Exploring How Interaction Types Influence Trust in Sphero Robots

Raed Seraj, Russell Abedeen, Brian Farrell

1. Introduction

An overlooked aspect of the relationship between humans and robots is trust. A robot can perform the action it was created to perform perfectly, but they are not likely to be meaningfully used if humans, the primary users, do not trust it. Building trust between robots and the humans that interact with them is essential to the robots being used effectively. This is the relationship our study was designed to investigate. We designed our study to determine if humans would feel certain emotions when interacting with a robot assisting them.

Our study examined how “hurting” the assistive robot would impact the perceived relationship between the robot and the participants of our study. The two separate trials were designed intentionally only to differ in how the human directly interacted with the robot. The first trial had the participant interact with the robot with a neutral rolling action. This was designed to be a baseline for how the interaction affected the participant’s emotions regarding the robot. The second trial had the participant kick the robot rather than roll it. This action, often associated with violence, was intended to help us measure if the participant would feel remorse for “hurting” the robot assisting them. We hypothesized that participants would feel more remorse or less comfortable when kicking the robot.

In our results, we found no significant difference between how the participants felt about kicking and rolling the robot. Our results did not support our hypothesis. Some participants felt more uneasy rolling the robot than kicking it. This disproved our hypothesis that the participants would feel more remorse for kicking the robot. Another finding was that nearly all the participants felt comfortable interacting with the robot and said they would interact with it daily. This showed that there is potential for a robot to assist people in this way in the future. Our results showed that the method of interacting with the helper robot does not significantly impact the user's trust in the robot's functional ability.

2. Background

Many researchers have considered the importance of developing trust and incorporating safety into human-robot interactions. Prior work has experimented with different frameworks to ensure that the interactions between humans and robots are safe and designed to increase trust. Our work builds on this background work to test how the human's actions toward the robot impact the perception of safety and trust towards the robot and the interaction itself.

There are multiple current approaches to ensuring robots safely interact with humans. Work by K.-B. Cho and B.-H. Lee involved building new sensors for helping with robot safety in the context of improving robot-assisted navigation for the visually impaired. We built upon this existing work by using the existing sensors in the Sphero Bolt robot. Work by P. Svarny, M. Tesar, J. K. Behrens, and M. Hoffmann included experimenting with different distance thresholds for the robots to ensure the safety of the humans interacting with them. Our work built on this study by working with different distance thresholds with our Sphero Bolt robots in a classroom setting. Other relevant work in this subject includes using fluid-based approaches for robotic joints and creating force maps (M. R. Ahmed, I. Kalaykov; P. Svarny, J. Rozlivek, L. Rustler, M. Hoffmann).

Researchers have tested different approaches to increase trust in human-robot interactions to investigate the primary causes of this relationship. Work by Venkatesh, Viswanath, et al involved creating new frameworks to measure the level of trust in the interactions and then implementing them. Kok, Bing Cai, and Harold Soh did similar work by developing new frameworks to measure the trust level. These researchers found that developing trust in robots and humans is similar. Reliability was the biggest factor in building trust. Failure and betrayal were the biggest detriments to the trust. Onishi, Yuya, et al attempted to replicate an owner-pet relationship between their participants and social robots. The researchers found treating the robots as pets and going through “training” similar to that of a pet caused the participants to view the robots as pets and fostered a bond between them. This was relevant to our work because the small dimensions of the Sphero bolt robot make it closer to a pet than a person. This was an important part of our study because we wanted to ensure the participants were comfortable and trusting of the robot. Work by Rossi, Alessandra, et al. created standards for human-robot interaction in a home setting. We furthered this work by conducting our experiment in home environments. Other relevant work includes developing a trust scale and measuring how physical touch can induce positive responses without prior bonding (Yagoda, Rosemarie E., and Douglas J. Gillan; Willemse, Christian J. A. M., and Jan B. F. van Erp).

Our work built on this previous research about safety and trust in human-robot interactions. Our study focused on the impact of the participant’s actions toward the robot and how these actions affect the perceived trust in this interaction. We sought to examine whether a human “hurting” an assistive robot would negatively impact the trust in the human-robot interaction and the bond between the human and the robot.

3. Methodology

Our study was conducted to explore how different methods of rolling a Sphero Bolt robot impacted the level of trust between a human and their helper robot. Our study involved two different methods of interacting with the Sphero: rolling it and kicking it. We hypothesized that our participants would feel more comfortable and trust the Sphero more when they rolled it (neutral action), instead of kicking it (violent action). Additionally, we predicted the participants would feel less comfortable about kicking the robot assisting them. During the experiment in both trials, the trust in the functional ability of a Sphero bot in detecting collisions and reporting back to the user was tested.

3.1 Algorithm

The algorithm and code design aimed to test if a Sphero bolt encountered an obstacle and communicated information back to the user. The algorithm was written in JavaScript code and implemented through the Sphero Edu application.

For both trials, the algorithm performed similarly as the collision detection was enabled at the start of the code. The algorithm is organized into a finite-state machine with four states. The first state is called “waiting for collision” where the robot remains in this state until it is kicked or rolled in the experiment. Once this collision is detected, the robot moves into the “moving forward” state. The robot then rolls forward until it detects a collision. Once a collision is detected, it moves into the “moving backward state”. Here, the robot makes a 180-degree turn from the colliding object and starts moving backward to the user, where the user then stops the robot by triggering another collision. Finally, the robot reaches the terminal state where it tells the participant how far away it detected the collision from the starting point using the speaker. The program is then terminated and set up again to run another trial.

3.2 Robot Design

The robot chosen for our study was the Sphero Bolt robot. The Sphero is a round ball non-humanoid robot. The dimensions of the robot are 2.7 x 2.7 x 2.7 inches. The Sphero Edu app was how we connected to the Sphero and ran our algorithm.

3.3 Experiment Design

The study was performed on a total of 5 participants. Each participant was allowed to go through both trials of the experiment, so the study was done under within-subject conditions. Before each trial, the participant was given a brief overview of the Sphero bot, its capabilities, how to interact with it, and the functions it will be performing after the user input. They were then allowed to familiarize themselves with the robot and the surrounding environment under which the test was performed. Once comfortable with the robot, the participant was then given the first trial where they placed the Sphero on the ground and waited for it to be ready to receive the user input. This was indicated by displaying the word “Waiting” on the LED screen. In the first trial, they gently rolled the Sphero out and once this was detected, the Sphero continued moving forward until it hit an obstacle and detected a collision. The Sphero would then rotate 180 degrees and move backward towards the user. In this motion, the user stops the Sphero by lightly tapping it or any other motion of their preference. The Sphero waits around 7 seconds before speaking the distance at which the collision is detected and ends the program. The whole experiment with both trials took around 10-15 minutes to complete with each participant.

The second trial was performed in similar conditions with the function of the Sphero remaining the same. In this trial, however, the initial user interaction was different as they were told to kick the Sphero in this case, this being the “violent” action that was tested. After both trials, the participant was allowed some time to evaluate how they felt about interacting with the Sphero and then given a survey to take. The participants then reported their thoughts on the experiment by filling out both quantitative and qualitative data on the experiment.

The participants did not interact with other participants in this study. The participants were told that this device was designed as a navigational tool to help people avoid objects in their path. Each participant took part in both trials. Each participant was also instructed to stop the robot when it was coming backward to trigger the final collision.

The figures below demonstrate the interaction between the human and the robot, and the video link shows how both trials were performed with one user.

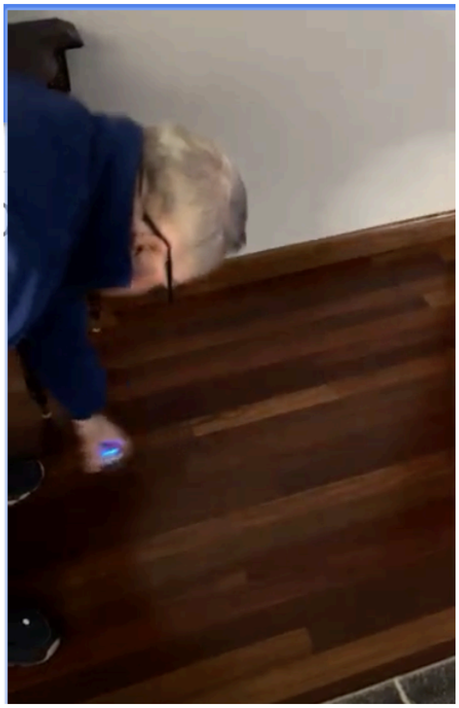

Figure: A participant throwing the Sphero

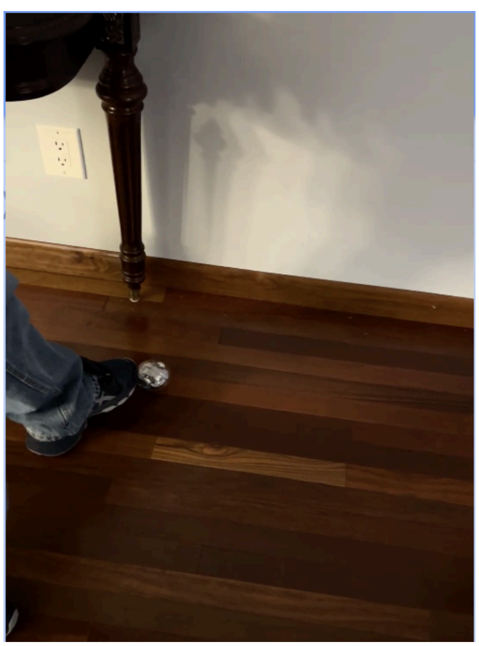

Figure: A participant kicking the Sphero

Video Links:

[Rolling Trial]

[Kicking Trial]

3.4 Measures

Our goal with this study was to measure how intuitive users find two different kinds of physical interactions with the robot. We measured this by adapting the UTAUT questionnaire, which consists of questions that gauge how well users have accepted a new technology, and the Likert scale, which involves giving a numerical rating to statements according to how well a participant agrees with them. UTAUT questions are based on key constructs that influence technology acceptance (Venkatesh et al, 2003). We decided to use questions that assessed the metrics of performance expectancy, effort expectancy, attitude toward using the technology, and anxiety. There were a total of 8 questions asked to the participant after both trials and they were designed to capture both qualitative and quantitative data. The following lists all the questions asked of the participants.

Question 1: How comfortable did you feel throwing the Sphero?

Question 2: How comfortable did you feel kicking the Sphero?

Question 3: Do you think it is socially acceptable to kick or throw a robot as part of an interaction? Why or why not?

Question 4: How much did you trust the robot's ability to accurately detect and report collisions when you threw it?

Question 5: How much did you trust the robot's ability to accurately detect and report collisions when you kicked it?

Question 6: Would you be willing to interact with a Sphero Bolt similarly in daily life or during other social experiments? Why or why not?

Question 7: Did anything unexpected happen during the interaction? If so, please describe it.

Question 8: Did you feel uneasy about how the robot was treated in this experiment?

In the above list, questions 1,2,4, and 5 were Likert-type questions with an answer scale of 1-7. For questions 1 and 2, 1 = “Extremely Comfortable”, 2 = “Very Uncomfortable”, 3 = ”Uncomfortable”, 4 = “Neutral”, 5= “Comfortable”, 6 = “Very Comfortable”, 7 = “Extremely Comfortable”. For questions 4 and 5, 1 = “No Trust At All”, 2 = “Very Low Trust”, 3 = “Low Trust”, 4 = “Neutral”, 5 = “Moderate Trust”, 6 = “High Trust”, 7 = “Complete Trust”. The rest of the questions were open-ended questions that provided qualitative data on the experiment.

3.5 Participants

For the participants, we had five different people who we personally knew complete our study. The participants varied in age with some being college-aged and others being middle-aged. Each participant completed both trials of our study and completed the survey following the study.

4. Discussion

We did not find a significant difference in attitudes with kicking versus rolling the Sphero, which did not support our hypothesis. We expected respondents to feel uncomfortable with kicking the Sphero, as we felt they would perceive kicking a robot to be an aggressive action that they may not feel as comfortable performing or imagining as integrated with their daily lives. We also found that respondents generally trusted the robot to report accurate information about obstacles they encountered. Interacting with the robot in different ways did not seem to impact their willingness to trust the information reported by the robot.

Interestingly, only one respondent reported that engaging physically with the robot via throwing or kicking was socially unacceptable out of a concern for the welfare of the robot itself, stating that they “felt hesitant fearing [the robot] would break up”. Respondents did have some caveats in regards to when exactly it was socially acceptable to throw or kick a robot, such as only when it was specifically designed for this purpose, or only if the robot becomes “more of a nuisance than a tool”.

Further research could investigate other factors that could impact these attitudes. For example, the appearance of the robot may play a factor in how respondents are willing to treat a robot; Sphero robots are not very anthropomorphic, which may have contributed to a lack of discomfort when kicking the robot.

5. Results

The results from the survey showed several conclusive data. A link to the survey responses can be found here.

For question 1, all participants reported being Neutral (4) to Extremely Comfortable (7) throwing the Sphero with Very Comfortable (6) receiving the highest number of responses. The mean calculated here would be a 5.6 which would indicate participants felt Very Comfortable on average.

How comfortable did you feel throwing the Sphero? 5

Q1 - How comfortable did you feel throwing the Sphero?	↑ Percentage	Count
4	20%	1
5	20%	1
7	20%	1
6	40%	2

Figure: Q1 results

For question 2, the responses ranged from Uncomfortable (3) to Extremely Comfortable (7) with Comfortable (5) receiving the most responses. The mean here is a 4.8 which is lower than when throwing but it still indicates the participants felt Comfortable on average with kicking the robot.

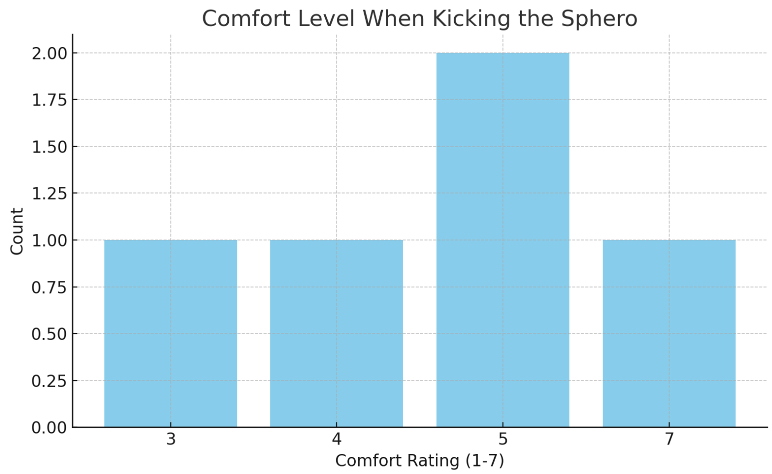

Figure: A chart for Q2 responses

For question 3, we can do a thematic analysis here with the themes being Conditional Acceptance, Hesitation, and No Moral Concern. This would place 40% of the responses in the Conditional Acceptance category since the participant mentioned that kicking is acceptable only in useful cases like a football with a sensor or depending on how useful of a tool it is in general. 40% of the participants would fall in the No Moral Concern category as they are fine with kicking something that is not living. The last 20% of the participants reported being Hesitant to kick out of fear of damaging the robot.

Do you think it is socially acceptable to kick or throw a robot as part of an interaction? Why or why not? 5

Do you think it is socially acceptable to kick or throw a robot as part of...

Yes

I think it is acceptable if it becomes more of a nuisance than a helpful tool.

No. Kicking it is acceptable only if its meant to be used that way, for example, a football with sensors

felt hesitant fearing it would break up

I think it's socially acceptable to kick or throw robots since they aren't really living.

Figure: Q3 responses

How much did you trust the robot's ability to accurately detect and report collisions when you threw it? 5

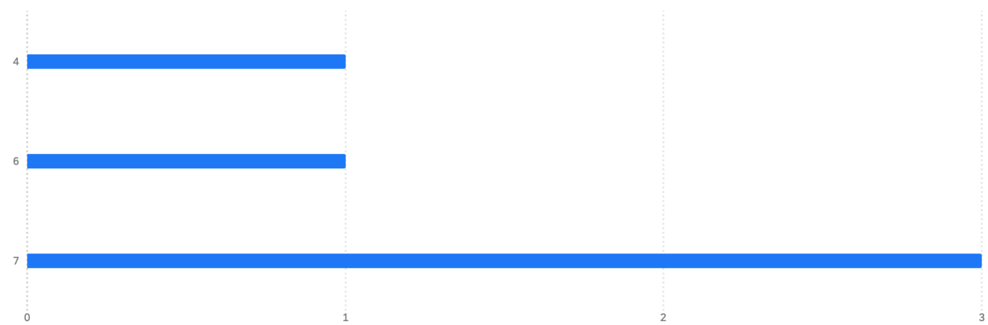

Figure: Q4 results

How much did you trust the robot's ability to accurately detect and report collisions when you kicked it? 5

Q6 - How much did you trust the robot's ability to accurately detect and report collisions when you kicked it?	Percentage	Count
4	20%	1
6	20%	1
7	60%	3

Figure: Q5 results

From the above figures, we can see that Q4 and Q5 results were identical. This means that in both cases participants in general placed strong trust in the robot's ability to perform its function properly regardless of how they initially interacted with it. This is because in both cases the Complete Trust (7) option received the most responses at 60% of the votes.

Would you be willing to interact with a Sphero Bolt similarly in daily life or during other social experiments? Why or why not? 5

Would you be willing to interact with a Sphero Bolt similarly in daily life...

Yes

I would be willing to interact with it to see if it becomes more helpful in the future.

Yes. It is an interesting piece of machinery and can have multiple different uses

no...it takes extra care

I would be willing to interact with a sphero bolt in daily life. It does not seem threatening.

Figure: Q6 results

The results for question 6 showed that after both trials, 80% of the users wanted to interact with a Sphero in their daily lives whereas one participant reported they are not likely to since it takes extra care to handle. This is consistent with the fact that the users felt a high degree of trust in the robot performing its actions.

Did anything unexpected happen during the interaction? If so, please describe it. 5

Did anything unexpected happen during the interaction? If so, please descri...
No
The robot took a long time to correct itself.
No
it came back to me
Nothing unexpected happen

Figure: Q7 response

The Q7 responses indicated that the participants were generally satisfied with how the experiment was performed without any significant unexpected issues occurring. Only one participant reported the robot taking a long time to correct itself.

Did you feel uneasy about how the robot was treated in this experiment? 5

Did you feel uneasy about how the robot was treated in this experiment?
No
No, I did not feel uneasy.
Yes
yes
I do not feel uneasy about how the robot was treated.

Figure: Q8 responses

The results from question 8 show that only 2 out of the 5 participants felt uneasy about how the robot was treated during the experiment. This suggests that while there is still evidence to suggest a “violent” or negative interaction may not be preferred by the users, they would still place a high level of trust in a robot’s capability as long as the experiments do not give any significant issues and the robot performs as expected.

6. Conclusion

We programmed a Sphero robot to search for obstacles ahead and report to users their distance from obstacles. Users could initiate this service by either throwing or kicking the robot. We had our subjects try both possible interactions with the robot and report their attitudes towards each behavior and their trust in the robot’s reporting. We found that the type of behavior (either throwing or kicking) did not seem to impact attitudes towards the robot, indicating that the type of behavior had little influence over a user’s willingness to interact with robots in daily life or trust in its functional capabilities. In terms of the implications of this study, Sphero robots are a popular choice for educating young children on robotics. Given the results of this study, it would provide valuable insight into choosing the interactive methods best suitable for garnering trust and usability of Sphero bots within children. Their willingness to adapt the technology would then directly impact their learning experience.

7. Acknowledgments

Brian:

I created the structure of the finite state method of structuring our algorithm and provided a skeleton for most of the methods. I also worked to debug the several issues we encountered with the algorithm not working properly, including the speed of the algorithm. I created the survey from the questions that Raed gathered from previously published questionnaires. I created it from the questions we agreed would be good for

our survey. For the paper, I wrote the Introduction, Background, and parts of the Methodology. I wrote the methodology introduction paragraph as well as the Robot Design and Experimental Design sections of the methodology. I also experimented with two people for the data collection part of our study. I also proofread all sections of the paper.

<u>Raed:</u>

I proofread our paper document and contributed to creating the presentation for the project. Specifically, for the paper, I added to the Methodology, Measures, Results, Conclusion, and Acknowledgements. I also tested out the code and gathered data from 2 participants out of the 5. Before this, I also researched and gathered preliminary experiment questions from which we carefully selected to ask for the survey of our experiment.

<u>Russell:</u>

I worked on and tested the code based on Brian's skeleton and worked on the Methodology, Measures, Participants, Discussion, and Conclusion sections. I designed the robot's core functionality and identified specific problems with the state machine that needed to be resolved. I also did some preliminary research in the types of questionnaires used for evaluating trust, gathered data from one participant out of the five, and helped proofread our paper.

Work Cited

D. Popov, A. Klimchik and N. Mavridis, "Collision detection, localization & classification for industrial robots with joint torque sensors," 2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), Lisbon, Portugal, 2017, pp. 838-843, doi: https://doi.org/10.1109/ROMAN.2017.8172400.

K.-B. Cho and B.-H. Lee, “Intelligent Lead: A Novel HRI Sensor for Guide Robots,” Sensors, vol. 12, no. 6, pp. 8301–8318, Jun. 2012, doi: https://doi.org/10.3390/s120608301.

Kok, Bing Cai, and Harold Soh. “Trust in Robots: Challenges and Opportunities - Current Robotics Reports.” SpringerLink, Springer International Publishing, 3 Sept. 2020, link.springer.com/article/10.1007/s43154-020-00029-y.

M. R. Ahmed and I. Kalaykov, "Static and dynamic collision safety for human robot interaction using magneto-rheological fluid based compliant robot manipulator," 2010 IEEE International Conference on Robotics and Biomimetics, Tianjin, China, 2010, pp. 370-375, doi: https://doi.org/10.1109/ROBIO.2010.5723355.

Onishi, Yuya, et al. “Applying Human–Animal Social Bonds to HRI: Fostering Intimate Relationship with Mechanical Robots.” Libert Pub, Aug. 2024, www.liebertpub.com/doi/full/10.1089/gyn.2013.0033?mobileUi=0.

P. Svarny, J. Rozlivek, L. Rustler and M. Hoffmann, "3D Collision-Force-Map for Safe Human-Robot Collaboration," 2021 IEEE International Conference on Robotics and Automation (ICRA), Xi'an, China, 2021, pp. 3829-3835, doi: https://doi.org/10.1109/ICRA48506.2021.9561845.

P. Svarny, M. Tesar, J. K. Behrens and M. Hoffmann, "Safe physical HRI: Toward a unified treatment of speed and separation monitoring together with power and force limiting," 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Macau, China, 2019, pp. 7580-7587, doi: https://doi.org/10.1109/IROS40897.2019.8968463.

Rossi, Alessandra, et al. “Investigating Human Perceptions of Trust in Robots for Safe Hri in Home Environments.” ACM Conferences, 6 Mar. 2017, dl.acm.org/doi/abs/10.1145/3029798.3034822?casa_token=p5bdRdg63AoAAAAA%3AYo8QwE5wtX8RL69cHUGB624YT5--YbZU0NVjC5wXZA0UsnWgLDO9J68vOhoxznDfBUWg1CyH-hFFmA.

S. Haddadin, A. De Luca and A. Albu-Schäffer, "Robot Collisions: A Survey on Detection, Isolation, and Identification," in IEEE Transactions on Robotics, vol. 33, no. 6, pp. 1292-1312, Dec. 2017, doi: https://doi/10.1109/TRO.2017.2723903.

Venkatesh, Viswanath, et al. “User acceptance of information technology: Toward a unified view.” *MIS Quarterly*, vol. 27, no. 3, Sept. 2003, pp. 425–478, https://doi.org/10.2307/30036540.

Willemse, Christian J. A. M., and Jan B. F. van Erp. “Social Touch in Human–Robot Interaction: Robot-Initiated Touches Can Induce Positive Responses without Extensive Prior Bonding.” SpringerLink, Springer Netherlands, 8 Nov. 2018, link.springer.com/article/10.1007/s12369-018-0500-9.

Yagoda, Rosemarie E., and Douglas J. Gillan. “You Want Me To Trust a Robot? The Development of a Human–Robot Interaction Trust Scale.” SpringerLink, Springer Netherlands, 17 Mar. 2012, link.springer.com/article/10.1007/s12369-012-0144-0.