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How Movements of a Non-Humanoid Robot Affect Emotional Perceptions and Trust

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Abstract
The way that we move often carries emotional meaning that the people with whom we interact are adept at detecting. Humans treat the movements of robots similarly, attributing the same emotions when the robots move in ways that are analogous to emotionally-charged human movements. However, this HRI work has primarily been done on humanoid or animal-shaped robots. In this paper, we examined whether this effect would hold when people observed the movements of a non-humanoid robot, Cozmo. Moreover, the attribution of emotional stance to another agent is key in the process of predicting the behavior of the other (Eivers AR et al. in Br J Dev Psychol 28:499–504, 2010). This process is laid bare in transactional scenarios where the predicted level of trust guides the humans behavior. The ultimatum game is a transactional framework that we have adapted to allow us to test in stages how humans predict and react to the behavior of the robot. We performed a study in which people played two rounds of the ultimatum game with a non-humanoid robot that moved in either a positive or negative manner. We found that in both rounds people in the Positive Movement condition rated Cozmo's emotional valence as higher than those in the Negative Movement condition. In the second round, after Cozmo had responded to the first offers that the participants made, Cozmo's bid response was a significant factor in the Positive Movement condition, in which participants whose first bids were rejected by Cozmo rated its emotional valence as lower than those whose bids were accepted by Cozmo. There was not an effect of movement on trust. We also ran a series of exploratory analyses to explore how various factors affected participants' reasonings about Cozmo's behavior, and found that unexpected, non-social behaviors (such as moving in a negative manner or rejecting a participant's offer) lead to an increase in anthropomorphic behavior explanations.

Keywords Human–robot interaction · Trust · Movement · Emotional perception · Body language

1 Introduction

In human–robot interaction (HRI), the use of humanoid robots in research is quite prevalent, beginning with landmark research at the field's conception with Kismet [10] and Cog [12]. Humanoid robots continue to dominate current research in social robotics, with popular platforms such as Nao, Pepper, Vizzy, Kaspar, Emys, and iCub [19,38,51,52]. Extremely humanoid robots such as Ishiguro's Geminoid Robot series [53] and Hanson Robotics' Sophia robot have captured public attention and fascination. Additionally, many non-humanoid robots seen in HRI research take the forms of commonly-recognized animals, such as Paro (baby seal), Sony's Aibo (dog), and Innvo Lab's Pleo (dinosaur). Since all of these morphologies are models or variants of existing species, it is difficult to disentangle a humans emotional response to the robot from their automatic recognition of its biological model.

To probe the full range of the human responses to embodied emotional expression, we propose to use systems that move without limbs or other forms of biomimetic propulsion. While researchers can move the bodies of robots in ways that mirror human movement and expression [62], the humanoid body's shape and movement, in the form of gestures, invokes

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our anthropomorphic response in a manner proportional to the human-like quality of the movement [58]. This manipulation of the human response extends from gestures to faces and the posture of the whole body [32]. This human susceptibility to anthropomorphic responses appears to encompass not only simple emotional reads, but also dyadic transactional properties such as trust [70]. Given the central role that trust plays in the interaction of humans and robots, from teamwork [55] to companionship [64,69], it is essential that we understand the relation between trust, emotion, and movement.

Exploring the automatic inferences that humans make when they interact with humanoid robots brings with it a pronounced challenge that may be overcome with non-humanoid robots. The Uncanny Valley effect evokes strong negative emotional reactions to properties in the robot that are nearly human. This effect interacts with emotional inference directly; when people read about humanoid robots, the ones with the ability to experience emotions are viewed as more eerie than counterparts described as tools [1]. Thus moving the robot's morphology away from a humanoid form may create emotional distance that allows for increased social interactions and comfort, ironically. In a longitudinal study, children with severe intellectual disabilities were more engaged with a non-humanoid robot (LegoStorm) than a humanoid (Nao) [2]. But that emotional distance may incur a cost, with non-humanoid robots deemed less credible than humanoid counterparts [71]. If credibility is related to trust, and we predict that it is, then with non-humanoid robots we have a class of instrument—variable along many different dimensions of shape, size, and movement that allows us to test hypotheses related to human emotion and trust.

Non-humanoid robots can take any form so long as it lacks the morphology of a human or humanoid. With a different morphology, a non-humanoid robot is forced by the physical differences to generate movements—postures, gestures or whole-body movements—that are different. Therefore, if the robot is going to interact with humans and be emotionally expressive, it cannot rely on directly mirroring human bodily expressions to communicate its state. Following that, if these movements do effect a person's interpretation of a robot, it is important to understand if that interpretation affects other aspects of the interaction, such as the person's trust in the robot. The aim of this paper, therefore, is to investigate the role that movement has in emotional expression of a non-humanoid robot, and subsequently how that affects trust in human–robot interaction. Specifically, we are interested in the following research questions: (1) Can people interpret the emotional expression of a robot through movement when the movement is done by a non-humanoid robot? (2) Do the movements themselves, or a person's interpretation of the movements' emotional content, affect how much a person trusts a robot as seen through the reciprocal lens of the ultimatum game? To address these questions, we performed an experiment in which participants played the ultimatum game with a non-humanoid robot, Anki's Cozmo. We hypothesize that different movement styles will be perceived as expressing different emotional content, and that those perceptions will subsequently affect a person's trust in the robot.

2 Background

2.1 Emotional Expression

Humans have a variety of ways to non-verbally express emotions. Ekman's famous theory states that humans are able to recognize six basic emotions from facial expression alone [26]. While it is undeniable that faces are an important modality for emotional expressions, other theories have pushed back and said that emotion interpretation requires the interpretter to see the expressor's full body [4]. And even without considering faces, bodies are certainly an effective modality for emotional expression. We can make gestures [30] or subconsciously alter our posture [16] or movements [14] to reflect our emotional state.

We can utilize this human bias for interpreting emotion in agents when we design robots. There are some modalities that robots can utilize that humans cannot that are interpreted as being emotional, particularly changing colors on various body parts. Naos have LED eyes that can change color, and researchers have found that their eye color can be used to express emotion [37]. Color can also be a tool for emotional expression in non-humanoid robots. Terada et al. [63] found that color was an effective medium for emotional expression for a color-changing sphere robot. Like humans, however, a robot's body seems to be particularly useful for expressing emotions. While some researchers utilize a combination of color expression and body language [35], others rely on just the robot's morphology. Robots with human-like faces such as Kismet can directly mimic human facial expressions and have an emotional exchange with people [10]. Researchers have found that people can recognize a humanoid robot's body posture meaning in the same manner they can recognize a human's [50]. In a study in which participants were asked to position a Nao's head to display various emotions, most people chose roughly the same positions for most emotions [34]. This may suggest that what we recognize as emotional expression in human body posture can be easily translated to humanoid robots as well. Robot body language has also been used by researchers to help supplement emotional expression in those who cannot express it themselves. Valenti et al. [66] developed a model to detect emotion through text and have that emotion be expressed by the gestures of a Nao; this can be applied in instances such as people with Parkinson's Disease who sometimes lose control of their muscles and cannot express emotion using their own face or body. While static body language can be useful, body movement is especially expressive.

2.2 Body Movement as Emotional Expression

Body movement seems to be a particularly robust modality for emotional expression. People are so attuned to emotional expression in body movement that they are correctly able to identify many emotions just by the movement of light points placed at various joints along a human body [15,24]. Dynamic movement of these minimal light-point emotion cues has been found to be more useful for interpreting emotion than static cues [3]. This precise attunement seems to begin early in life; children as young as four and five years old have been shown to be able to identify happiness, sadness, fear, and anger based on emotionally expressive dances [9].

In robots, the use of body movement may be thought of as an artificial signal that may be used to affect human perception of or behavior towards a robot [33]. Ease of interpreting emotional expressions through body movements has been shown to translate to humanoid robots [50]. Multiple studies have found that participants were able to accurately perceive the emotions of robots that mimicked human body language. Häring et al. [32] found that when combining body language, eye color, and sound as the means of emotional expression on a Nao robot, body movement was the most reliable. Other researchers have shown that a Nao is a suitable platform for people to interpret emotional expression through body language [5,28]. Similar to human–human interaction studies, [6] showed that these results hold for adolescent children. Zecca et al. [72] developed a new humanoid robot, KOBIAN, and found that its emotions were best interpreted through a combination of facial expressions and body movements. Additionally, people are able to recognize the body movements of robots that are shaped like familiar animals; [43] built a dog-like robot and had it move in a dog-like manner to express emotions and found that people were able to attribute the proper emotional label to it. Adding animal-like features, such as lizard-like ears and a cockatoo-like comb that moved in ways analogous to their animal counterparts, improved participants' interpretation of emotional expression of the robotic face EDDIE [42,61]. Koay et al. did not use a dog-shaped body, but did mimic an assistive hearing dog's behavior in a non-humanoid robot, and found that participants were able to recognize the robot's intentions through its body movements [40].

Not only do body movements allow for people to better read the emotional expression of a robot, they can also affect a person's implicit perceptions of the robots. Destephe et al. [23] found that when people watched a humanoid robot perform different emotionally-charged gaits (happy or sad), participants could not explicitly tell the difference in emotional content of the gaits; however, the different gaits did affect people's perceptions of the robot. The sad robot was seen as more anthropomorphic and less intelligent, and a robot that walked normally (i.e., without an emotional charge) was more likeable.

While humanoid robots can directly mimic emotionally-packed body movements, therefore increasing the ease with which people can interpret the robot's behaviors, non-humanoid robots cannot rely on our attunement to the meanings of humanoid body shapes. Because the embodiments of non-humanoid robots are fundamentally different, body movement is one of the few emotional expression modalities that cannot be directly translated between humanoid and non-humanoid robots. Both types of robots could say the same emotionally expressive sentence if they have speech abilities, or make the same noise, or light up the same color if there are LEDs on their bodies. However, their different morphologies mean they must move in different ways. Despite this fundamental difference, there is less research about if the effects seen with humanoid robots hold up when the robot in question is non-humanoid and non-animal-like. Tsiourti et al. [65] asked if people could tell the emotional expression of two robots that varied in their level of humanoid-ness, Pepper and Hobbit, through their either faces, heads, voices, bodies, or locomotion. They found that humanoid-ness did not affect the reading of emotional expression but expression modality did, with the face, head, and locomotion expressing emotion the best. It is worth noting that even though Hobbit was considered their non-humanoid robot, it still had two eyes and a mouth for its face, and two arms and a torso-like structure. Novikova and Watts [54] developed a framework using nuanced and complex approach and avoidance behaviors to indicate various broad emotions like happiness, anger, and surprise, and more subtly different emotions like sadness, shame, and disgust. They showed this framework worked for people to recognize fear, anger, happiness, and surprise in a non-humanoid robot. Though the movements that the researchers developed were tested through a non-humanoid robot, each behavior was made to be able to map onto a humanoid robot as well. The movements, therefore, were still potentially recognizable to people because they could be easily thought of as having an equivalent movement on a humanoid body. It is less clear that movements performed by a non-humanoid robot that are not easily mapped to humanoid movement would be recognized for their emotional expression.

2.3 Trust

Trust in a robotic agent is an important aspect of HRI that can be affected by a number of factors. Without knowledge of an agents reputation, Landrum et al. [44] theorize that people rely on superficial, observational cues over the course of an interaction in order to gauge how trustworthy the agent is. This coincides with the importance of non-verbal, superficial cues such as emotional expression [8] and movement [57] as being indicators of trustworthiness. In human–human interaction, a person's emotional expression can affect how trusted they are by someone with whom they have no prior acquaintance, with expressions of happiness being conducive to trust, and expression of anger being detrimental to trust [7].

Broadly, factors that affect trust in human–robot interaction can be thought of as affecting a performance-based trust in the robot or a relation-based trust in the robot. Performance-based trust concerns the trustor's assessment of the robot's ability to complete a goal capably and reliably, whereas relation-based trust concerns the trustor's assessment of the robot as a social agent in the world [46]. Relation-based trust factors are often similar to Landrum's Reciprocal Trust Theory in that they are more often based on superficial cues about the robot than about knowing the robot's actual capabilities that may make it trustworthy. One such relation-based trust factor is the robot's level of anthropomorphism. Numerous studies have found that anthropomorphism in robots and machines increases trust [67] [70] [39]. However, others caution the assumption that more anthropomorphism is always beneficial for trust. Mathur and Reichling [49] showed that subtle anthropomorphic cues that cause a robot to fall into the uncanny valley negatively affect trust. Culley and Madhavan [18] warn that overly anthropomorphizing a system may cause a person to assume that it is more capable than it actually is, leading the person to over-trust the system. Over-trust can result in over-reliance on an imperfect machine [31]. Therefore, it is not clear that a humanoid robot that is already anthropomorphic is the best thing to use in cases where a person needs to trust a robot while minimizing the risk of over-trusting it.

Along with anthropomorphism, there are many other relation-based factors that can have an effect on a person's trust in a robot that has nothing to do with the actual capabilities of the robot. A similar result to the finding that happiness is more conducive to trust than anger is in human-human interaction [7] has been seen in human–robot interaction. When asked why children trusted a robot they were interacting with, [68] showed that children explained that the robot is nice and friendly. Additionally, a robot that is emotionally intelligent, empathizes with a person, and offers kind support has been shown to be trusted more than a robot that has no emotional intelligence and is non-empathetic to a person's situation [45]. Other relation-based factors that affect trust are emotional expression and movement. Savery, Rose, and Weinberg [60] showed that a robot that expressed emotions through musical prosody and gesture was trusted more than one that did not express emotions. Reinhardt et al. [57] found that a person's trust in a robot can also be influenced by the robot moving in either a dominant or submissive manner. However, it is not clear if the combination of these effects, emotional expression through movement of a non-humanoid robot, has an effect on trust.

In this paper, we use Rahman and Wang's [56] definition of trust, i.e., "Human's trust in the collaborating robot is the willingness of the human to rely on or to believe in the cooperation provided by the robot." We use the ultimatum game as our interaction platform to test for trust. The ultimatum game, described in more detail below, highlights trust as an expectation of cooperation and reciprocity. Interactions between humans contain a level of reciprocity; humans apply this same understanding of reciprocity when interacting with robots during the ultimatum game [59]. The expectation of this reciprocity, therefore, can indicate trust in the robot.

3 The Current Study

The current study tested whether a simple set of movements in a non-humanoid robot can induce changes in perceived emotional expression of, behavioral interactions with, and trust assessment of the robot. To assess this, we had participants play two rounds of the ultimatum game with our non-humanoid robot, Cozmo. In the ultimatum game, one agent, agent A, has a set of resources (here, the resources are ten pieces of candy). They get a chance to offer as much of their resource as they want to the other agent, agent B. If agent B accepts the offer, the two agents split the resource accordingly. However, if agent B rejects the offer, then neither agent A nor agent B get anything. In our study, the human participant played the role of agent A and got to choose how to split their resources between themselves and Cozmo, and Cozmo played the role of agent B, either accepting or rejecting the offer. We varied the emotional valence of Cozmo's movements, making Positive Movement and Negative Movement conditions. In the second round of the game, Cozmo's response to the participant's first offer acted as an independent variable, because the bid response could have provided Cozmo with a reputation that could override the initial first impression it made. We offer the following motivations, hypotheses, and predictions.

H1 is motivated by approach/withdrawal theories [20]. The Positive Movement condition involves exploratory behavior in which Cozmo approaches the participant. Exploratory behaviors indicate a low level of anxiety and willingness to be social in biological organisms, general positive emotions [17]. The Negative Movement condition involves withdrawal behavior in which Cozmo turns away and retreats from the participant. Retreat behaviors indicate fear in biological organisms [11].

- **H1** Different movement styles will be perceived as expressing different emotional content.
  - *P1* Participants in the Positive Movement condition will interpret Cozmos emotional state as more positive than participants in the Negative Movement condition.

H2 is motivated by Landrum's Reciprocal Trust Theory [44]. By the second round, Cozmo will have garnered a reputation based on its response to the participant's first bid. This reputation will supersede the superficial, observational cues they used to judge Cozmo in the first round. Its reputation will color their perceptions for the second round.

- **H2** Cozmo's reputation will affect perceptions of emotional content in the second round.
  - *P2* Participants whose first round offers were accepted by Cozmo will interpret Cozmo's emotional state as more positive than those whose first round offers were rejected by Cozmo.

H3 is motivated by the work on trust that shows that agents that are nice and friendly are trusted more than agents that are angry. This effect is found in both human–human interaction [7] and human–robot interaction [45,68]. The measure of trust, the expectation that Cozmo will accept their bid, is based on our definition of trust, i.e., the human's willingness to believe in the cooperation of the robot [56].

- **H3** Perceptions of Cozmo's emotional valence will affect a person's trust in Cozmo.
  - *P3* Participants will trust Cozmo more, i.e. be more likely to think that Cozmo will accept their bid, if they judge Cozmo to be in a more positive emotional state.

4 Methods

4.1 Participants

Eighty-four undergraduates at Vassar College participated in the study. They were recruited from Vassars on-campus dining hall, where the study was run. Participants were invited to participate by the researcher. Participants were compensated with up to 10 pieces of candy of their choosing after completing the experiment.

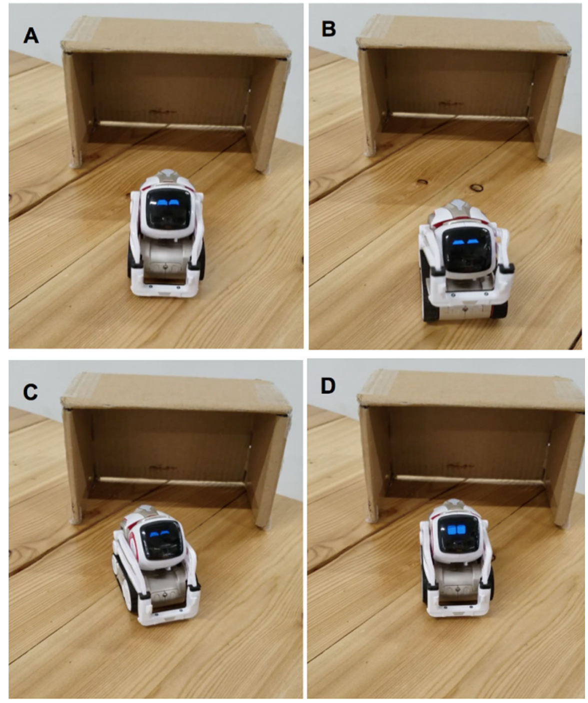

Fig. 1 Cozmos Positive movements. Cozmo starts in the hutch, makes noises, comes out, makes another noise, and then acts "Positive by squinting its eyes (1A), lifting its plow up and down (1B), and wiggling back and forth (1C). When the initial positive movement is done, it performs idle positive motions and facial expression, which include rocking slightly back and forth with its eyes wide (1D), or moving its plow slowly up and down with squinted eyes

4.2 Procedure

When participants first sat down, Cozmo was hidden in its hut. From a script, they were then told "This is Cozmo, a mobile robot. You and Cozmo are going to play a game, at which point Cozmo was revealed, they were told the rules of the ultimatum game, that Cozmo is able to make its own decisions about whether or not to accept an offer, and that Cozmo has both a camera and a microphone. Then, they were told that Cozmo was going to meet them. Cozmo then came out of its hut and performed its movements respective to the experimental condition (see Figs. 1 and 2).

After Cozmo performed its initial movements, participants were told to pick out their ten pieces of candy, of which they had the choice between M&Ms and Skittles. They wrote their offer down on a piece of paper "so that Cozmo could not see it. They were then asked if they thought Cozmo would accept that offer, and why. Both of these answers were given verbally in both experiments. Then they rated Cozmos emotional valence on a negative to positive scale of 1-7. After they finished, Cozmo was "informed of their offer, and randomly accepted or declined it by saying "Yes or "No. Participants were informed of Cozmos decision. Participants were then told that they would play again and could change their offer

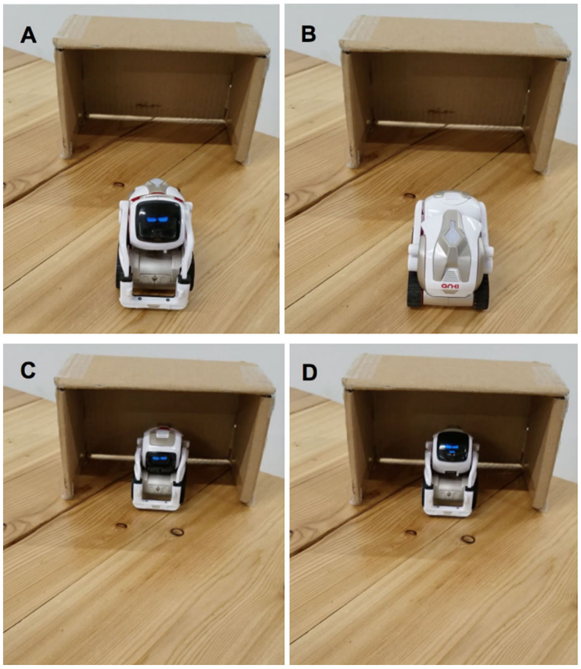

Fig. 2 Cozmos Negative movements. Cozmo starts in the hutch, makes noises, comes out, makes another noise, and then acts “Negative by squinting its eyes in a glare (2A), moving back and forth as if it was shaking its head, retreats back to its hutch (2B), and then stays there with glaring eyes (2C). When the initial negative movement is done, it performs idle negative motions and facial expressions, which include glaring and snapping its plow up and down in an aggressive manner (2D), and shaking in an agitated manner

or keep it the same, and the procedure from the point of deciding on an offer was repeated. Following Cozmos response to the second offer, participants were told that they could keep all of their candy then asked to fill out a final questionnaire regarding their previous exposure to robots and their comfort with computers, and then were debriefed.

The experiment was approved by Vassar College’s Institutional Review Board.

4.3 Conditions

There were two Cozmo Movement conditions: Positive and Negative. Cozmos behaviors were built from a combination of behavior packages built by Anki, the company that created Cozmo. In both conditions, the instructions were read to the participant and then they were told that Cozmo would now meet them. In both conditions, Cozmo at that point made initial vocalizations as if it were speaking. In the Positive condition, after making vocalizations, Cozmo would move out of its hut towards the participant, look up at them, make a second vocalization, then squint its eyes in a positive manner, move quickly back and forth while moving its plow slightly up and down, wiggle quickly side to side, move its plow up and down more, and then approach the participant (Fig. 1). In the Negative condition, Cozmo would follow the same sequence through making the second vocalization. Following that, Cozmo would narrow its eyes in a negative manner, move its body in a way that was analogous to a person shaking her head, then put its head down, turn 180°, and move back into its hut (Fig. 2). Cozmo would then wait five seconds after completing these initial movements (so the participant could choose candy and think about their offer) and then perform “idle movements for the remainder of the experiment. This involved randomly cycling through three behavior packages each for both movement conditions. The idle behaviors were intended to match the emotional valence of their respective movement conditions. In addition to unique movements, both conditions contained slightly different eye expressions, which may have contributed to the overall effect. Though we refer to the conditions as Positive Movement and Negative Movement, they can also be thought of as being Behavior Package A versus Behavior Package B. Analyses looking in closer detail at the individual behaviors, such as specific movements of the treads, lift, or eyes, are beyond the scope of this paper (we discuss the possible limitations of this in Sect. 6.1). See our Open Science Framework (OSF) page (https://osf.io/6pq5e/) for videos of Cozmo’s behavior.

4.4 Measures

We used a 7-point negative-to-positive Likert scale to measure participants’ interpretation of Cozmo’s emotional valence. We refer to this measure in the Results section as the participants’ *interpretation of Cozmo’s emotions*. We used the participants’ response to the question “do you expect Cozmo to accept your bid?” as our measure of trust. Because the participants played two rounds of the ultimatum game with Cozmo, both of these measures occurred twice, once per game round. Our other dependent measure was the participants’ bids to Cozmo during the first and second rounds of the games, and open-ended responses to the question of why they had the expectation of Cozmo’s response that they did.

5 Results

5.1 Emotional Interpretation

To assess Hypothesis 1, the effect of Cozmo’s movement on participant’s ratings of Cozmo’s emotional state, we used an ordered-probit model [48]. This model accounts for the ordinal structure of Likert scale data, allowing us to draw inferences about the continuous latent factor underlying the responses (i.e., the participants’ interpretations of Cozmo’s emotional state). We fit this model using Bayesian methods [21,41].

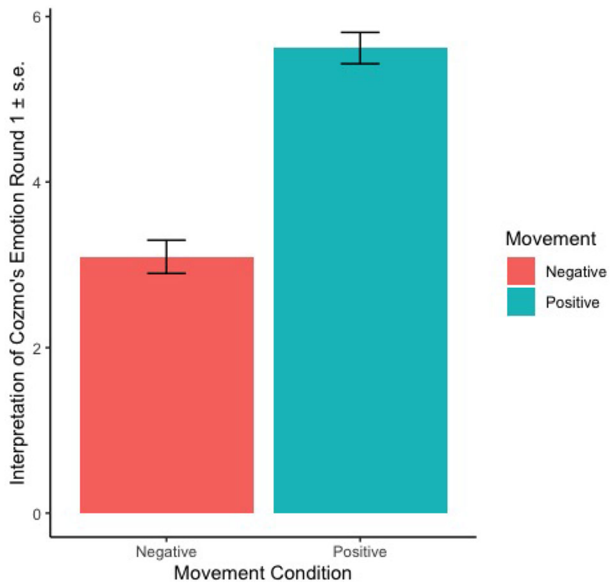

Fig. 3 Cozmo's emotional valence, first rating (mean ± 1 st. err.). The manner of Cozmo's movements drives how humans rate its emotions

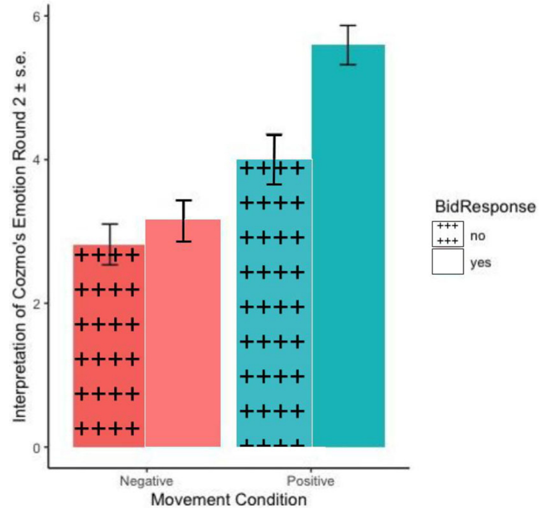

Fig. 4 Cozmo's emotional valence, second rating (mean ± 1 st. err.). After learning Cozmo's bid response, participants exposed to Cozmo's positive movements varied their reactions to the bid more than those exposed to negative movements

The model estimated that positive movements by Cozmo cause higher ratings of Cozmo's emotional state than negative movements. Participants who saw Cozmo's positive movements had a mean latent score of 5.56 (95% highest-density interval, 95% HDI: 5.07 to 6.05). Participants who saw Cozmo's negative movements had a mean latent score of 3.19 (95% HDI: 2.71 to 3.68). These parameter estimates are clearly non-overlapping, suggesting a strong effect of movement (Fig. 3).

The model also estimated the effect of Cozmo's bid acceptance or rejection, conditional on movement condition, on the follow-up rating of Cozmo's emotional state. This was done to assess Hypothesis 2. Here we found that a rejection by Cozmo led to a more negative interpretation of emotional state in the positive movement condition, with the mean latent score changing by -1.62 after bid rejection (95% HDI: -2.47 to -0.75). A rejection in the negative movement condition did not cause a reliable change in emotional interpretation, nor did Cozmo's acceptance in either movement condition (Fig. 4).

5.2 Trust

For the first round, because the participants gave binary responses, we fit a logistic regression to predict participants' stated expectation of whether Cozmo would accept their bid to assess Hypothesis 3. We take this expectation to indicate whether or not the participant trusted the robot to cooperate by accepting their bid. We used Cozmo's Movement condition and the participant's first interpretation of Cozmo's emotions as the predictor variables, and predicted that we would find that the likelihood of say "yes" would go up the more positive they rated Cozmo's emotional state to be. We found no significant effects ($\chi^2(2) = 0.031$, $p = .98$).

For the second round, we fit a similar logistic regression model to predict participants' expectations for whether or not Cozmo would accept the second bid. Cozmo's Movement condition, the participant's second interpretation of Cozmo's emotions, and Cozmo's previous bid response were the predictor variables, with analogous predictions to the first round. We found no significant effects ($\chi^2(3) = 0.38$, $p = .94$).

5.3 Exploratory Qualitative Responses

Based on our definition of trust being anticipated cooperation, we had assumed that our participants' expectations of whether or not Cozmo would accept their offer would be an indication of their trust in Cozmo to be a cooperative social partner. However, very few people responded "No" to this question, which made us reconsider its use as a trust indicator. In retrospect, this lack of "No's" makes sense; we asked participants to make an offer to Cozmo, which has the implicit assumption that the offers they made would be ones that they anticipated Cozmo would accept. Why would they make an offer that they would expect to get rejected? However, in addition to asking participants to provide yes/no answers about their expectations, we also asked them why they felt that way. These answers can provide us with some of the insight that our trust measure was lacking. We now turn to an exploratory qualitative analysis addressing the question of how participants reasoned about their expectations.

After participants said whether they expected Cozmo to accept their bid, they verbally provided a reason for why they

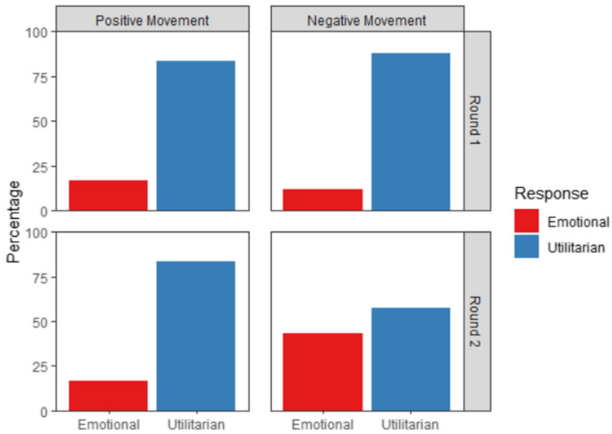

Fig. 5 Category of reasoning responses based on movement condition per round

held that expectation. We coded their responses into being either "Utilitarian" in which their explanation had something to do with the actual amount of candy that was offered or about the expectations of the game itself, or "Emotional" in which their reasoning had to do with Cozmo having an emotional state or something that did not have anything to do with the actual nature of the game. A clear example of a Utilitarian response is "Because I'm offering more than I am keeping for myself." Examples of Emotional responses are "He looks angry squinting and drumming on the table" and "Maybe it doesn't want me to have candy." Borderline examples that were coded as Utilitarian were "What if he doesn't want any? But if he does, how many would he want?" and "Because it's fair and we seem to get along." Borderline examples that were coded as Emotional were "Because I think Cozmo realizes he's still a robot and thus I'm superior so I made a fairly even offer but I think I deserve extra" and "Because it's pretty, it's all one color." A spreadsheet with all of the participants' responses and their coding are available at our OSF page (https://osf.io/6pq5e/). Because the experimenter was transcribing the participants' verbal responses as they said them, the responses are written in short hand.

First, we looked at whether the movement condition affected how participants reasoned. In the first round, Emotional responses made up 16.7% (7/42) of cases in the Positive Movement condition, and 11.9% (5/42) in the Negative Movement condition. In the second round, Emotional responses made up 16.7% (7/42) of cases in the Positive Movement condition again, but 42.9% (18/42) of cases in the Negative Movement condition. For the second round, therefore, it seems like negative movements may have resulted in participants attributing Cozmo with emotional states more than the positive movements did (Fig. 5).

Next, we looked at whether Cozmo's bid response after the participants' first offer affected their reasoning. Because Cozmo's bid response occurred after they gave their first explanations to their expectations, we only looked at the effect of Cozmo's bid response on their second round reasonings. Emotional responses made up 19.1% (9/47) of cases when Cozmo's bid response was "yes," and 43.2% (16/37) of cases when Cozmo's bid response was "no." Similar to how negative movements seemed to impact perceptions of Cozmo in the second round, Cozmo's non-cooperation, as indicated by rejecting a participant's offer, seemed to have an effect on participants in which they were more likely to attribute Cozmo with emotions than when Cozmo accepted their bid.

To see if participants' first response had an effect on their second response, we compared the two. When the first response was Utilitarian, the second response was Emotional 27.8% (20/72) of the time. When the first response was Emotional, the second response was Emotional 41.7% (5/12) of the time. Because there were so relatively few cases of Emotional first compared to Utilitarian first, it is difficult to draw conclusions from this.

Next, we looked at whether or not participants changed their reasoning between the first and second rounds, without considering the direction of that change, first based on movement then based on Cozmo's bid response. For movement, in the Positive Movement condition there was a change 23.8% (10/42) of the time; for Negative Movement, there was a change 40.5% (17/42) of the time. For Cozmo's bid response, when it was a "yes" participants changed their reasonings 19.1% (9/47) of the time. When the response was "no," participants changed their reasonings 48.6% (18/37) of the time. Bid response, therefore, seemed more likely than movement to have an effect on whether or not participants changed the rationale of their reasoning.

Finally, in the cases where the participants did change their reasonings, we looked at the direction of that change (i.e, Utilitarian → Emotional vs. Emotional → Utilitarian) as based first on movement, then on Cozmo's bid response. For Positive Movement, participants went from Utilitarian → Emotional (U → E) in 50% (5/10) of the cases. For Negative Movement, participants went from U → E in 88.2% (15/17) of the cases. For Cozmo's bid response, when the answer was "yes," participants went from U → E in 66.7% (6/9) of the cases, and when the answer was "no," participants went from U → E in 77.8% (14/18) of the cases. Those these sample sizes are small, there seems to be a trend of participants generally going from a Utilitarian reasoning to an Emotional reasoning, especially in the cases of the Negative Movement or Cozmo rejecting their bid.

6 Discussion

In the transactional context of the ultimatum game, people perceive the emotions of the robot Cozmo differently, depending on how Cozmo is moving. This corroborates Hypothesis 1, and coincides with other findings that saw humans reacting to non-verbal cues from a robot in the same manner that they would react to analogous non-verbal cues from humans [10,13,22,29]. A similar finding was seen in Johnson et al. [36] in which participants played a game with a Nao and were able to correctly identify what emotions the Nao was supposed to be expressing. Interestingly however, all of these studies used humanoid robots to evoke social cues from their participants. Here, in the context of the ultimatum game, we show that a non-humanoid robot can evoke the same types of perceptions and reactions despite its unique embodiment that required it to use different body language than humans or humanoid robots use. Thus these simple movement cues are general and, we argue, related to movement per se and not necessarily the specific morphology of the body that conducts these movements.

In the second round, we also see that the effect of movement supersedes Cozmos reputation as a determinant for peoples interpretations of its emotions if they were in the Negative Movement condition. Bid response had a significant effect on participants' interpretation of Cozmo's emotions in the second round only when Cozmo's movement condition was Positive. When the movement condition was Positive, participants whose first offers were accepted by Cozmo rated its emotional valence as significantly higher than those whose offers were first rejected by Cozmo. However, when the movement condition was Negative, there was not a difference in how participants rated Cozmo's emotions, no matter whether their offers were accepted or rejected. This finding, that reputation affects perceptions in only the Positive Movement condition, partially supports Hypothesis 2. Contrary to Landrum's Reciprocal Trust Theory in which learned reputation supersedes observational cues [44], this suggests that the superficial cues of movement were more powerful in determining how people perceive Cozmo's emotions when Cozmo was in a Negative emotional state.

The aforementioned Johnson et al. [36] study also found that the robot's emotionally expressive behavior did not affect how participants played or perceived the game. Similarly, and contrary to Hypothesis 3, we did not find that movement or bid response in either round affected whether participants trusted Cozmo, as defined by responding "yes when asked if they expected Cozmo to accept their offer. One explanation is that ours was an ineffective trust measure. Most people responded "yes" to the question of whether Cozmo would accept their offer. As previously discussed, participants were told to choose an offer to make, implying that it should be one that they would expect Cozmo to accept. It is possible that neither Cozmo's negative movements nor its non-cooperativeness in the first round were enough to convince people that it would act as a non-cooperative social agent. People may have had too great a relation-based trust in the robot's ability to conform to the social norm of cooperation, and its non-social behaviors were not enough to overcome that trust. Alternatively, the person's trust level may have affected the bid that they offered Cozmo, which they assumed Cozmo would accept since that was the decision they thought would make them most likely to win the game. The participants also may have interpreted Cozmo's bid-acceptance behavior as not necessarily collaborative, but rather hostile and a strategy that would allow it to win the game. This interpretation may have led participants to *not* trust Cozmo.

However, our exploratory analysis of the reasons that participants provided for their expectations of whether Cozmo would accept their offer seems to indicate Cozmo's non-social behaviors, i.e, moving negatively and rejecting participants' offers, did have an effect on how participants viewed Cozmo and reasoned about its behavior. When Cozmo was non-social, people seemed to be more likely to attribute a theory of mind to Cozmo, by way of describing its behavior through emotional explanations, than when it behaved in normatively social ways (i.e., moving in a positive, or friendly, manner, and cooperating in a social game). When Cozmo did behave in normatively social ways, participants readily attributed its behavior to abiding by the rules of the social game, and perhaps implicitly expecting that it understood how the game was expected to be played. Once Cozmo broke that norm, people needed new explanations for its behavior, and increased their anthropomorphism of it.

6.1 Limitations and Future Work

One limitation of the study is that participants were not particularly vulnerable during the ultimatum game. They were only playing for candy, which may not have been a salient enough motivator with which to play the game. Vulnerability is a key factor in trust, and lack of vulnerability may not have triggered the need to trust Cozmo [47]. Additionally, if the participants did not feel invested in the game, they would not care if Cozmo did not accept their offer. Additionally, they may not have believed Cozmo's role because, as a robot, Cozmo has no ability to eat candy and thus would not be motivated by the desire to win it. Future work should play the ultimatum game with a different resource. Additionally, future work should use a different measure of trust, as ours seemed to have a ceiling effect of trusting Cozmo to always cooperate.

Additionally, future work should further isolate movement as being the cause of evoking social cues by having Cozmos facial expression stay the same for both movement conditions. Though studies have shown that people can accurately guess someone elses emotion from a photograph of that persons face [4,27] found that people are actually mediocre at guessing emotions from a photo of a stagnant facial expression, and instead are cued more by body language. Our study had minimal facial expressions in the form of Cozmo's simple LED eyes. Future work should see if Cozmos facial expressions are a significant part of being able to manipulate peoples interpretation of Cozmos emotions, or if the body movement alone is sufficient.

Finally, the results of our qualitative analyses should be followed-up with studies made to test those findings specifically. These results could have interesting implications for factors that affect anthropomorphism, and perhaps varying levels of performance-based vs. relation-based trust. Expected social behaviors in a transactional setting like the ultimatum game may have an effect on performance-based trust because people anticipate that the robot understands how to perform in the game, while non-social unexpected behaviors may have an effect on relation-based trust because participants no longer believe the robot understands social norms. These should be followed up with studies of their own with better measures of trust.

7 Conclusion

We were successful in eliciting different emotional perceptions from participants by manipulating simple movements and facial expressions of a small, non-humanoid robot, Cozmo. Participants found the Positive Movement condition to indicate a more positive emotional valence than the Negative Movement condition. This finding is interesting in the sense that we used a non-humanoid robot that could not directly mirror human body language to express emotion. This emotional expression interpretation was then affected by the reputation that Cozmo built through its behavior in the ultimatum game; when participants were in the Positive Movement condition, they rated Cozmo's emotional valence as being more negative if Cozmo had rejected their previous offer than if it had accepted their previous offer. However, the Negative Movement condition superseded this reputation based on bid; in that condition, there was no difference in emotional perception based on Cozmo's bid response. Though participants' emotional perceptions of Cozmo were influenced by its movements, their levels of trust in Cozmo were not affected by how it moved or how it behaved in the ultimatum game. Exploratory analyses seem to indicate that the movement condition and Cozmo's bid response also affected how people reasoned about Cozmo's behaviors. This was seen to the effect of non-social uncooperative behaviors (i.e., moving negatively or rejecting a bid) leading to increased anthropomorphism in the sense of attributing emotional explanations to its behavior. This study was an attempt to begin to fill a gap in our understanding of how movement as an emotional expression modality affects a humans interaction with a non-humanoid robot. Our non-humanoid robot has shown itself to be an effectively emotive interaction partner.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have noconflict of interest.

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