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How Do People Perceive and Trust a Lifelike Robot

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***Abstract*—This paper reports the results from an experiment examining people's perception and trust when interacting with an android robot. Also, they engaged in an economic trust game with the robot. We used proxemics, the physical distance to the robot, and questionnaires to measure the participants` character and their perception of the robot. We found influences of the subject's character onto the amount sent in the trust game and distance changes over the 3 interaction tasks. The perception of the robot changed after the interaction trials towards less anthropomorph and less intelligent, but safer. This study would enable future researches to compare different robot types, personality traits and cross-cultural effects.**

***Index Terms*—Human Robot Interaction, android robot, trust game, Godspeed**

I. Introduction

ROBOTS no longer belong to the world of science fiction, they are reality and more sooner than later will be having a real impact on the way we live. In our schools, homes, workplaces, museums, hospitals, shops we are, and will continue to be, interacting with robots so it is crucial that we begin to examine this young and fast changing field. Today, the production of sophisticated robots enables researchers to examine the interaction between people and robots for the first time.

Social aspects of Human Robot Interaction (HRI) are critical for the future scenario if robots are to become a part of people's life. HRI research faces a number of key challenges. There are technological hurdles on the engineering side and interaction of the many factors forming social experiences on the human-factor side. To come to a broad understanding what forms interaction (with robots) these factors must be teased apart for proper studies.

Despite recent progress of robotics and robots showing more and more capabilities, our perceptions and expectations towards robots are more shaped by what we see in the news, videos or movies than by real interaction with an actual physically present robot [26]. Real interactions of people with robots are not a common scenario, but it has been shown that the physical embodiment [1], means the actual presence of a robot, does play a crucial role in HRI and the perception of a robot. Previous studies examined the effect of robot design and appearance onto people's perception and expectation towards them [2],[3]. In these studies, the android robot triggered significantly different reactions from subjects compared to other robot types (e.g. humanoid robot, pet robots). This study addresses this issue by letting humans directly interact with a very human-like android robot.

Fig. 1. The very life-like android robot Geminoid-F. The female version of this robot is so close to a real human that, on a picture, it is very difficult to distinguish it from a real human. The left photo was taken by the ATR Hiroshi Ishiguro Laboratory, the right photo shows the setting of this study.

An android robot is a very specific robot type that is designed to look and attempts to act like a human. Like a humanoid robot, it has the shape of a human being, but has in addition detailed features like skin, eyelashes, hair, etc. For this study, the female version of the android robot Geminoid was used. Such human-like robots enable researchers to investigate how humans recognize others. In a short glace (under 2 sec.), human observers tend to recognize this android robot as a human (70% of subjects failed to distinguish human and android). Android robots also give humans an eerie feeling, which was defined as "uncanny valley" [4]. It is stated that, as the appearance of robots becomes more human, they seem more familiar, until a point is reached at which the response from the observer quickly drops from positive to a strong revulsion.

To examine the perception towards this potential "uncanny" robot we decided to conduct a study in which subjects met an android robot "in person" for the first time.

A. Perception

We wanted to examine how the perception of the robot would change after interacting with the robot. For that, the

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robot was rated on a scale before and after the interaction tasks and the outcome was compared.

B. Trust game

Another interesting and challenging research question is how much people trust such a life-like. Under laboratory conditions, one way to measure trust is a so-called economic trust game [22], which allows us to empirically quantify trust in relationships in a reliable and standardized way. With these trust games, interaction behavior can be measured between humans and therefore we applied this game to an emerging relationship, the one between humans and the robot.

Social exchange is influenced by many factors. Recent research developments have looked directly at subject's decisions from the perspective of personality psychology and suggested that individual character and personality type influence subject's decisions in laboratory experiments [5], [6], [7], [9], [10]. Our application of the game-theoretic approach to human robot interaction provides a model of empirical measurement of trust towards robots. This method can be applied to any type of robot and future data can be easily compared.

Investigation of specific personality traits has shown [5] that extrovert personality type subjects (directed towards the objective world) exhibited stronger than expected feelings of trust with the amount sent in the trust game. Extrovert types offered in this previous study approximately $1.14 (from totally $10) more. The question was therefore: If people with extrovert personality traits would also trust (and endow) the robot more than people with introvert personality. Related research in the field of HRI [8] suggests that people's preferences for robot appearance and behavior may be related to their personality traits. It has been indicated that more introverted individuals tended to prefer mechanoid robot appearance and extroverts preferred more humanoid robots.

The inevitable interpersonal nature of non-cooperative trust games allows us to address this question here by involving the subject after several interaction tasks with the robot in a trust game. Only very recently researchers started to use robots to assess cooperative intentions of novel partners by using nonverbal signals with the help of robots and a variant of the prisoner's dilemma game [11]. Another study focused on the physical appearance of the robot face and stated that participants acted as if they attributed complex human-like motivations to the shown robots. Participants did not have direct contact with a robot but were presented a photo-based survey [12].

C. Interaction

Ratings are quick ways to measure human perception. However, there are some limitations to this method as participants administer questionnaires only after the actual interaction and might be biased. It is therefore crucial that also objective methods through observation of the subject's behaviors are applied. An example for such observations would be the times a subject needs to fulfill a task or spends with the robot and also the distance he or she keeps away from the robot.

There exist some studies that examined the complex relationship of proxemics to robots. It was found that 60% of the participants chose distances to the robot that were comparable to normal human-human social interaction distances [16]. It was also found that the experience with owning pets and robots decreased personal space and the directions of the robot's gaze had an effect on proxemics behavior [17].

Factors like prior experiences with robots, prior relationships with non-human agents like pets [16], and the subject's personality [18], [19], [20] may influence the measurements. Another crucial factor is the physical presence of the robot [1].

This led to the construction of a complex experiment that intended to evaluate changes in participant's perception in relation to their personality traits, trust in relation to their personality traits and observations like proxemics and task times. The goal of this study was to bring together people and the android robot under laboratory conditions to examine their character, perception and trust towards when actually interacting with the physically present robot. We used previously validated scales and questionnaires that would enable future research to compare robot types, personality types and also the development over time when contact with robots increases.

Participants interacted with the robot three times, allowing them to get more familiar with the robot. It engaged them in a short conversation (e.g. introducing itself, asking the name) and then instructed a very simple task (move a box) in the first two trials and to touch its hand in the third. We conducted a 2x2 condition experiment and participants were assigned randomly to one of the two condition conditions: the robot turned the head toward the boxes when talking about them and a higher/lower payback in the trust games as described below.

We hypothesized that:

1. Subjects would reduce the amount of space between them and the robot over the three trials
2. The subject's performance in the trust game would be linked to their likeability toward the robot.
3. Participant's previous experience with non-human agents (e.g. pets, virtual agents, etc.) would decrease their distance to the robot [17]
4. Individuals with extrovert personality traits would make higher offers in the trust game.

II. Material and Methods

A. Participants

Fifty-six subjects were recruited from local universities in Japan. One subject was eliminated from the examination due to participant bias (demand characteristics), which left 55 subjects. Age ranged from 18 to 66 years (with the mean of 22.6 years). 37 participants were female, 18 male. None of the participants had experienced any interaction with an android robot before. The interaction context and questionnaire were all in Japanese. The participants received monetary reimbursement for their participation. They were randomly assigned to the experimental conditions.

A. *Trust game*

The experiment consisted of three main stages. In the first stage, the subject's basic demographic data, personality traits (Eysenck Personality questionnaire [21], and perception of the robot were evaluated (Godspeed, [13]). To evaluate changes in participant's perception of the robot, the questionnaire was administered before the interaction tasks (showing pictures of android robots) and after the interaction tasks with the robot. In addition to age, sex etc., participants were asked their prior exposure to robots, their exposure to virtual agents (e.g in computer games), and if they had ever owned a pet.

The second stage consisted of 3 simple interaction tasks with the robot. In trial 1 and 2 the robot asked the subject to move a box to another position, in task 3 it asked to touch its hand. Before each task, the robot engaged the participant in a small conversation and then gave instructions of the task. When the task was completed, the robot thanked them for their cooperation and asked the subject to wait outside the room.

In the third stage an economic trust game was 'played' between the robot and participants in a similar context to that used during human-human interaction [22, 23]. In the two-player trust game player 1 (here always the subject) was endowed with a fixed amount of money (JPY1000, approximately $10), and given the option of sending any portion of the money to player 2 (the robot). The returning amount from the robot to the subject was manipulated by the researcher. Depending on the randomly assigned condition the payback would be either JPY200 less or more money than the subject had initially sent to the robot.

B. *Measurements*

We asked participants if they ever owned a pet and how often they were in contact with virtual agents (e.g. in computer games). This was rated on a 5-point scale from 1 (never) to 5 (nearly daily).

Eysenck Personality questionnaire

The Eysenck Personality questionnaire [23] categorizes personalities in a systematic way, using the three factors of psychoticism, extroversion and neuroticism. It is also one of the few personality questionnaires that is validated in Japanese and other languages for a later direct comparison of intercultural studies. We used the Japanese version of the short-form Eysenck Personality Questionnaire—Revised (EPQ-R) [22]. The questions were presented in random order.

Godspeed Robot perception

The Godspeed questionnaire [13] measures five key concepts in HRI using 5-point scales. Anthropomorphism is the attribution of a human form and human characteristics. As mentioned, in a short glance for example (under 2 sec.), humans tended to recognize the here used robot as a human. Animacy is the perception of the robot as a lifelike creature. Perceiving something as alive allows humans to distinguish humans from machines. As it is emphasized in Piaget's framework [14], major factors of "being alive" are movement and intentional behavior. Likeability describes the first (positive) impression people form of others. Research suggests [15] that humans treat robots as social agent and therefore judge them in a similar way. Perceived intelligence states how intelligent and human-like subjects judge the behavior of the robot. The android robot we used here is mainly interacting with pre-programmed speech and head turns, and tele-operated by a researcher. According to Bartneck and colleagues [13], the subject's rating depends on the robot's competence. Perceived safety describes the perception of danger from the robot during the interaction and the level of comfort the subject's experience. The questions were presented in random order.

To compare the perception, we calculated the mean of every category of the 5-scale Godspeed questionnaire before and after the interaction trials. Before the experiment, subjects were shown two pictures of the android robot, after the experiment, they only had to fill in the questionnaire.

Eysenck Personality questionnaire

For the proxemics, we measured the distance from the robot to the position the subject put the chair during the interaction task. For that, the robot asked them to sit on a chair that was positioned at the end of the room in a way that participants had to pick it up from there and roll it to a position they wanted to sit down. The researchers readjust the chair position before the subject entered for the next task. The subjects did not know that their distance to the robot and the task times were measured during the experiment.

We also measured the times when the subject initiated touch as the robot verbally asked subjects to touch its hand. The time was measured from the first request until the subjects made physical contact with the robot's hand. All participants did touch the hand. If they hesitated, the robot asked again. In addition, we recorded how long the subjects were touching the hand (with minimum of 1 second).

Statistical tests

The data was analyzed with the statistical software R. The data was summarized over means and we employed hypothesis tests. There were no outliers outside of 3 standard deviations of the mean.

III. Results

The reaction of people interacting with the android robot ranged from apathetic to exhibiting great enjoyment and excitement. Most participants were open to the experience with the robot and curious about it.

A. *Distance to the robot*

The data supports the hypotheses 1, that participants come significantly closer to the robot in each trial (pairwise t-test, trial 1vs. trial 2 $t(54) = 4.87$; $p < 0.001$, trial 2 vs. trial 3 $t(54) = 2.67$; $p < 0.05$, Bonferroni corrected). The mean absolute distances from the robot during the interaction tasks are presented in table 1.

TABLE I
DISTANCE TO THE ROBOT IN THE THREE INTERACTION TRIALS

Trial 1	Trial 2	Trial 3
128.2cm	119.9cm	116.2cm

B. Perception before and after the trials

The data does not show any significant difference in animacy and likeability for differences before and after the task (paired *t*-test), but we found significantly different results for Anthropomorphism ($t(53) = 4.22$, $p < 0.001$), perceived intelligence ($t(53) = 7.55$, $p < 0.001$) and perceived safety ($t(53) = -1.99$, $p = 0.05$). We missed the data from one subject because the questionnaire was not filled in. The results are displayed in Table 2. Participants perceive the robot as much less anthropomorphic and intelligent after the interaction tasks, but also much safer.

TABLE II
MEAN VALUES OF THE GODSPEED ROBOT PERCEPTION QUESTIONNAIRE BEFORE AND AFTER THE INTERACTION TRIALS

	before	after
Anthropomorphism	3.10	2.45
Animacy	2.83	2.85
Likeability	2.85	2.85
Perceived Intelligence	3.49	2.85
Perceived Safety	2.67	2.85

C. Robot perception and trust game

When looking at the robot perception and the trust game, we could not find any support for the hypotheses 2, but the amount sent in the trust game to the robot after the interaction tasks was higher, if the participants rated the perceived intelligence higher before the interaction trials (correlation, $r = 0.28$, $p = 0.03$). However, the amount sent in the trust game did not show any significant correlations with other categories of robot perception.

D. Personality and trust game

We examined the hypothesis 4 that extroverts would endow the robot with a higher amount in the trust game. The data showed that the more extrovert a person was, the higher the amount sent in the trust game (correlation, $r = 0.44$, $p < 0.001$). Other character traits did not correlated with the amount sent in the trust game.

E. Exposure to virtual agents

We found that the more people were exposed to virtual agents in their daily life, the higher they rated anthropomorphism and animacy before the trials (but not after) and intelligence and safety after the trials (but not before). The perception of anthropomorphism and perceived safety followed the general trend, but significant differences were found in animacy ($F(1,52) = 5.21$, $p = 0.02$, one subject's data is missing because the questionnaire was not filled in) and perceived intelligence ($F(1,53) = 3.03$, $p = 0.08$).

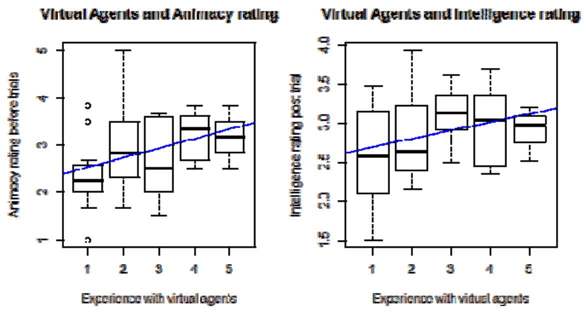

Fig. 2. The prior experience with virtual agents and the influence on the animacy rating before and the intelligence rating after the interaction trials.

F. Non-human agents and reward condition

When subjects never had a pet, then the payback from the robot in the trust game had an influence on the perception of animacy (2-way ANOVA, $F(1,51) = 6.44$ $p = 0.01$), likeability ($F(1,51) = 5.63$, $p = 0.02$), perceived intelligence ($F(1,51) = 6.26$, $p = 0.01$) and safety ($F(1,51) = 6.69$, $p = 0.01$) (the trust game took place after the interaction tasks). If the (manipulated) payback from the robot was more than the amount the subject sent, the subjects who never had a pet rated these categories significantly higher than the subjects in the lower payback group.

G. Robot perception and reward condition

Subjects in the higher payback condition tended to rate the robot slightly more as a lifelike creature (animacy) than subjects in the lower payback condition. But it did not reach significance (ANOVA, $F(1,53) = 3.24$, $p = 0.07$).

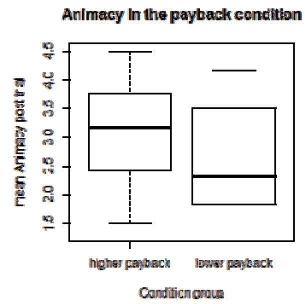

Fig. 3. The difference in the rating of the animacy after the interaction trials in the two payback condition of the trust game.

H. Robot perception and reward condition

We observed some weak effects for the time it took until subjects touched the robot. It seems like that a higher likeability before the interaction tasks was correlated with a shorter time until people touched the robot. There was no correlation found in the data for a change in likeability after the interaction tasks. In humans, touch is an important channel for social communication. Yet, the scenario of someone requesting to touch the hand might be quite unlikely and therefore sound odd. To get comparative data here, we are now planning a follow-up experiment comparing the touch times to a human interaction partner.

For the total touch time, we removed one outlier from the data. One female participant held the robot's hand for nearly 80 seconds (mean touch was $M = 5.51$, $SD = 10.46$, outside of

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7 standard deviations of the mean). After excluding her, we split the data at the mean animacy rating of all the subjects and compared them. The statistical analysis showed that the total touch duration was longer if the animacy of the robot was rated higher ($F(1,49) = 4.06$, $p = 0.04$, one subject's data is missing because the questionnaire was not filled in, two touch time data were not measured correctly).

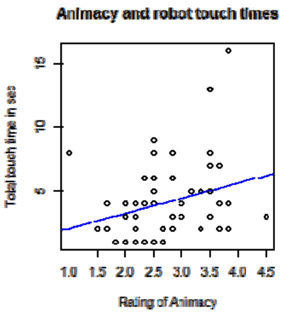

Fig. 4. The subjects touch the hand of the robot longer when the rating of the animacy before the interaction trials is higher.

IV. Discussion

The interaction with this highly realistic looking robot revealed that people get more familiar with the robot over time and their perception of the robot changed significantly when they actually interacted with it. We found that prior experiences with non-human agents had an influence on the interaction and the participants, depending on their personality traits, entrusted the robot.

When observing their distance to the robot there were clear tendencies that participants got more familiar with the robot and came closer. This effect was strong enough to go beyond the initial surprise effect this robot would have. From the literature we know that people maintain shorter distances to somebody they feel close with [29],[30], but larger distances to somebody they dislike or that carries a physical stigma [29]. People maintain a personal space of roughly 1.2 m around themselves that is usually not violated by others [30]. In the present study, we observed roughly similar distances to this.

As expected, the participants rated the robot before the experiment as quite anthropomorph and intelligent. At the same time, they exhibited a kind of uncomfortable feeling when judging safety and pleasantness of the interaction. We think that at the beginning most of the subjects only knew androids from the description of the picture that they saw a robot. After interacting with the robot, they rated it as less anthropomorph and intelligent but at the same time as safer. This indicates how important the actual embodiment of the robot in direct interactions would be. It seems that the participants had high expectations in terms of human form and characteristics (anthropomorphism) and intelligence towards the robot that were not fulfilled. This is congruent with a study stating that the exterior of a robot shapes the expectations towards it [3]. One explanation could be that the participants recognized the shortcoming of the robots after the interaction, which they could not judge from the picture shown before the interaction. As the robot is by far not as realistic as the very first impression in the picture suggested, they would also perceive it less as a thread and more as a "safer" agent. These results could indicate that the importance of the exterior is still underrated and that future robot designers should carefully consider not only the abilities of the robot, but also how it looks.

The subjects also sent more money to the robot if they perceived the robot as intelligent before the interaction tasks. The perception of intelligence might lead them to think that the robot might be able to increase both their outcome in the trust game.

As stated in the hypotheses 4, extrovert people were more open and more likely to endow to robot with a higher amount in the trust game. This is consistent with the results of the previous study [5]. Also, the subjects paid a similar amount of money to the robot as on other studies before by using human agents [22]. We conclude therefore that the robot, in a sense, was perceived as a trustworthy and intelligent partner for such an economic game under laboratory conditions.

It seemed that a higher payback in the trust game influenced how life-like the participants perceive the robot and their impression with a higher payback made the robot slightly more "human" than "machine" to them, as they benefit from the robot's "decision". In particular, if subject's never had a pet, a higher payback in the trust game influenced the perception of the robot. It could be that people who never experienced the "rewarding" company of a pet rely here on more on the monetary outcome from the human robot relationship.

If the subjects had a prior higher exposure to virtual agents, they perceived the robot very life-like (animacy) at first but this perception changed after the interaction with the robot. This could indicate that the robot "in movement" was perceived less life human-like than the picture of it might suggest. Also, if the exposure to virtual agents was higher, the perceived intelligence was higher after the experiment. This could be that the subjects highly exposed to virtual agents did not expect a real robot to leave that level of competent impression. This could be an indication that future robots could adjust their interaction with people to their possible preferences and infer interaction strategies and models directly from the reaction of humans to maximize the positivity of the experience.

V. Future work

There are several analyses and experiments of interest. We are planning to evaluate the video data towards how the subjects touched the robot. There have been studies examining how people touch strangers and what kind of touch expresses a certain emotion [24],[25].

To evaluate the data in comparison with a human interaction partner, we also plan to conduct an experiment with a human agent with the same interaction tasks. This will enable us to compare the distance, touch times, and the perception of a human agent compared to a robot. It would also be interesting to examine possible effect of cultural background.

The android robot Geminoid-F is a very specific and human-like robot. To compare the data to a different, more machine-like robot, we also plan to conduct this experiment with a humanoid robot that is not designed to look exactly like a human. We expect people to perceive and approach this

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robot in a different manner than the Geminoid-F.

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