Behavioral-economic games with commercially available robots

Kleijn, R.E. de; Dev, A.; Mukherjee, S.

Behavioral-economic Games with Commercially Available Robots

Roy de Kleijn
kleijnrde@fsw.leidenuniv.nl
Leiden University
Leiden, Netherlands

Avantika Dev
avantika.dev@hss.iitd.ac.in
Indian Institute of Technology Delhi
Hauz Khas, New Delhi, India

Sumitava Mukherjee
sm1@hss.iitd.ac.in
Indian Institute of Technology Delhi
Hauz Khas, New Delhi, India

ABSTRACT

Behavioral-economic games such as the dictator game have been a popular method for studying human-human interactions which can also be used to study human–robot interaction. Using commercially available robots, we showed participants photographs of 18 robots, and had them play a dictator game against these robots after answering a set of 12 questions regarding each robot's characteristics. Using principal component analysis and linear mixed effects modeling, we found that we could reduce our original 12 robot characteristics to three components—likability for the robot, anthropomorphism, and utility—which individually predicted dictator game offers. The findings are potentially of interest to robot designers and social scientists.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; *Laboratory experiments*.

KEYWORDS

human–robot interaction, dictator game, anthropomorphism, social robotics

ACM Reference Format:
Roy de Kleijn, Avantika Dev, and Sumitava Mukherjee. 2024. Behavioral-economic Games with Commercially Available Robots. In *Companion of the 2024 ACM/IEEE International Conference on Human-Robot Interaction (HRI '24 Companion), March 11–14, 2024, Boulder, CO, USA.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3610978.3640575

1 INTRODUCTION

Paradigms from the field of social psychology and behavioral economics can be valuable tools for investigating human–robot interaction. One example is economic games, in which participants share or divide amounts of money or tokens. In one particular economic game, the dictator game, participants are offered an amount of money that the participant can share with another participant. Based on the assumptions of rational self-interest, one would expect a player to keep the entire stake for themselves, giving nothing to the other player. However, this is not what we see in experimental settings using a "standard" dictator game, where only 40% of participants keep the entire stake for themselves [6]. Interpretations of the amount of money offered in the dictator game range from altruism to strategic behavior conforming to social norms [4, 5].

HRI '24 Companion, March 11–14, 2024, Boulder, CO, USA

ACM ISBN 979-8-4007-0323-2/24/03.
https://doi.org/10.1145/3610978.3640575

Dictator games in human–robot interaction are scarce but are vital to understanding the public psychology of robots as a window to social interaction. This in turn can reveal the changing fabric of human–robot relationships.

The growing interest among social scientists, designers and engineers to study human behavior towards robots is leading to a greater understanding of how we think, feel, and behave towards robots; rooted in tendencies for mindless social behavior, anthropomorphism, uncanny feelings, and formation of emotional attachments [1]. This study is among the first to test behavioral economic interactions with commercially available robots using the dictator game along with measuring tendencies towards these robots to find which could be underlying psychological mechanisms that guide behavioral-economic decision making. If we mindlessly apply social rules to robots—judging technology as if they are human (media equation; [9]), then one should observe similar behavior in dictator games with robots as those with humans.

2 CURRENT STUDY

Earlier work on anthropomorphism has investigated human–robot interaction in the context of the economic games (e.g. [2, 8]). Several findings suggest that participants cooperate with or give away money to a robot and are guided by how anthropomorphic the robot appears to be. In the current study, we aimed to expand on several earlier findings (e.g. [2, 7, 10]). First, we selected 18 commercially available robots listed on the IEEE website, maximizing heterogeneity. Second, we used multiple measures of judgment toward robots aimed at understanding why people give money to robots. Specifically, we investigated the relationship between anthropomorphic qualities, likeability, and utility of robots with dictator game offers. As far as we are aware, this is one of the first studies to have examined behavioral economic game behavior for a wide variety of commercial robots in India, an emerging market in the global south—and hardly represented in the human–robot interaction space.

3 METHOD

3.1 Participants

We recruited 361 undergraduate engineering students from a university in India. All participated for course credit and did not receive any monetary award.

3.2 Procedure

Participants were instructed to open a web survey. On each page, they were shown a photograph of one of 18 robots in random order (see Appendix A), and 12 questions asking about that robot's characteristics, followed by a question about how much they are willing to give to the robot—as the dictator game question (see

Table 1: Component loadings for all items.

Item	RC1	RC2	RC3
Can this robot plan its own actions independently?	**0.903**	0.044	0.108
Can this robot feel emotions?	**0.895**	−0.147	−0.050
Does this robot think like a human?	**0.894**	−0.034	0.008
How friendly is this robot?	**0.550**	0.494	−0.073
How physically similar is this robot to a human?	**0.506**	0.054	0.275
How creepy is this robot?	0.255	**−0.868**	0.269
How much do you like this robot?	0.277	**0.727**	−0.058
Would you like to touch this robot?	−0.137	**0.725**	0.210
Would you want to have this robot?	−0.055	**0.658**	0.320
Would you let this robot vacuum your house?	−0.182	0.022	**0.914**
Would you let this robot cook for you?	0.033	−0.091	**0.903**
Would you let this robot take care of your family?	0.180	0.164	**0.535**

Appendix A), before continuing to the next robot. The 12 questions about robot characteristics were answered using a continuous slider, with labels from "not at all" to "very much". The dictator game was not played for actual money but was phrased as a hypothetical ("If you were given ₹250, how much would you give this robot? Please enter a value between 0 and 250.").

3.3 Stimuli

We used photographs of 18 different commercially available robots from the IEEE Spectrum robots website [11], ranging from industrial to humanoid robots. Robot names were not shown to participants. Appendix A lists all robots used, as well as all questions asked. We refrained from using established scales such as ROSAS in favor of using a short but heterogeneous set of questions.

4 RESULTS

4.1 Principal components analysis

We performed a principal components analysis (PCA) on the 12 questions about robot characteristics with oblique rotation (promax). The scree plot, together with an assessment of interpretability, showed an inflexion justifying retaining three components. Table 1 shows the component loadings after rotation. The items on the three components suggest that component 1 represents a measure of anthropomorphism, including physical and cognitive similarity to humans. Component 2 represents general likability, and component 3 seems to represent a measure of utility. We will refer to these components as the Anthropomorphism index (AI), Likeability index (LI), and Utility index (UI), respectively.

4.2 Dictator game behavior

Between robots, the average proportion of the dictator game stake offered to each robot ranged from 0.31 (Cubelets) to 0.74 (Sophia). Across robots, the average proportion of the dictator game stake offered was 0.50.

Across participants, the average proportion of the dictator game stake offered—averaged over all robots—ranged from 0.00 (never giving anything to a robots) to 1.00 (always giving the entire stake to each robot). The distribution of the proportion of the dictator game stake offered per participant is shown in Figure 1.

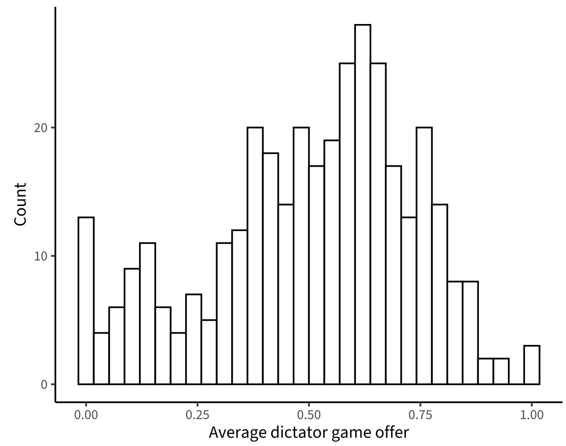


Figure 1: Histogram of the average proportion of the dictator game stake offered for each participant.

4.3 Effects of robot type

There was a main effect of robot type on the proportion of the dictator game stake given away, $F(17, 6120) = 137.5$, $p < .001$, $\eta^2_G = 0.13$. The distribution of dictator game stake offered by robot type is shown in Figure 2. As is visible in Figure 2, more humanoid robots (Sophia, NAO, Asimo, Pepper) tend to receive a larger proportion of the dictator game stake, with Sophia being the top recipient. There was also a main effect of robot type on all three PCA components, Fs(17, 6120) > 176.4, ps < .001, η^2_Gs > 0.23.

4.4 Predictors of dictator game behavior

We performed a linear mixed effects analysis of the relationship between several perceived robot characteristics and dictator game behavior. As fixed effects, we entered each robot characteristic (i.e. each question asked, excluding all other robot characteristics) into the model. As random effects, we had intercepts for subjects and robots, as well as by-subject and by-robot random slopes for the effect of the fixed factor. Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality. P-values were obtained by likelihood ratio tests of the full model with the effect in question against the model without the effect in question. All variables were scaled to the $[0, 1]$ interval.

All tested fixed effects affected dictator game behavior ($\chi^2(1)$s > 39.54, ps < 0.001). Estimates of the coefficients are displayed in Table 3 (Appendix B), and indicate the difference in the proportion offered in the dictator game between participants rating the characteristic as 0 (minimum) versus 1 (maximum), i.e. every 0.1 increase in the response to "How much do you like this robot?" leads to a 0.037 increase in dictator game proportion offered.

Next, we performed a linear mixed effects analysis of the relationship between the component loadings returned from our PCA and dictator game behavior. As fixed effects, we entered all three component loadings into the model. As random effects, we had intercepts for subjects and robots. This resulted in a significant model ($\chi^2(3) = 2485.5$, $p < 0.001$) with all three predictors $p < 0.001$

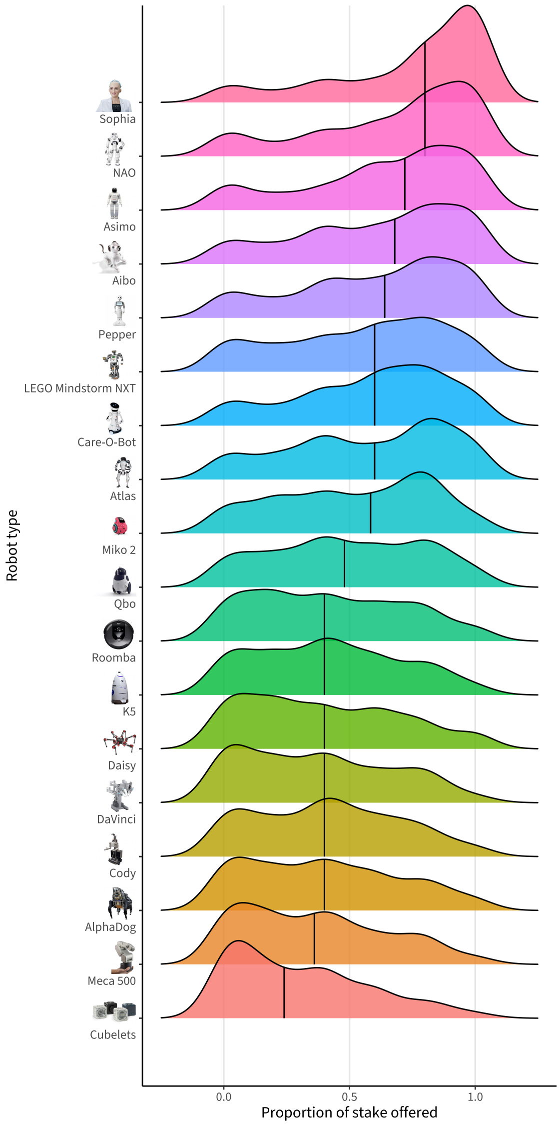


Figure 2: Smoothed density estimates of mean proportion of dictator game stake offered to each robot. Black vertical lines indicate the median value.

showing that all three components contribute to dictator game behavior.

5 DISCUSSION

Based on several papers highlighting the importance of anthropomorphization on prosocial behavior toward robots [2, 7, 10], we investigated the determinants of dictator game behavior against different types of robots. Dictator game behavior differed strongly between different robots, and on average people were willing to give away half of the stake. Although hypothetical dictator games result in larger stakes given away than real ones, overall patterns seem to remain consistent in our earlier—not yet published—work comparing hypothetical vs. real money stakes. This is somewhat similar to dictator game studies with human opponents such as [3], where a large proportion of people give away money in hypothetical dictator games. This underscores the possibility of the media equation: integrating robots—even commercial ones—as social actors, with humanoid robots being given the maximum share.

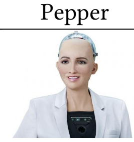
Additionally, we studied the determinants of dictator game behavior and their structure. Hence, we predicted dictator game behavior from three PCA components: Anthropomorphism index (AI), Likeability index (LI), and Utility index (UI). Comparing the estimated coefficients, likeability of a robot was the most important determinant of dictator game behavior, followed by utility and anthropomorphism. This shows that although anthropomorphism does have an effect on dictator game behavior, other factors seem to be more important. Humanoid robots received most money in our hypothetical dictator game, but we conclude that social interactions and decisions can be driven by both likeness towards a robot and anthropomorphism, with a potential social component of the Utility index, as the questions mainly pertain to social situations. These findings are potentially of interest to robot designers.

This is among the few studies from a non-Western emerging market where many robot companies are planning to expand in the near future. As we move towards international sales of these robots, cross-cultural studies could shed more light on the universality of these components as a determinant of dictator game behavior. Such studies can provide an interesting view of robots that can impact various other fields.

REFERENCES

[1] Elizabeth Broadbent. 2017. Interactions With Robots: The Truths We Reveal About Ourselves. *Annual Review of Psychology* 68, 1 (2017), 627–652. https://doi.org/10.1146/annurev-psych-010416-043958
[2] Roy de Kleijn, Lisa van Es, George Kachergis, and Bernhard Hommel. 2019. Anthropomorphization of artificial agents leads to fair and strategic, but not altruistic behavior. *International Journal of Human-Computer Studies* 122 (2019), 168–173. https://doi.org/10.1016/j.ijhcs.2018.09.008
[3] Anabel Doñate-Buendía, Aurora García-Gallego, and Marko Petrović. 2022. Gender and other moderators of giving in the dictator game: A meta-analysis. *Journal of Economic Behavior & Organization* 198 (2022), 280–301. https://doi.org/10.1016/j.jebo.2022.03.031
[4] Catherine C. Eckel and Philip J. Grossman. 1996. Altruism in Anonymous Dictator Games. *Games and Economic Behavior* 16, 2 (1996), 181–191. https://doi.org/10.1006/game.1996.0081
[5] Aileen Edele, Isabel Dziobek, and Monika Keller. 2013. Explaining altruistic sharing in the dictator game: The role of affective empathy, cognitive empathy, and justice sensitivity. *Learning and Individual Differences* 24 (2013), 96–102. https://doi.org/10.1016/j.lindif.2012.12.020
[6] Francesco Guala and Luigi Mittone. 2010. Paradigmatic experiments: The Dictator Game. *The Journal of Socio-Economics* 39, 5 (2010), 578–584. https://doi.org/10.1016/j.socec.2009.05.007 Special Issue:Topics on Contemporary Behavioral Economics.
[7] Saskia Heijnen, Roy de Kleijn, and Bernhard Hommel. 2019. The Impact of Human–Robot Synchronization on Anthropomorphization. *Frontiers in Psychology* 9 (2019). https://doi.org/10.3389/fpsyg.2018.02607
[8] Te-Yi Hsieh, Bishakha Chaudhury, and Emily S. Cross. 2023. Human–robot cooperation in economic games: People show strong reciprocity but conditional prosociality toward robots. *International Journal of Social Robotics* (2023), 1–15.
[9] Clifford Nass and Youngme Moon. 2000. Machines and Mindlessness: Social Responses to Computers. *Journal of Social Issues* 56, 1 (2000), 81–103. https://doi.org/10.1111/0022-4537.00153
[10] Sari R.R. Nijssen, Barbara C.N. Müller, Tibor Bosse, and Markus Paulus. 2021. You, robot? The role of anthropomorphic emotion attributions in children's sharing with a robot. *International Journal of Child-Computer Interaction* 30 (2021), 100319. https://doi.org/10.1016/j.ijcci.2021.100319
[11] IEEE Spectrum. 2023. Explore robots. https://robotsguide.com/robots

Table 2: Robots used in the current study

		
Aibo	AlphaDog	Asimo
		
Atlas	Care-O-Bot	Cody
		
Cubelets	DaVinci	Daisy
		
K5	LEGO Mindstorm NXT	Meca 500
		
Miko 2	NAO	Pepper
		
Qbo	Roomba	Sophia

A STIMULUS DETAILS

A.1 Robots used in this study

We used photographs of 18 different robots from the IEEE Spectrum robots website [11], ranging from industrial to humanoid robots. Table 2 shows an overview of all robots used.

A.2 Questions asked about each robot

The questions that appeared on screen after the photograph of a robot are listed below.

- How much do you like this robot?
- How physically similar is this robot to a human?
- Does this robot think like a human?
- How friendly is this robot?
- How creepy is this robot?
- Can this robot plan its own actions independently?
- Can this robot feel emotions?
- Would you let this robot vacuum your house?
- Would you let this robot cook for you?
- Would you let this robot take care of your family?
- Would you like to touch this robot?
- Would you want to have this robot?
- If you were given ₹250, how much would you give this robot? Please enter a value between 0 and 250. *[Note: ₹250 corresponds to USD 3.01 as of November 2023.]*

B LINEAR MIXED-EFFECTS MODEL COEFFICIENTS

Table 3: Estimates for coefficients of the different linear mixed models predicting dictator game behavior. The last three fixed effects were used together in one model.

Fixed effect	Value	95% CI
Would you want to have this robot?	0.424	[0.388, 0.461]
How much do you like this robot?	0.369	[0.335, 0.404]
Would you like to touch this robot?	0.365	[0.323, 0.407]
Would you let this robot take care of your family?	0.310	[0.275, 0.345]
How friendly is this robot?	0.302	[0.266, 0.338]
Would you let this robot cook for you?	0.274	[0.236, 0.312]
Does this robot think like a human?	0.249	[0.212, 0.286]
Would you let this robot vacuum your house?	0.231	[0.198, 0.265]
Can this robot plan its own actions independently?	0.229	[0.196, 0.262]
How physically similar is this robot to a human?	0.211	[0.161, 0.262]
Can this robot feel emotions?	0.195	[0.150, 0.242]
How creepy is this robot?	−0.188	[−0.228, −0.148]
Likeability index	0.111	[0.105, 0.118]
Utility index	0.056	[0.048, 0.063]
Anthropomorphism index	0.038	[0.030, 0.046]