# A Comparison Between the Effectiveness of a Virtually and a Physically Present Robot when Evoking Prosocial Behavior in Humans

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*Abstract*: Robots are a fast-evolving sphere of technology that can provide people with incredible benefits. They can replace or assist humans in various types of tasks. Although they can be very useful, they may also have an unexpected beneficial psychological influence on people through verbal interactions. Depending on the way they speak and the state of their physical presence in a room, robots may boost a human's prosocial behavior which can be beneficial for an individual.

This research focuses on how a robot affects a person in a prosocial aspect through positive verbal encouragements depending on how a robot is present in a room – physically or virtually. An experiment has been performed with two groups of random people. Both groups interact identically with a robot with the only difference that the first group had to communicate with a physically present robot and the second – with a virtual one. After the experiment, participants were asked to fill in a questionnaire that was used to measure prosocial behavior and robot perception.

An analysis on the results was done to find whether there is a significant difference between the answers of the participants from the two groups. The goal of this study is to provide a better understanding of human-robot interactions, robot use and development in spheres such as teaching, healthcare and sports where a boost in prosocial behavior can improve the general well-being and health of a human.

Additional Key Words and Phrases: Prosocial behavior, robot, Human-Robot Interaction, PSA, Physically Present Robot, Virtually Present Robot

## 1 INTRODUCTION

Nowadays, with the constant technological advancements, robots are becoming more and more advanced. This has led to the possibility of using them in situations where they can assist and help people through verbal interactions [e.g., 1, 2, 3, 4]. However, this can be a difficult task since humans' perception and acceptance of robots can vary depending on the way the robot interacts with an individual [1, 5, 6, 7]. If verbal interactions between robots and humans can have an influence on a person, then it follows that different types of communication can have a specific effect [e.g., 1, 5, 11]. This means that robots can be designed and programmed in such a way that when they interact verbally with humans, they could possibly evoke prosocial behavior through their communication which can increase positive thinking and happiness in a person.

Prosocial behavior has always played an important role in societies. Studies suggest that a positive environment and mental state can evoke more prosocial behavior in an individual [8, 9, 11] and more prosocial behavior can lead to more happiness and benefits for a society as a whole [10]. If people interact with robots, then it would be ideal for robots to be designed in such a way that they can have a positive influence as much as possible.

When considering robot design, physical embodiment is a very important aspect. Jamy Li [14] suggests that when people interact with robots, they prefer a physically present robot. This raises the important question – how do two robots with different physical embodiments compare to each other, when measuring their effectiveness in evoking prosocial behavior through verbal encouragements? Moreover, if it is known how to make robots in this manner, then they could find further uses in spheres such as teaching and healthcare where they can be used to improve the lives of patients, students, etc. not only through aiding but also through creating a more prosocial and positive environment.

In this paper, I present the approach, design methodology and results of a comparison between a virtually and physically present robot when looking at their effectiveness in provoking prosocial behavior in people through verbal interactions. The results were measured by asking participants to fill in a validated survey – PSA (for prosocial behavior) [12]. The study tries to give insight on the influence a robot can have on a person in a prosocial aspect and whether the physical form of the robot has any consequences on the outcome.

## 2 Related works

The effect of prosocial behavior on a person's mental state is often researched and several scientific publications could be found that hint of its positive effects. Hamlin and Aknin [10] prove that in a small-scale rural society, an increase in prosociality can boost the overall happiness of individuals. Spivak [9] further shows that verbal encouragements and prosocial behavior can increase happiness in children which leads to a more positive environment. Furthermore, Stellar and DeMarco [8]. reinforce the claim that prosocial behavior and positive emotions are interlinked and can improve the general well-being, physical health and relationships of an individual. Unfortunately, most of the research performed on prosociality is only on children while literature about adults is lacking.

Human-robot interactions is a topic that is constantly researched and therefore it is rich in scientific literature. There is both research done on how robots can help and assist people including verbal interactions - [3, 4, 5, 6] and on how their actions affect humans - [1, 2, 11]. Furthermore, it is also important to note how to design a robot in order to make it more likeable and trustworthy in order to maximize the effectiveness of the machine. An example of research on this is [7].

In this research, prosocial behavior was measured. To do that, the PSA questionnaire was used. Caprara, Steca, Zelli and Capanna [12] show that the PSA is an effective way to measure this type of behavior.

## 3 METHODOLOGY

I designed and conducted a user study with random participants to evaluate the effectiveness of robots provoking prosocial behavior when encouraging people. The study aimed to investigate the influence of embodiment on evoking prosocialness. Specifically, the research compared the effectiveness of a physical humanoid robot to that of a virtual representation of the same robot shown on a screen.

### 3.1 Study Design

Study participants were divided into two groups, physical robot embodiment vs. virtual robot embodiment. The study consisted of a 5-minute quiz, 1 questionnaire once the quiz was finished and a debriefing afterwards, conducted over a one-week period. The quiz consisted of random questions and the questions were asked by the robots. The robots were not autonomous but were controlled through wizard of Oz (a method where participants interact with a system that they believe to be autonomous but is controlled by an unseen human operator in the next room).

Due to time constraints and facility limitations, no physical interactions were possible. That is why a simple quiz was chosen for the interaction. When a person answers a question correctly, Nao gives encouragements and congratulations which Spivak [9] ha argued to boost prosocialness. At the same time, if a participant gives a wrong answer, the robot shows empathy and understanding – both of which are suggested to be contributors to prosocialness in Roberts's and Strayers's research [15].

### 3.2 Participants and groups

A total of 22 people participated in the study. Recruitment was done through verbal invitations and personal messages on social media. There were no criteria for participant selection, however, due to the experiment taking place on the university grounds, all the people that were invited were associated with the University of Twente and were in the age range of 20 to 30.

Participants were divided into two groups – one with the physically present robot and one with the virtually present. However, while conducting the experiment, the physical robot malfunctioned and behaved differently from what it was expected twice. This resulted in removing two participants' results from the data as their data could have been influenced by the robot's faulty behavior.

### 3.3 Materials

For the physical robot, the autonomous, programmable humanoid Nao robot was used. It was programmed and controlled using Choregraphe. A photograph of the robot can be seen in Figure 1(a).

For its virtual representation, a virtual Nao robot was used from the Choregraphe IDE. The virtual robot was shown on a 24-inch monitor. The virtual robot used prerecorded dialogues that were played through the LEICKE Bluetooth DJ Roxxx speaker. Figure 1(b) shows how the virtual Nao looked like.

A room separator was used to make participants feel alone with the robot and a tablet was used to monitor them

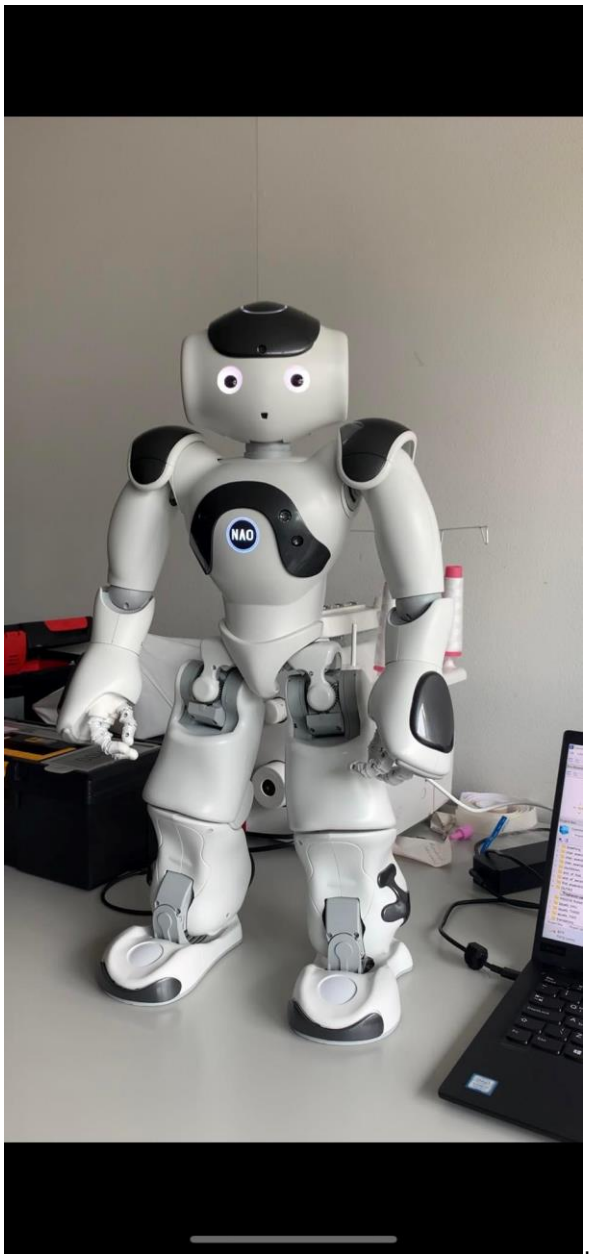


Figure 1. (a) Physical Nao robot

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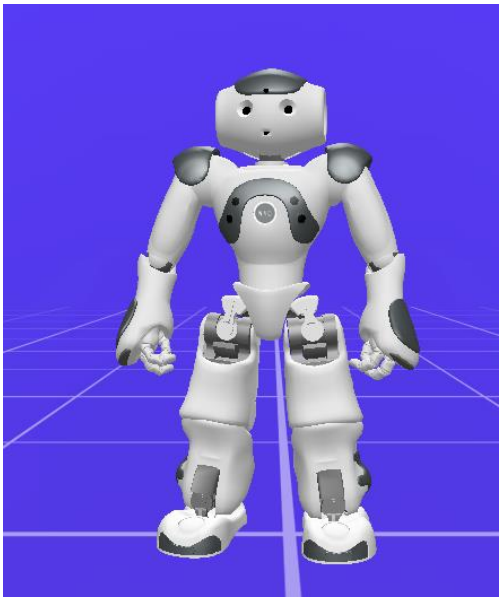

Figure 1. (b) Virtual Nao robot

### 3.4 Experiment setup and procedure

The experiment took place in room 2051ZL in the University of Twente. Participants were left in the room with the robot and a supervisor. A room separator was used, so that participants cannot see the supervisor. The purpose of this was to increase the feeling of autonomy of the robot and to avoid participants feeling awkward that someone might be looking at their interactions with the robot. Furthermore, the separation was used to decrease the feeling that the robot was being controlled by someone and to create the illusion of them being alone in a room. Throughout the quiz, a tablet was used to monitor participants, in case some problem arises. A photograph of the room setup can be seen in Figure 2.

The experiment itself consisted of the Nao robot greeting the participant, introducing itself and asking for the name of the person. Then Nao would proceed to ask whether the participant is ready to begin with the quiz. Once a positive answer was given, the robot would ask a total of 9 random questions. After it was given an answer, it would reply whether the answer is correct and would try to encourage the participant for the attempt to answer the question. After completing the 9 questions, Nao informed participants that the quiz is over and thanked them for their time. Then it would say it had fun and inform them that they can go to the supervisor to be debriefed. Table 1 provides all the preprogrammed replies. A table with the exact robot replies can be found in the appendix in Table 1.

Afterwards, the supervisor would remove the room separator and provide the participants with the PSA questionnaire. Once the questionnaire was filled, the supervisor would debrief participants in more detail about the experiment and the purpose of the research.

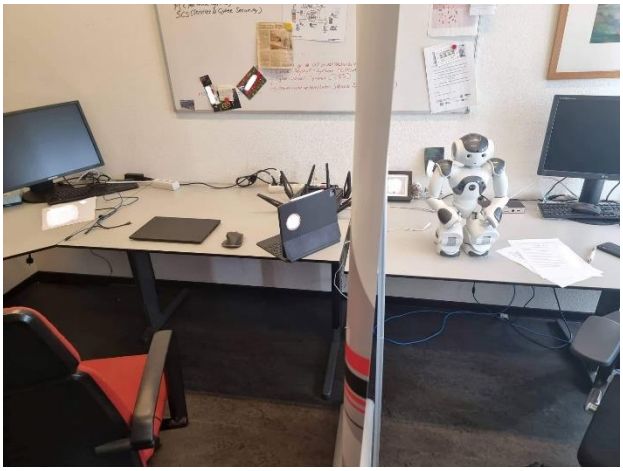

Figure 2. Room setup

### 3.5 Variables

The variable that had to be measured in order to compare the effectiveness of the two robots was prosocial behavior. Therefore, the questionnaire that was used for measurement was the Prosocialness Scale for Adults (PSA). PSA measures an individual's prosocial behavior through 16 prosocialness items. Each statement has a five-point Likert scale with the following options as answers - never/almost never true (coded as 1), occasionally true (coded as 2), sometimes true (coded as 3), often true (coded as 4), and almost always/always true (coded as 5). The PSA questions can be found in the appendix as Figure 3.

## 4 RESULTS

The results of the PSA are calculated by finding the mean of the 16 answers of a participant. The results of both participant groups can be found in the appendix in Table 2. After calculating each participants' PSA results, the results were separated into two data variables each representing the results of one of the groups. The descriptive statistics of the variables can be seen in Figure 4 in the appendix. The mean value of the physical robot group is m1 = 3.856250, while the mean of the virtual robot group is m2 = 3.200000.

In order to see if there was a significant difference between the results of the two groups, a comparison of the means was necessary. The comparison was done using a One-Way ANOVA test. One-Way ANOVA ("analysis of variance") compares the means of two or more independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different. The descriptive statistics of the ANOVA test can be found on Figure 5 in the appendix. On Figure 6 the significance value is p = 0.015.

## 5 DISCUSSIONS

By looking at the table in Figure 6, it can be seen that the significance value p = 0.015 of the test is below 0.05 and therefore, there is a statistically significant difference in the mean PSA results of a participant that interacted with the physical Nao and a participant that interacted with the virtual Nao. These results suggest that a robot that is physically present in a room is more effective in provoking

prosocial behavior when compared to a virtually present one.

We hope that by carrying out this experiment and analyzing the results, we have contributed to the sphere of HRI and helped any future scientific research related to robotics.

## 6 FUTURE WORK

The research that was carried out suggests that physical robots are more effective at provoking prosocial behavior, however more experiments would be necessary to confirm this. Due to time constraints, for this experiment a quiz was used. When doing such experiments in the future, it would be best to avoid activities that can be measured with success, as this could influence a participant's results. A person might feel more prone to prosocial behavior when constantly giving correct answers or less prone when constantly making mistakes.

Additionally, this paper does not cover how robots with a difference in their physical embodiment can influence people's prosocial behavior when instead of encouragements, they give negative or neutral replies.

Finally, the only measurement used for this experiment is the PSA. Future works can include not only validated questionnaires but also other types of measurements such as asking participants to donate to charity or to help the researchers with a specific task. With a second type of measurement, researchers could have more evidence to prove or disprove their hypothesis.

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## APPENDIX

Table 1. Preprogrammed robot replies

| Type of reply | Reply | Replies to correct and incorrect answers |
|---|---|---|
| Greeting | Hi, my name is Nacho. What is your name? | - |
| Ask to begin the quiz | Well, it's nice to meet you. Yordan should have explained the experiment to you already. So, if you don't have any questions I am going to start with the quiz. | - |
| Question 1 | First question. Is one a prime number? | 1. That is correct. Nice. You are starting off pretty good.<br>2. That is incorrect. Don't worry, math is lame anyway. |
| Question 2 | Question 2 let's go. What is the capital of Madagascar? | 1. That is correct. That was a hard one. I am impressed.<br>2. Don't worry, nobody knows the capital of Madagascar anyway. |
| Question 3 | Question number 3. What are the three main macronutrients? | 1. Good job, that is correct. It is important to know your nutrition. |

| | | |
|---|---|---|
| | | 2. That is incorrect. But don't get discouraged. Nutrition is important so I advise to learn more about it. |
| Question 4 | Question 4. Which planet is closest to the sun? | 1. That is exactly the answer. You are pretty good at astronomy.<br>2. Unfortunately, that is incorrect. But you are going to ace the next one! |
| Question 5 | We are halfway through. Let's go with question 5. Who wrote Les Misérables? | 1. That is correct. Outstanding work! Les Misérables is one of my favorite books by the way.<br>2. That's wrong. You should read it though. It is a great book. |
| Question 6 | Next, number 6. Which grain is used to make saké? | 1. Correct. Keep on going with the correct answers!<br>2. Well, that's wrong. But I know you are gonna ace the next question! |
| Question 7 | Question 7. From which book series is the fictional character Katniss Everdeen? | 1. Correct. Keep it up!<br>2. You are wrong. I am sure you are gonna get the next one though. |
| Question 8 | We are almost done. Question 8. Who won the 2010 Football World Cup? | 1. Correct. Waka waka.<br>2. Unfortunately, you got this one wrong. But don't worry about it. |
| Question 9 | Last question. Question 9. How many French open titles does Rafael Nadal have? | 1. That was a hard one and you gave a correct answer. I am very impressed.<br>2. That was a pretty hard one, so don't worry you gave a wrong answer. |
| | This concludes our quiz. Thank you for | |
| | participating. I hope you had as much fun as I did. Now that the quiz is over you can go to Yordan, so he can debrief you. Good luck and goodbye. | |

Figure 3. PSA questionnaire:

The following statements describe a large number of common situations. There are no right or wrong answers; the best answer is the immediate, spontaneous one. Read each phrase carefully and fill in the number that reflects your first reaction.

**1 Never/Almost Never  2 Rarely  3 Occasionally  4 Often  5 Always/Almost Always**

| | |
|---|---|
| 1. I am pleased to help my friends/colleagues in their activities. | 1 2 3 4 5 |
| 2. I share the things that I have with my friends. | 1 2 3 4 5 |
| 3. I try to help others. | 1 2 3 4 5 |
| 4. I am available for volunteer activities to help those who are in need. | 1 2 3 4 5 |
| 5. I am empathic with those who are in need. | 1 2 3 4 5 |
| 6. I help immediately those who are in need. | 1 2 3 4 5 |
| 7. I do what I can to help others avoid getting into trouble. | 1 2 3 4 5 |
| 8. I intensely feel what others feel | 1 2 3 4 5 |
| 9. I am willing to make my knowledge and abilities available to others | 1 2 3 4 5 |
| 10. I try to console those who are sad. | 1 2 3 4 5 |
| 11. I easily lend money or other things | 1 2 3 4 5 |
| 12. I easily put myself in the shoes of those who are in discomfort | 1 2 3 4 5 |
| 13. I try to be close to and take care of those who are in need | 1 2 3 4 5 |
| 14. I easily share with friends any good opportunity that comes to me | 1 2 3 4 5 |
| 15. I spend time with those friends who feel lonely | 1 2 3 4 5 |
| 16. I immediately sense my friends' discomfort even when it is not directly communicated to me. | 1 2 3 4 5 |

Table 2. PSA results of every participant:

| Physical robot group | Virtual robot group |
|---|---|
| 3.0000 | 2.3125 |
| 3.3125 | 2.5625 |
| 3.7500 | 2.6250 |
| 3.8125 | 2.8750 |
| 3.8750 | 3.1875 |
| 3.8750 | 3.3125 |
| 4.0000 | 3.3750 |
| 4.0625 | 3.6250 |
| 4.1250 | 3.9375 |
| 4.7500 | 4.1875 |

*Figure 4. Descriptive statistics of the PSA results of both groups:*

| | | PhysicalRobot | VirtualRobot |
|---|---|---|---|
| N | Valid | 10 | 10 |
| | Missing | 0 | 0 |
| Mean | | 3.856250 | 3.200000 |
| Median | | 3.875000 | 3.250000 |
| Std. Deviation | | .4686806 | .6122307 |
| Range | | 1.7500 | 1.8750 |
| Minimum | | 3.0000 | 2.3125 |
| Maximum | | 4.7500 | 4.1875 |

Figure 5. Descriptive statistics of the One-Way ANOVA test:

**Descriptives**

Result

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Physical | 10 | 3.856250 | .4686806 | .1482098 | 3.520976 | 4.191524 | 3.0000 | 4.7500 |
| Virtual | 10 | 3.200000 | .6122307 | .1936043 | 2.762037 | 3.637963 | 2.3125 | 4.1875 |
| Total | 20 | 3.528125 | .6284363 | .1405226 | 3.234008 | 3.822242 | 2.3125 | 4.7500 |

Figure 6. One-Way ANOVA test results:

Result

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.153 | 1 | 2.153 | 7.244 | .015 |
| Within Groups | 5.350 | 18 | .297 | | |
| Total | 7.504 | 19 | | | |

**ANOVA Effect Sizes[a,b]**

| | | Point Estimate | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower | Upper |
| Result | Eta-squared | .287 | .011 | .536 |
| | Epsilon-squared | .247 | -.044 | .510 |
| | Omega-squared Fixed-effect | .238 | -.041 | .497 |
| | Omega-squared Random-effect | .238 | -.041 | .497 |

a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

b. Negative but less biased estimates are retained, not rounded to zero.