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Is Perceived Intentionality of a Virtual Robot Influenced by the Kinematics?

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IS PERCEIVED INTENTIONALITY OF A VIRTUAL ROBOT INFLUENCED BY THE KINEMATICS?

by

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ABSTRACT

Research has shown that in Human-Human Interactions kinematic information reveals that competitive and cooperative intentions are perceivable and suggests the existence of a cooperation bias. The present study invokes the same question in a Human-Robot Interaction by investigating the relationship between the acceleration of a virtual robot within a virtual reality environment and the participants perception of the situation being cooperative or competitive by attempting to identify the social cues used for those perceptions. Five trials, which are mirrored, faster acceleration, slower acceleration, varied acceleration with a loss, and varied acceleration with a win, were experienced by the participant; randomized within two groups of five totaling in ten events. Results suggest that when the virtual robot's acceleration pattern were faster than the participant's acceleration the situation was perceived as more competitive. Additionally, results suggest that while the slower acceleration was perceived as more cooperative, the condition was not significantly different from mirrored acceleration. These results may indicate that there may be some kinematic information found in the faster accelerations that invoke stronger competitive perceptions whereas slower accelerations and mirrored acceleration may blend together during perception; furthermore, the models used in the slower acceleration conditions and the mirrored acceleration provide no single identifiable contributor towards perceived cooperativeness possibly due to a similar cooperative bias. These findings are used as a baseline for understanding movements that can be utilized in the design of better social robotic movements. These movements would improve the interactions between humans and these robots, ultimately improving the robot's ability to help during situations.

ACKNOWLEDGEMENTS

This thesis is the combined effort of so many people that I would never have met if I hadn't switched to Psychology. I owe these people so much and want to make sure they know how grateful I am for all the support and help I received. First and foremost, I want to thank Dr. Daniel McConnell for your guidance and introducing me to psychological avenues I hadn't even known existed. I want to extend my thankfulness and gratitude to Dr. Janan Smither for allowing undergraduates the freedom to explore psychological endeavors within Technology and Aging Lab. My heartfelt appreciation to the many future Ph.Ds. and current Ph.Ds. I have met my last year and the guidance they all bestowed upon me. Though I was split between two labs both were special to my heart and allowed me to grow as a researcher for that I want to thank Andrew Talone, Javier Rivera, Jessica Michaelis, Eva Parkhurst, and especially thank Fernando Montalva, Rhyse Bendell, and Gabby Vasquez, for more help than I could ever ask for and more support than I can ever repay. I am indebted to all the friends and advisors that I have made along the way to becoming a researcher. To everyone that has ever been in my life: friends, teachers, professors, and family I want to thank each and every one of you for molding me to who I am today… Thank you for everything from the bottom of my heart.

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Introduction

Social interactions are a defining characteristic among humans. Our brains have evolved via primitive interactions (e.g. hunting, gathering, courtship, fighting, and assimilation) for encoding and interpreting social signals and cues allowing for improved survivability (Dunbar, 1998). Even now, after the industrial revolution and inventions such as the computer and automobiles, our ability to process social interaction continues to develop (Buss, 2015). Processing social cues is not the exclusive domain of living organisms. Technology has continued to develop at an exponential rate allowing for possibilities of newer machines understanding social cues and signals through sensors and high-level processing. However, the processing of social signals and cues has never been a necessity in the design of machines, until recently. Recent developments in automation necessitate the integration of ideas to process social cues and signals into the design. A human-in-the-loop automated system, where a user has the ability to perceive and understand the actions of the automation (Dautenhahn, 1998), would provide more socially interactive and socially realistic experiences. The social experiences could improve user knowledge of system status and activities of the automation. The knowledge gained could provide the user with more beneficial social interaction with the automation.

The introduction of robotics into the workforce and households warrants research to provide answers to problems thought only to be science fiction: how can robot companions be perceived to be more trustworthy and cooperative? Could these social robots work in office spaces shared with humans and could these social robots be trusted within homes?

An appropriate path to take towards answering such questions is to mimic social interactions between two people. The goal should be to maximize the appearance of humanlike behaviors in

technology to recreate the social signals and cues interpreted by humans, rather than replicate human-like physical features such as realistic faces and body proportions. Although investigations into human-like physical features are steadily increasing among robot companies, this avenue of design is a pitfall. Findings have indicated that people will fall into an uncanny valley effect, in which highly humanlike features in robots reduce people's trust in their intentions; as well as creating almost instinctual discomfort in the presence of such robots (Mathur & Reichling, 2016; Strait, Floerke, Ju, Maddox, Remedios, Jung, & Urry, 2017). Therefore, behavioral traits that simulate social signals and cue (e.g. gaze, bodily sway, head sway, or acceleration) are the optimal avenue for design implications in incorporation of social robotics.

Regarding the workplace, one notable method to proceed with research would be cooperative behaviors: efficient actions towards a specific common goal between the robot and its user (Tyler & Blader, 2000). Future technological implementations derived from findings in cooperative behavior research could potentially provide individuals in the work environment comfort to trust these social agents to assist them in their day-to-day workload, discouraging disuse, misuse, or abuse of the social robotic assistants (Parasuraman & Riley, 1997).

Research must start with remaking social interaction tasks into a human-robot interaction with the human as the only cognitive perceiver and the social agent as the cue and signal performer. Interpreted intentions from kinematics (Runeson & Frykholm, 1983) are the optimal starting point for this avenue of research in social agents. Though the question remains, can kinematics play an active role in perceived behaviors from social agents?

Understanding the problem

The disconnection found within social robotics and kinematics is the inability to convey correct robotic body stances during interactions that simulate human interactions. Any possibility of advancing research with social robotics requires that there be a fundamental understanding of the topic using human to human interactions. The core understanding of kinematics with social event perception can be rooted in the concept of direct social perception (see Wiltshire et al., 2015 for a review). Direct social perception is an extension from the ecological approach of visual event perception (i.e. Gibson, 1979). The idea is that information via the environmental cues must be available to the observer to allow for direct perception of the event. To further explain the information contained in the sensations we receive from the environment, a separate theory proposes the concept of event dynamics (Bingham, Schmidt, & Rosenblum, 1995; Bingham & Wickelgren, 2008), attempting to explain how the dynamics of an agent in a scene allow for the recognition of an event. Both theories help inform social robotics and at the same time present the following empirical challenge: how does a social robot manipulate its kinematics to affect the direct social perception of their co-worker in a positive manner?

When approaching this challenge from a mechanical perspective this puzzle appears to be an easy fix if we were to utilize a closed-loop control system. In such a closed-loop system, the emotional status of the user is collected via a robot vision machine learning algorithm and then an action is carried out by a robot, following the action, data returns at several intervals of time. The system then uses the collected data to make any corrections needed to remain on its predetermined course. Potential problems that can arise in collection of emotional states could include accuracy of detected emotional states and correctness of actions following detection of the emotional state.

Theoretical challenges involving robot vision processing utilizing machine learning are outside the scope of this study. Machine learning that could be used by social robotics would involve feeding information about appropriate actions based on emotional states by learning through sorting the actions based on positive versus negative cues (i.e. a smile versus a frown). The problem that arises with closed-loop controls in robotics are time and available processing power. These finite resources cannot be assigned to every point of motion in robotic movement, limiting the use of closed loop systems. Thus, open-loop controls must be used during some robotic movements. However, processing power and time are still a concern with open-loop systems because the system must use up time at the beginning of a task to make all calculations required for successful detection of the emotional state to occur. The action following the calculation will need to be swift for the state not to change during the time of calculation and action performed. When compared to that of a closed-loop system, the processing power is less due to the nature of only having one calculation rather than several interval calculations.

In anthropologic motion, a mixture of closed-loop and open-loop controls are applied by the nervous system depending on the expected outcome and event (Collins & Luca, 1993). Employing the same mechanics in a robotic social agent could allow for better models of movements which could potentially improve a human's ability to directly perceive robotic motion. In this way, a hybrid system would increase the human-likeness of the kinematics of the social agent. Well-performed humanlike kinematics could correlate to a positive social presence, meaning that perceived behaviors would be more significantly portrayed as a social cue. A good starting point is to determine base kinematics that can be applied by a social robot to be efficient in its tasks, while also being perceived as cooperative during all interactions. The needed level of required calibrations for perceived cooperative actions to occur during interactions are unknown.

The unknown calibrations previously mentioned are never addressed in previous research but indirectly event identification can be applied to the problem. The event identification between natural-moved objects and hand-moved objects depicted spatio-temporal trajectory forms within a phase space, the forms where recognized as different events implying that the differences in the events are perceivable due to distinct patterns (Bingham, 1987a; Bingham, 1987b; Bingham, 1995).

Literature Review

This line of research originates with Gibson's (1979) theory of direct perception, which proposes the existence of meaningful information that can be collected from the world around the observer via an optic array. This optic array changes due to observer locomotion resulting in different points of observation, meaning that at serval different visual points gradual changes may occur to the optic array (Gibson, 1979). These slight changes provide information about the world through overlapping and identifying invariance across the arrays, created by changes such as ratios, gradients, discontinuities, and other relations in ambient light that are due to features of the environment being observed, otherwise known as optic flow (Gibson, 1979). The understanding that ambient light could provide some form of visual perception into our environment via patterns leads to the investigation of whether kinematic information is included into the optic array. Utilizing point-light displays, a study by Runeson and Fykholm (1983) revealed that humans can accurately perceive certain types of properties of another person including gender, identity, current action (lifting a heavy box or throwing something far away), intentions/ expected action (to lift a heavy box), and whether the person is deceptive or emphatic from kinematic information. The

results of this previous research, paired with the Principle of Kinematic Specification of Dynamics (KSD), serves to establish kinematics specification as a vital source of information about others (Runeson & Frykholm, 1983), and highlights kinematics and overall motor activation as highly relevant to social functioning. Interest in the conceptual link between kinematics and social functioning leads to research on intentionality to find the extent of the information provided by kinematics. Research conducted by Georgiou, Becchio, Glover, and Castiello (2007) found that prior intentions can be depicted by kinematics. Cooperative and competitive actions utilized in this previous research are reflected by specific kinematic patterns that can be observed (Georgiou et. al, 2007).

Further research was conducted on whether cooperative or competitive stances affected kinematic parameters within a social context. It was found that when trying to cooperate with an agent displaying competitive stances, an illusion that their actions were more competitive was created. A similar effect was found when competing with an agent displaying cooperative stances (Becchio, Sartori, Bulgheroni, & Castiello, 2008). Accurately distinguishing competitive and cooperative movements by observing videos of reach-to-grasp kinematics (Satori, Becchio, & Castiello, 2011) provides further evidence that kinematic information can provide a basis for inferring social intentions. When isolating movement to point-light displays, participants were still able to distinguish between the competitive and cooperative actions of actors, illustrating that even basic kinematic information provides enough data to infer social intentions (Manera, Becchio, Cavallo, Sartori, & Castiello, 2011).

Purpose

The problem within social robotics, the current inability to carry out the correct body language to display adequate kinematics, can be addressed in the context of direct perception. The previous research indicates that social intentions can be perceived by kinematic information; however, the distinct patterns that invoke social intentions are not identified nor classified. The current research considers the possible informational basis of intentionality of the social agent based on specific accelerations towards a common goal. The research will examine whether certain accelerations are deemed to be cooperative or competitive by the observer. The present research will use five conditions for the acceleration of the agent: mirrored with participant's acceleration, always ahead of participant's acceleration, always behind participants acceleration, varied acceleration with a win, and varied acceleration with a loss. The current research hypotheses are:

Hypothesis$_1$: Slower acceleration will be perceived as more cooperative by the observer (i.e., the condition always behind participant's acceleration will be perceived as more cooperative).

Hypothesis$_2$: Faster acceleration will be perceived as more competitive by the observer (i.e., the condition always ahead participant's acceleration will be perceived as more competitive).

Hypothesis$_3$: There will be an interaction between negative attitude towards robots and perceiving intentionality.

Methods

Participants

Participants were 40 undergraduate students from the University of Central Florida, a university in the southeastern United States. Participants were recruited from the University of Central Florida through the Psychology Department's online recruitment website, SONA. After analysis, 39 of the participants were retained. The participant removed preformed the satisficing behavior of straight-lining answers to all surveys. The sample included 17 males (43.6%) and 22 females (56.4%). The participants' age ranged from 18 to 36 with a mean age of 20.41 (*SD* = 3.41). All participants were rewarded 1.5 points for their participation which could be exchanged towards course credit.

Material

Oculus Rift VR Headset and Equipment. Oculus Rift consumer version head-mounted display which tracks head movements using a six DOF ultra low-latency (around 20 milliseconds) head tracker, displaying the virtual environment with a diagonal field of view FOV of 110° at a resolution of 2160 × 1200px at 90Hz split over dual displays. Touch controllers track hand movement as well as containing an analog stick, three buttons, and two triggers per hand. Three Constellation sensors are used for tracking the user within the infrared tracking area.

Virtual Environment. An immersive nature VE was created for use. The environment was created in the Unreal Engine 4 (UE4), a game design engine that is an industry standard for highly immersive 3D environments. The environment created is a sunny mid-day forest area with

hills in the background of the walkable area (See Figure 1). The playable area is within a large clearing in the center of the forest. The center of the clearing has large tree that is provided in base model pack and is free for education and non-commercial use. The virtual agent was placed in the left section of the clearing at roughly a nine o'clock position in reference to the large tree, and roughly ten-thirty position in reference to the user. The environment contains trees, plants, and the social agent.

Figure 1: UE4 Virtual Environment created for specific use of the present research utilizing open source models for depth to the interactive world.

Head-up Display (HUD). The participants HUD contained one constant feature in the lower left of the screen, a timer. The timer will not obstruct the participants view of the environment due to the location as well as the size, being large enough to accurately interpret. The timer counts down from thirty seconds to zero seconds. The timer only instills urgency, meaning there is no penalty for staying in the simulation longer than the thirty seconds.

Virtual Robot. The virtual robot created is a modified version of the UE4 mannequin. The mannequin was modified using Blender software. The body of the mannequin still possesses the human-like appearance but made to appear closer to that of a robot rather than human (See

Figure 2). The modified mannequin has two arms and two legs with a medium sized torso area. The head of the modified mannequin has a smooth oval shape without facial details (e.g. eyes, nose, or mouth). The virtual robot created is more similar to an android rather than a robot in the literary sense. Androids are built to resemble a human as closely as possible, whereas a robot may look mechanical. For ease the created virtual robot had been called a robot.

Figure 2: The UE4 mannequin that was utilized during the present research as a virtual robot.

Negative Attitude towards Robots Scale. A 14-item self-report measure of attitude towards robots with all items answered on a seven-point scale (Nomura, Kanda, Suzuki, & Kato, 2004). The scale has been utilized previously across multiple domains of HRI and has shown to predict interactions and explain individual differences in participants' behaviors.

The Godspeed Questionnaire Series. Three sub-scales used to determine specific robot attributes (Animacy, Perceived Intelligence, and Perceived Safety) totaling in 14-items that are

self-reported and split into 6-items (Animacy), 5-items (Perceived Intelligence), and 3-items (Perceived Safety). All items will be answered on a five-point scale (Bartneck, Kulić, Croft, & Zoghbi, 2009).

Likert scale. A scale determining the perceived intentionality of the social agent consisting of 1-item "From a scale of very competitive to very cooperative how do you perceive the agent acted?" with seven answer points (1-very competitive, 2-moderately competitive, 3-slightly competitive, 4-neither competitive nor cooperative, 5-slightly cooperative, 6-moderately cooperative, 7-very cooperative).

Networked Minds Social Presence Inventory. A revised Networked Minds Social Presence Measure reduced to 36 total items with each factor item having 6-items that are scored using a seven-point Likert scale. The scale is divided into two sections of self and other each having 18 total items.

Demographic scale. A participant's background questionnaire was administered. This scale will collect basic demographic information.

Self-report Questions. The survey contained three exclusion questions: a corrected vision question, which determines if the participant has good vision or corrected-to-normal vision; prior history of seizures, which determines whether the participant has had a history of seizures; and prior history of motion sickness question, which determines whether the participant had had a history of motion sickness.

Conditions

Mirrored with participants acceleration. The acceleration of the social agent responded to the participant's acceleration via the participants inputs by the touch controllers. The acceleration of the social agent had matched the participant's acceleration in a 1:1 ratio.

Always ahead of participants acceleration. The acceleration of the social agent was set to an acceleration that is an increase of roughly 40% of the participant's set acceleration. The value was determined through observation of three different accelerations and selected to be the best fit. The social agent will respond to the participant's stops by stopping and returning to the set value once the participant begins accelerating.

Always behind participants acceleration. The acceleration of the social agent was set to an acceleration that is a decrease of roughly 30% of the participant's set acceleration. The value was determined through observation of three different accelerations and selected to be the best fit. The social agent will respond to the participant's stops by stopping and returning to the set value once the participant begins accelerating.

Varied acceleration with a win. The acceleration of the social agent responded to the locations on the map that are reached by moving forward via reading in the participant's controller inputs by the touch controllers. The acceleration of the social agent fluctuated around the locations on the axis of travel. The social agent began at an acceleration of an increase of roughly 20% compared to the participant's set acceleration. The social robot then decreased acceleration by roughly 10% then after roughly 5 seconds the social agent increased acceleration by roughly 60% to reach the "goal" first. These values were determined through observation of several different

accelerations and selected to be the best fits. The social agent responded to the participant's stops by stopping and returning to the set value once the participant begins accelerating.

Varied acceleration with a loss. The acceleration of the social agent responded to the locations on the map that are reached by moving forward by reading in the participant's controller inputs by the touch controllers. The acceleration of the social agent fluctuated around the locations on the axis of travel. The social agent began at an acceleration of a decrease of roughly 20% compared to the participant's set acceleration. The social robot then increased acceleration by roughly 25% then after roughly 5 seconds the social agent decreased acceleration by roughly 43% to reach the "goal" after the participant. These values were determined through observation of several different accelerations and selected to be the best fits. The social agent responded to the participant's stops by stopping and returning to the set value once the participant begins accelerating.

Virtual Task

The participant will begin at the south side of the clearing in the forest, roughly the six o'clock position referencing the large tree. The social agent began perpendicular of the participant on the west side of the clearing in the forest, roughly the nine o'clock position referencing the large tree. The objective of the task was to reach the center of the clearing in the forest before the timer reached zero. The function of the timer is to provide a sense of urgency to the task prompting the participant to continue forward without turning the task into a race (avoiding biasing the results towards competitive). The acceleration of the participant was controlled via the touch controller. The joystick on the touch controller was used to adjust the speed at which the participant was

moving forward, all directional movement had been disabled to deter straying from the path to the center. The acceleration could vary based on the position of the joystick (i.e. the distance between the origin and the edge of the upper y-axis or lower y-axis). The center of the forest, under the large tree, was the area that the "goal" was located in and there was a prompt screen letting the participant know that the current trial was completed. The total time on task was never be greater than thirty seconds, based on observation of trial times, but varied based on the number of stops taken by the participant.

Procedure

The participants were given a summary of the study upon arrival to the lab and the participants were asked for their informed consent to partake in the study. Upon obtaining their consent to participate, the participant was prompted to fill out the self-report questions. The report was used as a screening tool to exclude participants with vision problems, prior history of seizures, and prior history of motion sickness. Once the criteria mentioned above were completed, the participants were told to complete a demographic scale and the Negative Attitude Towards Robots scale. The participant was then set up with the virtual reality headset and put through a trial to get familiar with the controls for interacting with the virtual environment. The participant then interacted with all five conditions twice in a randomized, counterbalanced fashion. After completion of each condition, the participant stopped and answered the Godspeed questionnaire series and the Perceived Intentionality Likert scale. After all the virtual task conditions were completed, the participant completed the Networked Minds Social Presence Inventory. After

completion of the Network Minds Social Presence Inventory, the participant was given a debriefing of the study.

Results

Judgements of the situation as competitive or cooperative were first averaged across the two viewings of each condition. Next, differences in judgements of these perceptions were compared in a one-way repeated measures ANOVA. Due to sphericity being violated the Greenhouse-Geisser correction was assumed.

Judgements across the five conditions differed in terms of perceived intentionality, $F(2.71, 102.81) = 12.394$, $p < .001$, $\eta^2_p = .25$ (See figure 3). Pairwise comparisons ($p < .01$) revealed that the condition of Always Ahead of the Participant's Acceleration was rated significantly more competitive than all other conditions except Varied Acceleration with a Win and Varied Acceleration with a Win were rated significantly more competitive than Mirrored Acceleration and Always Behind of Participant's Acceleration.

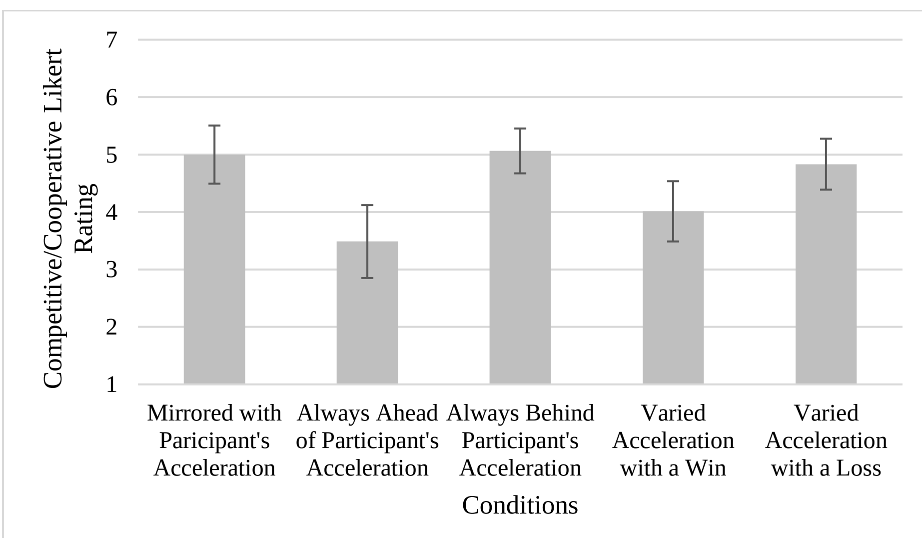


Figure 3: Rating on the Likert Scale across the five conditions (max. competitive score = 1, max. cooperative score = 7, neither score = 4). Error bars represent standard error of the mean.

When introducing the covariate of the summation of the ratings from the Negative Attitude towards Robots Scale (Nomura et al., 2004) into the analysis of the one-way repeated measures ANOVA the significance is lost, $F(2.69, 99.36) = 0.42$, $p = .718$, $\eta^2_p = .01$, implying that the competitiveness ratings were accounted for by participants who scored high on negative attitudes.

Additional judgements on animacy, intelligence, and safety were collected. Judgments of animacy, intelligence, and safety were first averaged across the two viewings of each condition. Next, differences in judgments of these attributes were compared in three separate one-way repeated measures ANOVA. Sphericity was assumed for each test.

First, judged animacy varied across the five conditions, $F(4,152) = 20.78$, $p < .001$, $\eta^2_p = .35$ (See Figure 4). Pairwise comparisons ($p < .01$) revealed that Always Behind Acceleration condition was rated significantly lower in animacy than all other conditions and the Varied Acceleration with a Win condition was rated significantly higher in animosity than all conditions except Faster Acceleration.

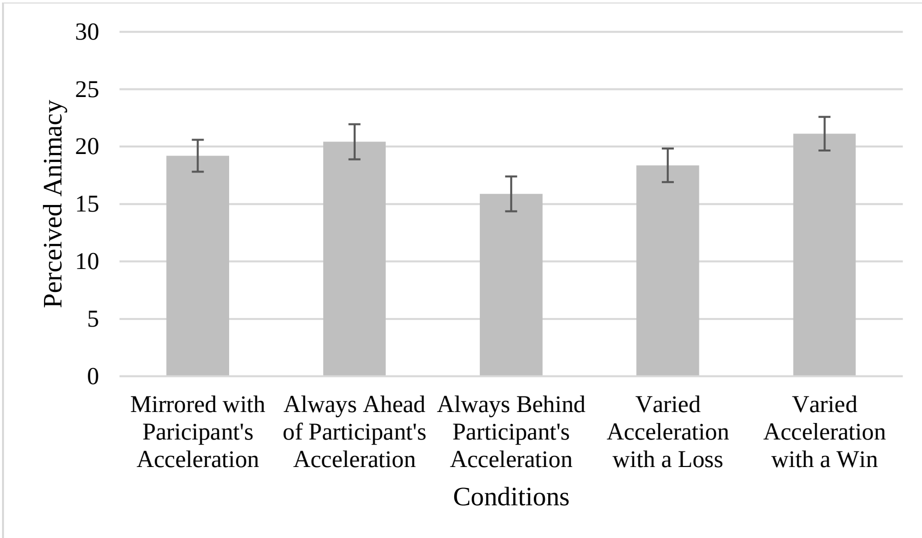


Figure 4: Perceived animacy across the five conditions (max. possible score = 30). Error bars represent standard error of the mean.

Perceived safety across the five conditions, $F(4, 152) = 2.38$, $p = .054$, $\eta^2_p = .06$, showed there was no significance found between any of the trials (Figure 5).

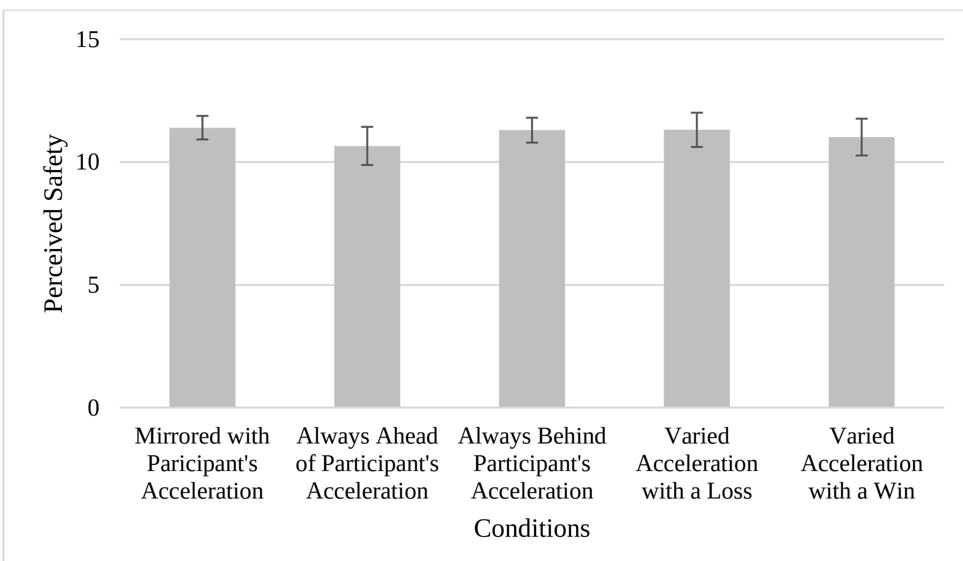


Figure 5: Perceived safety across the five conditions (max. possible score = 15).

Last, perceived intelligence of the agent varied across the five conditions, $F(4,152) = 9.18$, $p < .001$, $\eta^2_p = .19$ (Figure 6). Pairwise comparisons ($p < .01$) revealed that the Slower Acceleration was significantly different in intelligence than all other conditions except with Varied Acceleration with a Loss. No other conditions differed significantly.

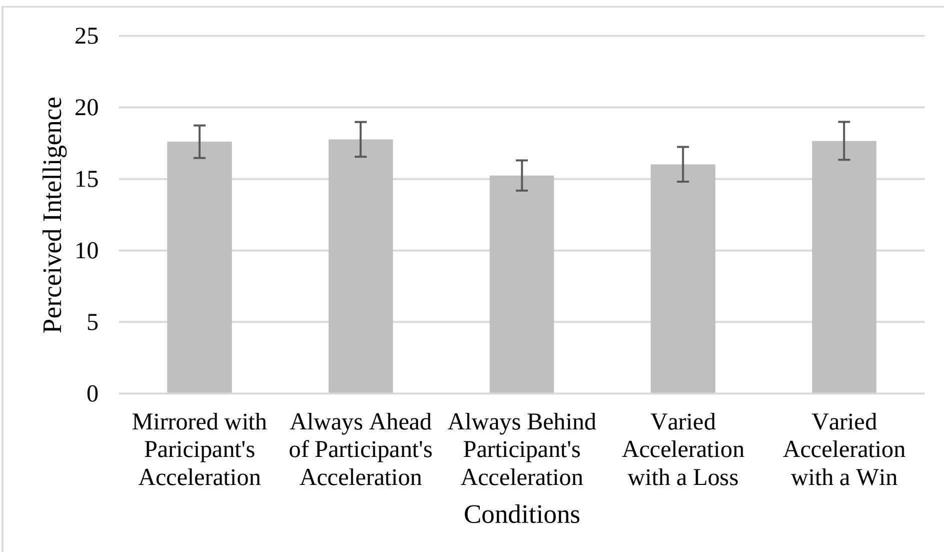


Figure 6: Perceived intelligence across the five conditions (max possible score = 25).

Additional judgements on social presence were collected. Judgments of co-presence (first-order), Attention Allocation, Perceived Message Understanding, Perceived Affective Understanding, Perceived Emotional Interdependence, Perceived Behavioral Interdependence were first averaged within each subscale. The second-order was collected by adding all sections except co-presence then taking an average. The measure is split in half where 18 questions are self-oriented and 18 are other-oriented. Totals were collected for Self and Other and averaged

separately. Last, a Total for both Self and Other was collected then averaged. Next, averages in judgments of these attributes were compared in a separate one-way repeated measures ANOVA. Sphericity was violated for the ANOVA, so a correction was used.

Last, the Networked minds Social Presence Inventory was analyzed, $F(3.86,146.51) = 15.95$, $p < .001$, $\eta^2_p = .296$ (Figure 7). Pairwise comparisons revealed that co-presence during the task was more present than any of the second-order attributes (Attention Allocation, Perceived Message Understanding, Perceived Affective Understanding, Perceived Emotional Interdependence, Perceived Behavioral Interdependence).

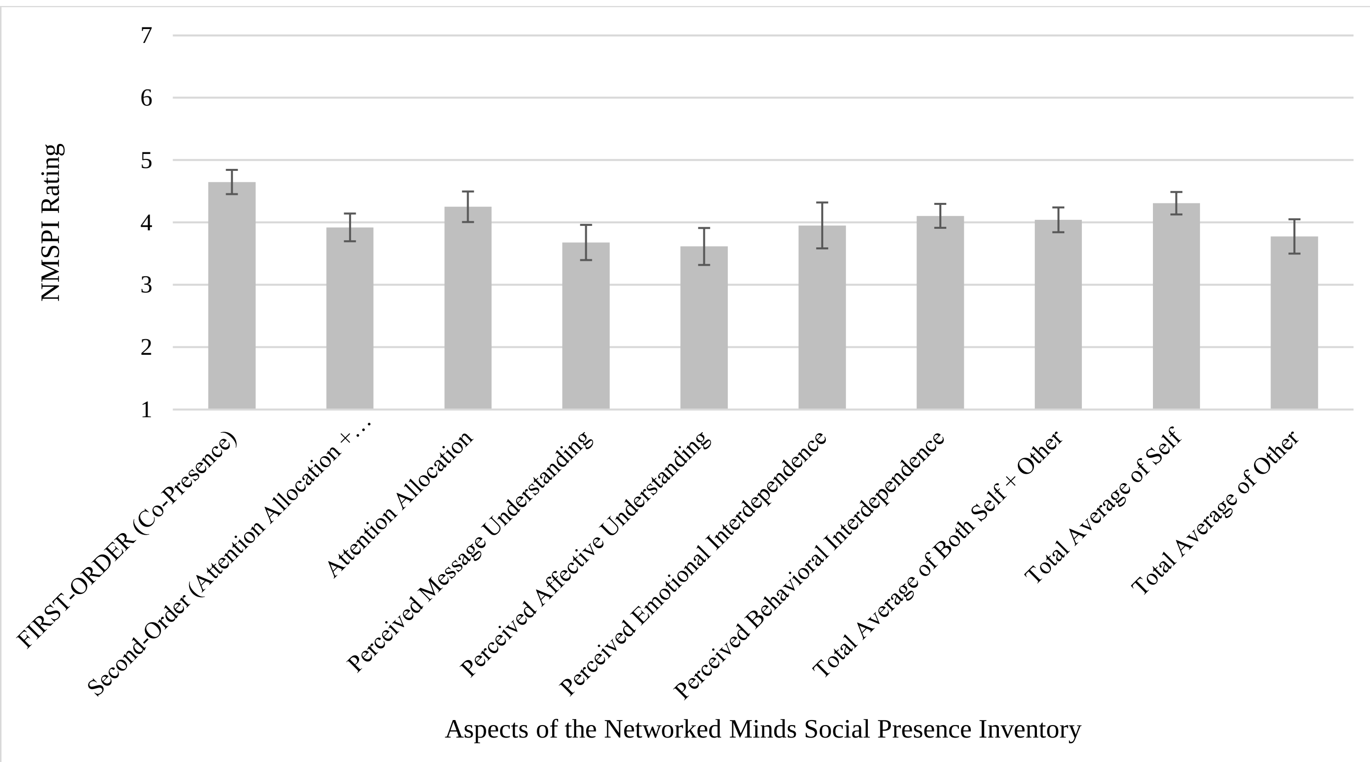


Figure 7: Social Presence Average scores separated by First-order, Second-order, Separated Second-order, Self-focused questions, Other-focused questions, and Total (max possible average score = 7; undecided = 4).

Introducing the covariate of the co-presence into the analysis of the Likert Conditions by means of a one-way repeated measures ANOVA the significance is lost, $F(2.71, 100.34) = 1.87$, $p = .146$, $\eta^2_p = .05$, implying that the competitiveness ratings were accounted for by participants who scored high on co-presence.

Discussion

The present study explored the effects of acceleration on perceived situational competitiveness/cooperativeness within the context of a virtual reality task. Additionally, this study also examined whether an interaction could be determined between prior negative attitudes towards robotics and the perception of the virtual task being competitive/cooperative. Overall, the results suggest there is a difference of perception of the situation based on the acceleration of the virtual robot as compared across the averaged five conditions. These findings will be discussed next in greater detail.

Acceleration of the Virtual Robot – Faster Acceleration

Within this section the two conditions of Always Ahead of Participant's Acceleration and Varied Acceleration with a Win will be analyzed further in the context of the significance towards competitiveness. Faster accelerations had the virtual robot tending to be in a "long stride" (See Figure 8) state for longer periods of the timeframe, possibly playing a part in the perception of competitiveness.

Varied Acceleration with a Win being significant over only Mirrored Acceleration and Always Behind Participant's Acceleration could be explained by the shifts in Acceleration taken by the virtual robot. The programming indicated accelerations as slow as the acceleration found in the Varied Acceleration with a Loss and as high as the accelerations in the Always Ahead of Participant's Acceleration condition. Acceleration overlaps could create situations where the participant found the kinematic information present to be similar to that of other conditions.

Always Ahead of Participant's Acceleration was significantly different from all conditions except the Varied Acceleration with a Win, these results may suggest the similarities in the kinematic information available in the Varied Acceleration with a Win. Other conditions did not reach the percent increase programmed into the Always Ahead condition, which could isolate the events of Always Ahead and Varied Win conditions as having their own specific kinematic information present. As mentioned previously, these increases percentages are linked to the "long stride" (Figure 8) possibly leading to longer perception of these kinematic movements, potentially inducing a sense of competitiveness through similar information known about urgency.

Figure 8: Visual of the "long stride" walking style that was used for faster accelerations.

Acceleration of the Virtual Robot – Slower Acceleration

Within this section the conditions of Always Behind of Participant's Acceleration and Varied Acceleration with a Loss will be analyzed further in the context of the significance towards cooperativeness. Slower accelerations had the virtual robot tending to be in a "short stride" (See Figure 9) state for longer periods of the timeframe, possibly playing a part in the perception of cooperativeness.

Always Behind of Participant's Acceleration was perceived significantly more cooperative than Varied Acceleration with a Win and Always Ahead of Participant's Acceleration. These could be potentially explained by the drastic difference in acceleration between the three conditions, even in Varied Acceleration with a Win the Acceleration never reached the Acceleration of the Always Behind condition. These differences in accelerations could be suggesting a difference in the kinematic information present during the Always Behind condition compared to the previously mentioned conditions.

Interestingly, in both animacy and perceived intelligence slower accelerations were perceived to be lower in both compared to the faster accelerations. These results may suggest that even though the robot is perceived as less intelligent and less animated it may be easier to be perceived as more cooperative. These finding could possibly be explained by average consumer bipedal robots being slow and clumsy and are defined as tools rather than partners implying that these prior experiences influenced the responses given.

Figure 9: Visual of the “short stride” walking style that was used for slower accelerations.

Acceleration of the Virtual Robot – Mirrored Acceleration

The Mirrored Acceleration condition of the present study was utilized as a control for the different conditions. Results indicated that the difference between Mirrored Acceleration and all conditions other than Always Ahead of Participant’s Acceleration were not significantly different in perceived intentionality and were perceived as more cooperative, possibly indicating that though these conditions had increased the perception of the situation as cooperative the kinematic information is not isolated. The overall perception of cooperation could suggest the presence of an overarching cooperative bias similar to Human-Human Interactions (Sartori et al., 2011).

Overall

In the given virtual task, the appearance of negative attitudes towards robotics changed the significance implying that these prior attitudes may influence the perceptions of the participants. These attitudes could potentially influence all research with robotics creating muddied results. These results may be skewed due to the sampled population.

Additionally, due to Mirrored Acceleration, Always Behind of Participant's Acceleration, and Varied Acceleration with a Loss are gauged to be roughly the same there is no way to definitively state that slower acceleration was viewed as more cooperative. The kinematic information found in all of these conditions could vary between the same acceleration, faster acceleration, and slower acceleration. Consequently, the judgement that can be made is that between constant fast acceleration (Always Ahead of Participant's Acceleration) and constant slow acceleration (Always Behind of Participant's Acceleration) tend to invoke more situations perceived as competitive and cooperative, respectively.

Limitations of the Present Study

Several limitations of the present study should be noted. First, the virtual environment task was not explicitly cooperative due to the only objective was to walk towards an object. The present task is more likely to be perceived as a race to the end goal rather than a cooperative task to possibly pick apples due to no situational instructions being given. Future research needs to adapt the task to create an overall neutral activity that could easily be perceived based on slight adjustments to accelerations. Additionally, future research may want to further investigate more exaggerated

accelerations in order to create more competitive/cooperative situations. Further, the environment used in the study was in a nature setting based on availability of Unreal Engine 4 assets. The environment was populated with trees with motion-based physics for immersion purposes possibly leading to points of breaking the user's direct perception of the virtual robot to analyze surroundings. Additionally, the simulation does not account any stops taken by the participant. Consequently, exposure time of the participant may vary up to 25 seconds. Future research should control environment design, record all stops taken by the participant, and create stricter perimeters for the participants within the virtual environment.

APPENDIX A: IRB APPROVAL LETTER

UNIVERSITY OF CENTRAL FLORIDA

Institutional Review Board
FWA00000351
IRB00001138Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

APPROVAL

February 6, 2019

Dear Daniel Mcconnell:

On 2/6/2019, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title:	Are Perceived Cooperative/Competitive Behaviors Influenced by Kinematics?
Investigator:	Daniel Mcconnell
IRB ID:	STUDY00000082
Funding:	Name: Undergraduate Research
Grant ID:	None
IND, IDE, or HDE:	None
Documents Reviewed:	• Competitive/ Cooperatitive Likert Scale, Category: Survey / Questionnaire; • Negative Attitude towards Robots Survey Items.docx, Category: Survey / Questionnaire; • Networked Minds Social Presence Measure, Category: Survey / Questionnaire; • Self-report Questions, Category: Survey / Questionnaire; • Protocol, Category: IRB Protocol; • Informed Consent, Category: Consent Form; • Demographics Questionnaire, Category: Survey / Questionnaire; • GodSpeed Questionnaires, Category: Survey / Questionnaire; • Virtual Environment, Category: Other; • Transition Screen , Category: Other; • Beginning Screen, Category: Other;

The IRB approved the protocol from 2/6/2019 to .

In conducting this protocol, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Kamille Chaparro

Kamille Chaparro
Designated Reviewer

APPENDIX B: GODSPEED SERIES QUESTIONNAIRES

Appendix

GODSPEED I: ANTHROPOMORPHISM

Please rate your impression of the robot on these scales:
以下のスケールに基づいてこのロボットの印象を評価してください。

Fake 偽物のような	1	2	3	4	5	Natural 自然な
Machinelike 機械的	1	2	3	4	5	Humanlike 人間的
Unconscious 意識を持たない	1	2	3	4	5	Conscious 意識を持っている
Artificial 人工的	1	2	3	4	5	Lifelike 生物的
Moving rigidly ぎこちない動き	1	2	3	4	5	Moving elegantly洗練された動き

GODSPEED II: ANIMACY

Please rate your impression of the robot on these scales:
以下のスケールに基づいてこのロボットの印象を評価してください。

Dead 死んでいる	1	2	3	4	5	Alive 生きている
Stagnant 活気のない	1	2	3	4	5	Lively 生き生きとした
Mechanical 機械的な	1	2	3	4	5	Organic 有機的な
Artificial 人工的な	1	2	3	4	5	Lifelike 生物的な
Inert 不活発な	1	2	3	4	5	Interactive 対話的な
Apathetic 無関心な	1	2	3	4	5	Responsive 反応のある

GODSPEED III: LIKEABILITY

Please rate your impression of the robot on these scales:
以下のスケールに基づいてこのロボットの印象を評価してください。

Dislike 嫌い	1	2	3	4	5	Like 好き
Unfriendly 親しみにくい	1	2	3	4	5	Friendly 親しみやすい
Unkind 不親切な	1	2	3	4	5	Kind 親切な
Unpleasant 不愉快な	1	2	3	4	5	Pleasant 愉快な
Awful ひどい	1	2	3	4	5	Nice 良い

GODSPEED IV: PERCEIVED INTELLIGENCE

Please rate your impression of the robot on these scales:
以下のスケールに基づいてこのロボットの印象を評価してください。

Incompetent 無能な	1	2	3	4	5	Competent 有能な
Ignorant 無知な	1	2	3	4	5	Knowledgeable 物知りな
Irresponsible 無責任な	1	2	3	4	5	Responsible 責任のある
Unintelligent 知的でない,	1	2	3	4	5	Intelligent 知的な
Foolish 愚かな	1	2	3	4	5	Sensible 賢明な

GODSPEED V: PERCEIVED SAFETY

Please rate your emotional state on these scales:
以下のスケールに基づいてあなたの心の状態を評価してください。

Anxious 不安な	1	2	3	4	5	Relaxed 落ち着いた
Agitated 動揺している	1	2	3	4	5	Calm 冷静な
Quiescent 平穏な	1	2	3	4	5	Surprised 驚いた

APPENDIX C: NEGATIVE ATTITUDES TOWARDS ROBOTS

Negative Attitude towards Robots Survey Items

1. I would feel uneasy if robots really had emotions.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
2. Something bad might happen if robots developed into living beings.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
3. I would feel relaxed talking with robots.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
4. I would feel uneasy if I was given a job where I had to use robots.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
5. If robots had emotions, I would be able to make friends with them.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
6. I feel comforted being with robots that have emotions.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
7. The word "robot" means nothing to me.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
8. I would feel nervous operating a robot in front of other people.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
9. I would hate the idea that robots or artificial intelligences were making judgments about things.
   1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
10. I would feel very nervous just standing in front of a robot.
    1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
11. I feel that if I depend on robots too much, something bad might happen.
    1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
12. I would feel paranoid talking with a robot.
    1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
13. I am concerned that robots would be a had influence on children.
    1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree
14. I feel that in the future society will be dominated by robots.
    1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree

APPENDIX D: SELF-REPORT QUESTIONS

Vision Confirmation

1. Do you have normal or correct-to-normal visual ability (please circle):

   Yes No

   a. If corrected-to-normal visual ability, are you currently wearing the glasses/contacts?

      Yes No

History of Seizures

2. Do you have prior history of seizures (please circle):

   Yes No

**If "Yes" please vocally let the researcher know that you have had seizures in the past.

History of Motion Sickness

3. Do you have prior history of motion sickness (please circle):

   Yes No

**If "Yes" please vocally let the researcher know that you have had motion sickness in the past.

APPENDIX E: LIKERT SCALE

Likert Scale

From a scale of very competitive to very cooperative how do you perceive the agent acted?

(Please circle)

1-very competitive

2-moderately competitive

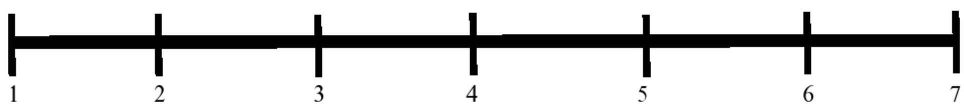
3-slightly competitive

4-neither competitive nor cooperative

5-slightly cooperative

6-moderately cooperative

7-very cooperative



APPENDIX F: DEMOGRAPHICS

Demographics

1) What is your age? ____________

2) Specify your gender (Please circle):
   a) Female
   b) Male
   c) Other, please specify: ___________
   d) Prefer not to say.

3) What is your major? ______________

APPENDIX G: NETWORKED MINDS SOCIAL PRESENCE MEASURE

Networked Minds Social Presence Measure

1. I noticed the virtual agent. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

2. The virtual agent noticed me. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

3. The virtual agent's presence was obvious to me. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

4. My presence was obvious to the virtual agent. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

5. The virtual agent caught my attention. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

6. I caught the virtual agent's attention. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

7. I was easily distracted from the virtual agent when other things were going on. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

8. The virtual agent was easily distracted from me when other things were going on. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

9. I remained focused on the virtual agent throughout our interaction. (Please circle a number)
   1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

10. The virtual agent remained focused on me throughout our interaction. (Please circle a number)
    1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

11. The virtual agent did not receive my full attention. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

12. I did not receive the virtual agent's full attention. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

13. My thoughts were clear to the virtual agent. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

14. The virtual agent's thoughts were clear to me. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

15. It was easy to understand the virtual agent. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

16. The virtual agent found it easy to understand me. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

17. Understanding the virtual agent was difficult. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

18. The virtual agent had difficulty understanding me. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

19. I could tell how the virtual agent felt. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

20. The virtual agent could tell how I felt. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

21. The virtual agent's emotions were not clear to me. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

22. My emotions were not clear to the virtual agent. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

23. I could describe the virtual agent's feelings accurately. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

24. The virtual agent could describe my feelings accurately. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

25. I was sometimes influenced by the virtual agent's moods. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

26. The virtual agent was sometimes influenced by my moods. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

27. The virtual agent's feelings influenced the mood of our interaction. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

28. My feelings influenced the mood of our interaction. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

29. The virtual agent's attitudes influenced how I felt. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

30. My attitudes influenced how the virtual agent felt. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

31. My behavior was often in direct response to the virtual agent's behavior. (Please circle a number)
1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

32. The behavior of the virtual agent was often in direct response to my behavior. (Please circle a number)
    1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

33. I reciprocated the virtual agent's actions. (Please circle a number)
    1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

34. The virtual agent reciprocated my actions. (Please circle a number)
    1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

35. The virtual agent's behavior was closely tied to my behavior. (Please circle a number)
    1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

36. My behavior was closely tied to the virtual agent's behavior. (Please circle a number)
    1-Strongly Agree, 2-Moderately Agree, 3-Agree, 4-Undecided, 5-Disagree, 6-Moderately Disagree, 7-Strongly Disagree

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