistently, very much like one would expect a complex machine to perform. Yet, there may be emerging situations in which the human must trust the robot in ways which are closer to the rich notion of trust between two humans. Our work extends previous robotic trust research by exploring how people trust robots in a situation that is not performance based: trusting that a robot will return a favor.

The decision to trust someone involves reasoning about the trustee's thoughts and intentions, or mentalization [15]. Hence,

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in a trust situation, one would expect activation of mentalizing brain areas. Neurobiological research in both social cognitive neuroscience and neuroeconomics that use functional magnetic resonance imaging (fMRI) have applied the trust game to study the neural processes of trust. Some game studies have studied participant's brain activation while playing against computer opponents. Interestingly, some results indicate that behavior and the underlying neural processes may differ, depending on whether the opponent is a human or a computer [16]. Further, [8] has evaluated brain regions associated with mentalizing through the iterated prisoner's dilemma game, in which increasing degrees of human-likeness for the game partner were introduced. The study showed that the tendency to infer the mental state of the counterpart increases linearly with its perceived human-likeness. We leverage a similar scenario using the trust game to explore the behaviors and justifications when people are asked to trust a humanoid robot, investigating why different brain regions activate when trusting a robot.

Psychologists have studied how people build trust for decades, investigating the features people use to evaluate trustworthiness, as well as models for how people build and re-evaluate trust through social interaction. For example, previous research shows that when people evaluate the suspicious nature (or trustworthiness) of others, cues such as facial expression [2], gender [3], age [4], race, and nationality [5] influence the initial assessment. We leverage these results by including some social cues – facial expressions, postures, and gaze – in our humanoid robot's behavior design.

Social cues can be used in a trust model – the overall process of building and maintaining trust between two people. One model is to make an initial assessment based on available information (e.g. social cues experience), and then update this judgement based on subsequent interactions with the counterpart [17]. This human-human (h-h) social trust model behavior can be partitioned into two: the initial, and the iterative assessments. This is consistent with other works [18], which portrays trust as building incrementally as a result of the trustee's choices to reciprocate cooperation, and declining drastically when the trustee does not to reciprocate. This process is often referred to as a tit-for-tat strategy, and has been demonstrated to be the optimal strategy for repeated h-h interactions [17]. We use this framework as a starting point, and investigate if and how these models emerge from people's interactions with robots, exploring differences that may occur only with robots.

III. METHOD

A. The Game

To evaluate and measure social trust, researchers use the trust game as a proxy for everyday situations involving trust

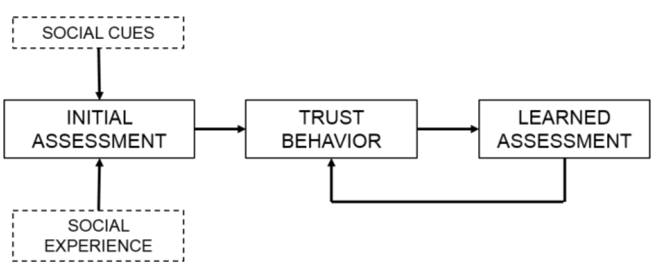

Figure 1. Human-human trust model [17].

[6]. This simple game involves two players, named the investor and the trustee. The investor is endowed with an initial amount of money and can choose to invest any amount of this endowment with the trustee. The amount that the investor invests is multiplied by the experimenter, and handed to the trustee. Following, the trustee decides how much of this enlarged endowment, if any, they would like to return to the investor. The trustee can choose to repay the investor's trust by returning more money than was initially invested, based on the enlarged amount they received after the invested multiplied. However, they can decide to return only the invested amount, or to abuse the investor's trust by keeping all (or most) of the money. In our study design we made the robot – Baxter – the trustee although other scenarios are possible, forcing the investor, a person, to evaluate the trustworthiness of the robot with their money. Additionally, Baxter's investment (money) will always triple, and he will return half of this new amount (rounded up) to the investor.

B. The Robot

For the pilot study our robot was Baxter, a humanoid robot built by Rethink Robotics [19]. It is a 3-foot tall robot with two 7-degree-of-freedom arms and an LCD screen head.

1) Idle Movements

As the human body is constantly moving, it always communicates the notion of being alive. Based on this idea, if a robot stops moving during idle periods of the social Human-Robot Interaction (sHRI), it appears inanimate and lifeless [20]. Therefore we designed a set of idle motions in order to provide a basic "illusion of life" and to reinforce the perception of the robot as a social actor. Figure 2 illustrates some of the robot's motions such as blinking, opening and closing grippers, gazing, among others (please also see the accompanying video figure for more details).

2) State-machine: Physical and Mental States

Baxter behaviors were partitioned in a finite-state machine that includes six physical states and five mental states. As described in Figure 4, each physical state establishes a series of physical actions that are sequentially applied to the robot. Note that the states were named as a manner to relate to the intent of their actions: state N stands for neutral, R for random, A for game administrator, P for player, S for screen, W for watchful, and G for play gesture. Figure 3 depicts the series of actions executed for each state – actions we specifically designed to make the robot appear more attentive.

Besides the state-related physical actions, there were actions that can be manually performed. To increase the robot's social presence, whenever the participant repeatedly looked to the robot, a hidden key would be pressed so the robot would

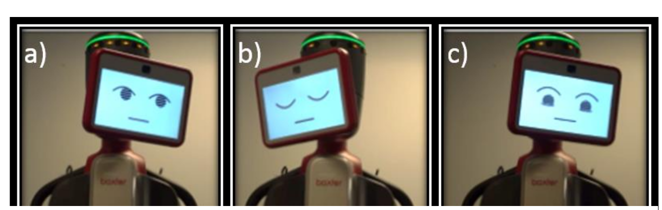

Figure 2. Examples of the robot's idle movements: gazing (a), blinking (b), and looking down (c).

STATE	PHYSICAL ACTIONS
N	Baxter moves its head to a random position; sets its eyes facing forward; sets neutral pose.
A	Baxter sets its eyes towards the administrator; moves its head towards the administrator.
P	Baxter sets its eyes towards the player; moves its head towards the player.
S	Baxter sets its eyes towards the screen; moves its head towards the screen.
W	Baxter gazes the administrator; sets watchful pose; squints its eyes.
G	Baxter sets play gesture pose; gazes the administrator; gazes the player.
R	Baxter performs idle movements.

Figure 4. Description of the robot's physical states.

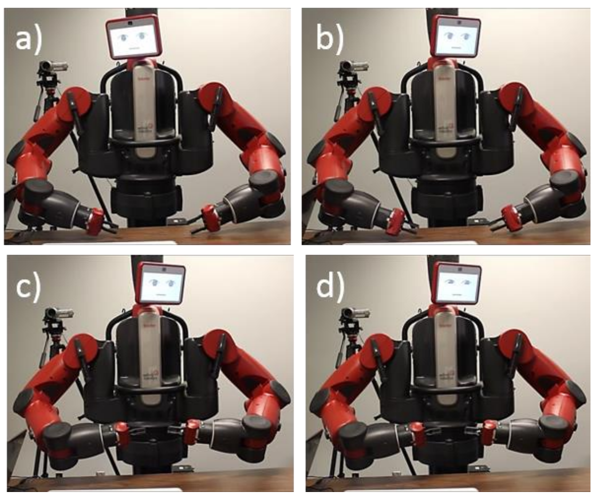

Figure 3. Set of actions performed by the robot on the W state: briefly gaze at A1 (a), return its look to the screen (b), to set the watchful pose (c), and to squint its eyes (d).

look back to the player, thus providing a more convincing behavior of being alive and aware of the environment. Yet, note that this manual control could be fully automated by implementing computer vision algorithms for tracking the participant's face (Figure 5).

Besides the physical states, the state machine also includes mental states: NO_FOCUS, FOCUS_A, FOCUS_P, FOCUS_S, and FOCUS_G. The transition between mental states occur automatically based on the combination of the transitions of the physical states. Note that the mental states were named as a manner to provide clues about its intended cognitive condition. For instance, FOCUS_A suggests holding a focus on the game administrator.

As can be observed in Figure 6, each mental state specifies a set of idle movements that the robot performs at the referred mental condition, and the rate of occurrence for each movement. The mental states were created to reinforce the robot's social presence. The body parts movements (or the lack of them) may reveal clues about the robot's inner state. On the other hand, we also believe that changes on the frequencies of occurrence of idle movements may create a richer communication channel between the human and the robot. For instance, in FOCUS_G state, the robot gazing to either the administrator

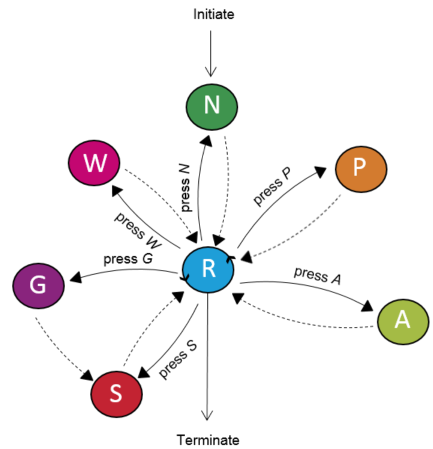

Figure 5. The robot's physical state transitions.

or the participant in a low frequency may be interpreted as being more focused on the game screen; yet, on this same mental state, the robot blinking and opening and closing its grippers in a slightly high speed rate may be viewed as it being anxious while deciding its game move.

3) Behavior Script

While the transitions between mental states are fully automatic, the transitions between the physical states can either be automatic or manual - that is, secretly performed by A2. In this sense, it is important to note that the transitions between the physical states followed a script in order to ease the replication of Baxter's behavior throughout the pilot sessions and, thus, to avoid bias on the results. As can be observed in Figure 7, the script was structured in accordance to the sequential procedures defined in the game protocol.

C. Protocol

While running the pilot study, we followed a protocol to increase replicability. After introductions to the researchers and the robot, the trust game is described, and demonstrated once with the A1 explaining possible investment decisions and possible implications. The participants are told the trust game is able to evaluate trust in a mutual-gain scenario. They are then then given a pre-study questionnaire that aims to understand what strategies people *intend* to apply while playing the trust game with the robot, and how they initially plan to judge the robot's trustworthiness, including questions such as *how much money do you expect Baxter to return?* and *why do you expect Baxter to return this amount?*

The participants are then asked to play one round of the trust game with Baxter. The investment and return amounts are decided by watching a monitor with different amounts of money displayed. As time passes, a cursor highlighting one amount slowly rotates through all options. When the desired amount is highlighted, the investor or trustee raises their hand to select that amount. This is to avoid the linguistic complications in a trust scenario. Following, we administer the post-study questionnaire with a brief interview. The aim of these were to complement the pre-study questionnaire in order to get further information regarding the human's expectations and impressions towards Baxter before and after the game. The post-study questionnaire includes three GODSPEED questionnaires [21], which measure participants' self-reported impressions of robots after an interaction by using Likert scales

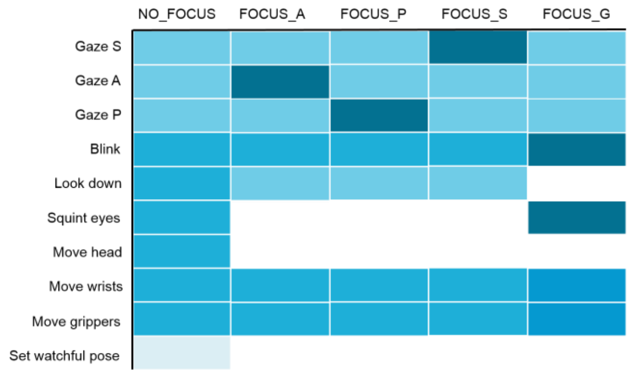

Figure 6. Description of the robot's mental states. Each mental state specifies a series of idle movements that may be performed at different frequencies – from zero (white) to high (dark blue) rates.

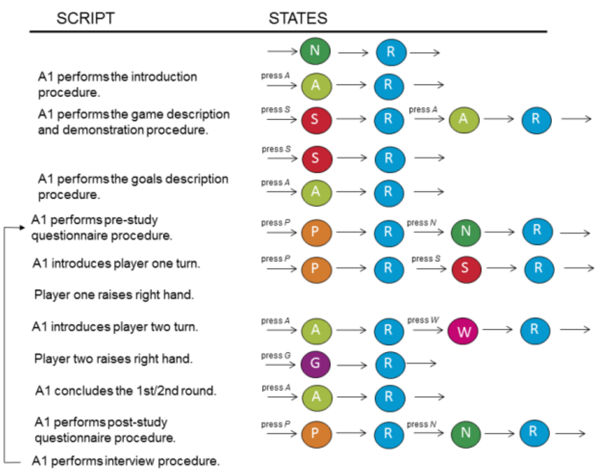

Figure 7. Behavior script describing the physical states transitions throughout the experiment.

for a number of questions for a number of categories. Specifically, we use the categories that evaluate how the participant perceives robots as social entities: anthropomorphism, animacy, and perceived intelligence. These measures are important as, according to the CASA paradigm [7], humans socially respond to machines only when they provide a minimum number of social cues. In addition, we included additional questions to see how people trust evaluation strategies changed, if at all, after the interaction.

The participant then repeated the pre-study, trust game, and post-study sessions. The purpose was to allow us to analyze both the participant's behaviour with no previous information regarding Baxter, as well as after they had acquired some knowledge of Baxter's trustworthiness.

1) *Experiment Layout*

Figure 8 shows an overview of the spatial setting of the game (please also see the paper accompanying video-figure). As can be observed, the participant is seated opposite across a table from the robot. To the left of the participant are the two administrators. Administrator One (A1) is responsible for explaining the game protocol's procedures; secretly controlling the game interface; conducting the pre- and post-study questionnaires; and monitoring the questionnaire responses on a laptop while interviewing the participant. Administrator two (A2) is responsible for secretly operating Baxter following a Wizard-of-Oz algorithm. To the right of the participant is an inactive camera device used to provide the pretense of tracking the movements of both players. A large display screen (on the rightmost side of the setup) is showing the trust game interface. In front of the participant are two devices: a smartphone recording the participant's comments and interview outcomes, and a tablet showing the questionnaires and the responses. Lastly, two cameras are positioned to the left and right of Baxter to record the procession of the game.

IV. Results

We performed an explorative pilot study with 7 participants, some with a computer science – but not robotics or AI – background with the aim to explore potential research directions for more targeted studies for behavioral studies of the trust game. The analysis only includes 5 people, as two participants figured out the study was Wizard-of-Oz, potentially biasing their results to human-human trust models. Our quantitative results looked at change in investment for the second round with a one-way ANOVA, but no results were significant. Qualitative data (interviews, behavioral observations) was analyzed with iterative open coding: we tagged the data points with codes and iterated over these groups, updated classifications and merging and deleting codes to allow emergent themes form from the data. Only one coder was used, as this was a pilot with low participant numbers; our goal was to explore the trust game scenario for HRI, and discover initial insights for further investigation. We had three major themes emerge: human-like trust strategies, social trustworthiness evaluation, and leveraging and building social experience.

A. *Human—human like trust strategies*

As mentioned in the related work, one model of human-human trust is to perform an initial trustworthiness evaluation of someone and then update that evaluation iteratively throughout interaction, slowing increasing trust, but removing it suddenly if trust is broken. 3/5 Participants used the game strategy of starting by investing a lower amount of money and increasing it as trust is earned. These participants justified this decision by talking about trust earned. For example: "[I invested more] because [the robot] was trustworthy in the first time, so he deserved my trust"– P3, "I also decide to invest more because of Baxter's return from the first round," – P2, or "I maintained my level of investment (up until he becomes greedy)" – P6. These quotes follow similar reasoning and patterns to classic human-human trust behavior, suggesting that that people use similar trust building strategies with robots.

B. *Social evaluation of trustworthiness*

One indicator of treating the robot as a social entity emerged as people analyzing the robot for suspicious traits, much like people do for other people [17]. 2/5 participants explicitly stated that they evaluated Baxter through instinct: "I'm sort of going with my gut feeling" – P2, and "He looks trustworthy" – P3. These participants sometimes also alluded to explicitly evaluating Baxter's trustworthiness by appearance "[I made the decision] based on [the robot's] expressions" and that they looked at Baxter many times "in case any moment he had a malicious expression" – P3. This may mean that participants evaluated Baxter's trustworthiness as they would other people: by appearance (including indications of "malicious" or "trustworthy" intent), suggesting they may use social cues to evaluate even a robot's trustworthiness.

C. Leveraging and building social experience

Most people have yet to interact with a social robot, and so lack a past social experiences that would allow them to gauge the trustworthiness of the robot. Instead, we saw some participants experiment with the robot's behaviors, or reason about the robot's construction or programming to inform their decisions about the robot's trustworthiness. P5 invested less money on the second round, even though they received a positive return, stating they did it "to make sure he will pay me back at least the amount I have invested." It is possible that people may try to compensate for their lack of social experience with robots by directly experimenting with them.

Three participants made comments directly about the algorithms or programmers of the robot, for example P1 who said "the robot has only steps to follow in the artificial intelligence algorithm, while human decide based on life experiences." In this quote, P1 notes a difference between people and robots, acknowledging that different ideas may be necessary to judge a robot's trustworthiness (in this case, reasoning about the robot's algorithm). P3 mentioned that a programmer is likely to program a robot to be similar to a trustworthy human, but cannot be sure of that, diverting the trustworthiness reasoning from the robot to its human programmer. P5 thought "A machine…is a reflection of its creator…robots will follow this majority and be trustworthy," again reasoning about the people who made the robot. While this data sides with the hypothesis that people do not treat robot's as social actors with agency (trustworthiness is programmed by another), they still reflect on a robot's social trustworthiness behavior, differing on the source of that trustworthiness (an algorithm or programmer, not the robot itself). One possible explanation is that when deprived from the ability to reflect directly on their rich past experiences of trustworthiness in other people, participants fell back to the closet human present, reasoning on the creator or programmer behind the robot.

V. Discussion

Our pilot suggests that people may follow a human-robot (h-r) trust model that is similar to the human-human trust model (see [17] or Figure 1) while playing the game with Baxter. On one hand, the h-r model resembles the h-h model as it has an initial assessment and an iterative update. In this sense, almost all participants used the strategy of starting investing with a lower amount and increasing it as trust is earned. In addition, some stressed that they invested more money as they were expecting Baxter to continue to reciprocate the trust on the second round; however, if Baxter broke trust, they explicitly stated they would not trust it again. However, the h-r model differentiates from the h-h model on the initial assessment. The question that arises then *how do humans assess the robot's initial trustworthiness?* Our pilot suggests that participants may try either to leverage or to build social experience.

In the former case, we observed what may be people trying to leverage their social experience looking for "suspicious traits". While they were not able to specify the traits and how they analyzed them (perhaps suggesting a failure to find such traits), people mentioned they were looking for social cues (See Section IV.B). Previous research shows that when people evaluate the suspicious nature (or trustworthiness) of others, cues such as facial expression [2], gender [3], age [4], race, and nationality [5] influence the initial assessment. Yet, we did not observe any of these factors being taken into account in the robot's initial trustworthiness evaluation. We believe this may be because, as Baxter exhibits some social behavior, participants mentally modelled Baxter as the closest entity they knew that had similar social behavior: other humans. However, since Baxter did not have nearly a sufficient range of social cues defined, participants' social experiences with other people were not as useful for determining the robot's trustworthiness.

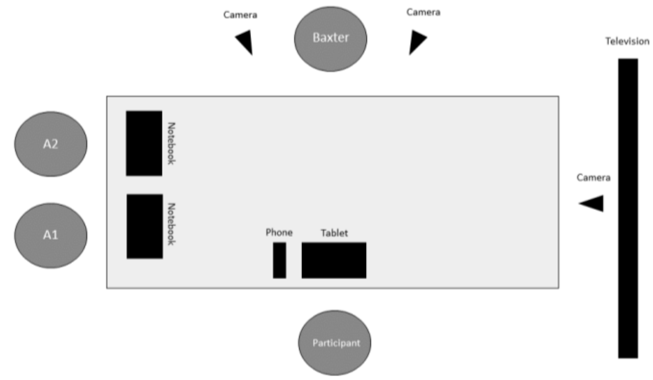

Figure 8. Layout of the sHRI Trust Game realization

On the latter case, we observed participants trying to create a stock of social experience either by leveraging general knowledge about robots and machines or by directly performing their own social experiments. We saw participants reason about artificial intelligence, algorithms, robots being built to resemble honest human models, and the people who build the robots - that is, people drawing on their general knowledge about robots and machines in order to understand the robot's social behaviors (Section IV.C). Also, we saw participants experiment with Baxter, testing it by giving Baxter more or less money and observing the game results (Section IV.C). Therefore, we suggest that in lieu of applicable social experience, our participants may have been attempting to create that social experience or fill it with other general knowledge.

Based on the above-mentioned rationale, we hypothesize that participants perceive robots as social actors and thus try to respond to them socially – as noted in HCI and HRI academia – by evaluating its initial trustworthiness and by using previous interactions to calculate trustworthiness in subsequent rounds. However, participants' social ground knowledge is not directly applicable to Baxter due to its deficiency of social cues present in humans. Thus, they try to fill in this gap by leveraging or creating social experience. This hypothesis perhaps explains why neuroscience has not detected similar activity in the brain during human-robot game scenarios: the brain cannot evaluate the robots based solely on social cues and experience. Thus, it turns to other ways to assess Baxter's trustworthiness.

VI. Future Work

Although our pilot provides an initial explanation for the cognitive process underlying the human social trust behavior towards robots, we aim to gain a greater understanding on the applied h-r trust model with a study including a multiple-round trust game in which participants will play against both humans and robots. This modification will allow the comparison between human-robot and human-human models. With increased number of rounds, we also plan on varying Baxter's return strategy; for example, we plan on comparing a generous strategy versus a selfish or neutral strategy, etc. Varying these strategies over time will also help understand how trust is built and destroyed with robots. As some of our participants detected the Wizard-of-Oz setup, where the controller was in the same room, the controller should be in another room. Finally, it is likely important for the participant invest real money (e.g. part of their honorarium) to increase participant's personal investment in the outcome.

A number of extensions are possible for this research. One alternative is to switch the players' roles so the participant acts as the trustee and the robot operates as the investor and investigate whether humans would return any money to the robot (reciprocation of trust [18]). It is an open question if people feel obligated to follow this social rule as money may not be seen as something a robot desires. All angles could also be investigated by adding or modifying a variety of social cues to the robot such as gender, facial expressions, embodiment, etc.

VII. CONCLUSION

This paper integrates theories and results from behavioral economics, neuroscience, and human-computer interaction to gain an initial understanding about how humans perceive and respond to robots in a social situation such as the trust game. More specifically, we conducted a pilot study to analyze human trust behavior towards robots in a two-round, not blind trust game. Our preliminary results suggest people still apply their human-human trust models to the robot, but due to lack of social cues and social experience with robots, the model fails, so people leverage other knowledge and try to build new experiences to better apply their existing model.

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