Research Article **Open Access**

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Appearance of a Robot Affects the Impact of its Behaviour on Perceived Trustworthiness and Empathy

DOI 10.1515/pjbr-2016-0005
Received July 31, 2016; accepted December 20, 2016

Abstract: An increasing number of companion robots have started reaching the public in the recent years. These robots vary in their appearance and behavior. Since these two factors can have an impact on lasting human–robot relationships, it is important to understand their effect for companion robots. We have conducted an experiment that evaluated the impact of a robot's appearance and its behaviour in repeated interactions on its perceived empathy, trustworthiness and anxiety experienced by a human. The results indicate that a highly humanlike robot is perceived as less trustworthy and empathic than a more machinelike robot. Moreover, negative behaviour of a machinelike robot reduces its trustworthiness and perceived empathy stronger than for highly humanlike robot. In addition, we found that a robot which disapproves of what a human says can induce anxiety felt towards its communication capabilities. Our findings suggest that more machinelike robots can be more suitable as companions than highly humanlike robots. Moreover, a robot disagreeing with a human interaction partner should be able to provide feedback on its understanding of the partner's message in order to reduce her anxiety.

Keywords: Human–Robot Interaction, Anthropomorphism, Trust, Empathy, Anxiety

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1 Introduction

Most developed countries face the problem of aging societies. An increasing number of older people will require regular help from others. At the same time, the number of potential younger helpers will decrease. As a result, it is hoped that technology can serve the changing demographics of these societies. As Kidd and Breazeal [1] noted, advancements in human–robot interaction enable us to start building robotic systems that are capable of interacting with people in their daily lives and assisting them in various tasks.

Robots have a great potential to become human companions owing to their physical appearance. Therefore, it is crucial to ensure that the design of robotic platforms and interaction will increase their acceptance. According to Heerink et al. [2], social abilities of companion robots contribute to their acceptance by users. For the maintenance of relationships, two particularly important components are empathy and trust [3, 4]. Furthermore, a robot should not induce anxiety, as negative feelings could lead to its rejection, especially in the context of long–term HRI.

1.1 Factors influencing empathy, trustworthiness and anxiety

Empathy is defined as "the ability to understand and respond appropriately to the affective states of others" [5]. It involves assessment of the other's affective state and a reaction that considers that affective state [6]. For a robot to be empathic, it should be capable of recognizing others' affective states, processing and expressing its emotions, communicating with others, and perspective taking [7].

Another important aspect for companion robots is their trustworthiness. Trust is one's belief that influential others will not engage in prejudicial actions to his or her well-being [8]. Therefore, a trustworthy robot is a robot that can evoke trust towards its actions in its interaction partners. Performance of robots is more important than environmental or human-related factors for their perception as trustworthy [8]. Therefore, in this study we focused on the impact of a robot's positive or negative behaviour as an important robot behavioral factor that can affect its perception. We chose positive and negative dimensions of behaviour, as in the future companion robots might be required to do not only positive actions but also behave in a way that can be perceived by people as negative, i.e. a robot requesting an elderly person multiple times to take a medicine when she does not want to take it.

Furthermore, the relation between a person's gender and a robot's perceived gender can affect trustworthiness; an opposite-gender robot was perceived as more trustworthy than the same-gender robot [9]. This effect was especially strong for male participants. In addition, it has been suggested that the accuracy of judging the trustworthiness of a novel partner robot depends strongly on nonverbal cues [10]. Moreover, although empathic behavior can increase a robot's trustworthiness, its perceived intelligence was not responsible for any change [11].

1.2 Effects of a robot's appearance

Although people rated humanlike communication more important for companion robots than humanlike appearance [12], the appearance of a robot can be an important factor modulating a robot's perceived empathy and trustworthiness. A physical form can affect initial trustworthiness of a robot [13]. Furthermore, people preferred a robot with humanlike appearance and attributes as a companion, although this effect depended strongly on individual differences [14]. Moreover, negative attitudes towards robots can decrease perceived humanlikeness of a robot [15]. A highly humanlike appearance of a robot can also negatively affect its trustworthiness [16].

Riek et al. [17] state that people show more empathy towards anthropomorphic robots because it is easier to relate to them. However, Misselhorn [18] hypothesizes that a robot with few, yet salient, humanlike features could be perceived as more empathic than a highly humanlike robot. On the other hand, in animals a relation was found between their anthropomorphism and perceived empathy [19]. Because highly humanlike robots could be used as long-term companions, it is important to understand how their appearance affects their perceived empathy and trustworthiness.

Previous studies indicated that there are cultural differences in trusting technology [20, 21]. US participants trusted a robotic assistant more than Chinese participants did, unless a robot was presented as a strong in-group member [21]. That means that studies on perceived trustworthiness might be culture dependent. Moreover, it is possible that these findings are not only specific for these particular countries, but rather the distinction is on individualistic vs collectivistic cultures. In our study, we use a highly humanlike android that resembles a member of the same group (Japanese) as participants who took part in the study. Since machinelike robot does not resemble in appearance a human being, its in-group membership is weaker. Therefore, we wanted to investigate whether the appearance of a robot will affect its perceived trustworthiness (this effect would occur if findings of [21] can be generalized for other than China collectivist countries).

Another important factor to consider in HRI is anxiety. Anxiety is a feeling of mingled dread and apprehension about the future that can be evoked by changes in a situation [22]. During interactions people should not feel anxiety induced by a robot. However, appearance of a robot can produce negative feelings. The relationship between appearance and emotional reaction experienced by people was described in Mori's uncanny valley theory [23]. He proposed that with increased humanlikeness affinity with a robot also increases. However, when a robot is almost indistinguishable from humans, but not perfect, people show strong negative emotional response. In the case of companion robots this could be especially profound as highly humanlike robots might be rejected as companions living with people in natural human environments.

1.3 Effects of trust, empathy and anxiety on HRI

Both trust and empathy can affect HRI. Perceived empathy of a robot has been shown to have positive consequences for human–robot interaction. Empathic behavior of a robot affected positively how children and adults perceived a robot [24, 25]. An empathic robot was also rated higher in terms of companionship, likeability, and trustworthiness [11, 26].

Trust and empathic abilities of a robot are also not completely independent from each other. In positive situations, an increase in a robot's trustworthiness was observed when there was congruence between its emphatic responses and the user's affective state [15]. However, in a negative situation, a robot that responded as if the situation was positive was rated as more empathic.

Previous studies investigated companion robots in neutral or friendly interaction scenarios that due to their nature can encourage relationships. However, modern societies suffer from fast-paced lifestyle that causes stress. In Japan 46.5% of people over the age of 12 report experiencing stress in their daily lives [27]. Therefore, companion robots should be ready to interact with people in highly stressful situations. According to Ono et al. [28] empathic behavior of others can reduce the experienced stress. Potentially, this goal could be also achieved by a companion robot. Therefore, we believe that in stressful situations, anxiety experienced by a human is another important metric for companion robots.

1.4 Research questions

Based on the above discussion, in this study we addressed the following research questions:

RQ_1: *How does a robot's behaviour and level of humanlike appearance affect perceived empathy and trustworthiness?*

RQ_2: *How does a robot's behaviour and level of humanlike appearance affect interaction anxiety?*

Moreover, because the initial effects of appearance and behavior of a robot might change with repeated interactions (that is relevant for companion robots) we also looked into that aspect through the third research question:

RQ_3: *Does the effect of a robot's appearance and behaviour on its perceived empathy, trustworthiness, and anxiety change with repeated interactions?*

In the next section we will present the experimental method used in the presented study. The results of the experiment are presented in Section 3 and discussed in Section 4. Finally, Section 5 presents the main conclusions of our study and its limitations.

2 Methods

This experiment was part of a bigger study that involved additional measurements. In this paper we present only the relevant measurements and results. We conducted an experiment with 3 factors. Our study was a 2 × 2 × 3 mixed design experiment with a robot's appearance (humanlike vs machinelike) and behaviour (positive vs negative) as between-subjects factors, and interaction round (Interaction I, Interaction II, Interaction III) as within-subjects factor. Therefore, in total there were 4 between-subjects conditions with 3 within-subjects measurement rounds. We used questionnaires to measure interaction anxiety and a robot's perceived empathy and trustworthiness.

2.1 Materials

We used two robots in this study. The first robot was the android Geminoid HI-2, the second generation of a robot copy of a real person (see Fig. 1). The second robot was a more machinelike and gender-neutral robot, Robovie R2. This robot has some humanlike features such as a head and hands, but it is easily distinguishable from a human. Both robots spoke with the same synthetic voice and had slightly jerky movements. Furthermore, to increase their animacy, both robots had idle motion during interaction. Geminoid HI-2's lips were synchronized with its speech, and it showed movements that resembled breathing. Robovie R2's idle movement involved head movement while talking and slight hand movements.

2.2 Participants

We recruited 60 native Japanese speakers for the study. They were recruited by a recruitment agency for students that posted a message on their web service. Each participant was paid ¥2000 as time compensation. Participants' assignment to conditions was random. Due to data corruption of 2 participants, belonging to different conditions, we excluded their data from the analyses. The remaining 58 participants (26 female and 32 male) were all undergraduate students of various universities and departments in the

Figure 1: Geminoid HI-2.

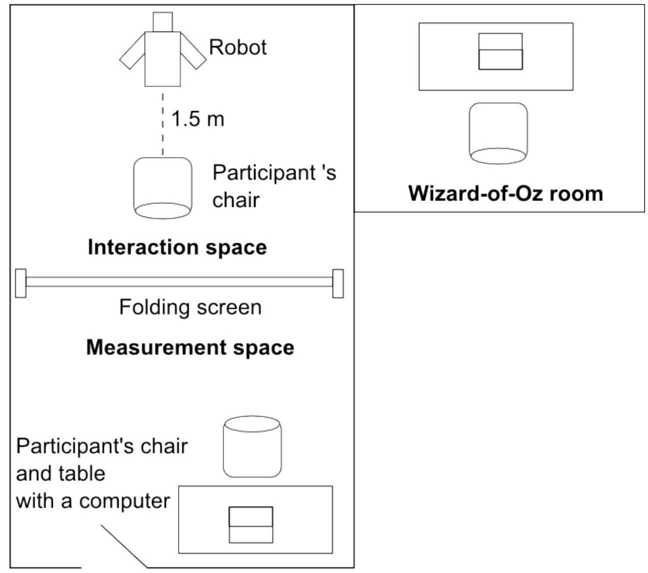

Figure 2: Experimental room divided by a folding screen into two areas: interaction and measurement. The robots' operator was hidden in an adjacent room.

Kansai region. Their age ranged between 18 and 36 years with a mean age of 21.5.

2.3 Setup

The experimental room was divided into two parts by a folding screen (Fig. 2). The interaction area is where all interactions occurred and where the robots were located. In the measurement area, participants completed the questionnaires on a computer. Separating these areas ensured that participants did not need to answer questions regarding the robot while sitting in front of it, as it could have affected the results if the media equation effect was applied in this situation [29]. During the experiment, the robots were controlled by a human operator hidden in another room (i.e., Wizard of Oz).

2.4 Procedure

After completing consent forms and watching an introductory video that explained the experiment's procedure, participants were told by the experimenter that the goal of the study was to investigate creative and persuasive talking. Their task was to persuade the robot during an interview to give them a job. Job interview is a highly stressful situation that is at the same time rather well structured. Since the robot took a role of an interviewer, it allowed us to program only a limited set of responses and ensure that all the participants received the same treatment. Moreover, in this specific context, a robot's approval or disapproval of human statements should be strong enough to be perceived as relevant for her. An interaction scenario in which a robot's positive or negative behaviour would not be important enough for a participant could decrease the strength of manipulation and their effect on dependent variables.

Participants were provided with identical prepared CVs and asked to base their responses on them. However, they were told that the CVs provided only a general background, and they can also add additional information when needed to convince the robot to give them a job. Moreover, to motivate participants for the task, they were told that if they could convince the robot to give them the job, their time compensation money would be increased. After participants confirmed that they understood the instructions, they were taken to a computer. The experiment was divided into 4 phases: pre-interaction, Interaction I, Interaction II, and Interaction III. When participants interacted with a robot or filled out questionnaires, they were left alone in the room.

Robots are regularly shown in Japan to wider audience in TV programs, during exhibitions or used in public settings, such as theaters or shopping malls. Although participants were carefully selected for the experiment by ensuring that they have never interacted with the exact robot to which they were assigned in this study, it was still possible that they saw it or another similar looking robot on TV. Therefore, to minimize variations in expectations, they watched a short video (19 seconds) of their assigned

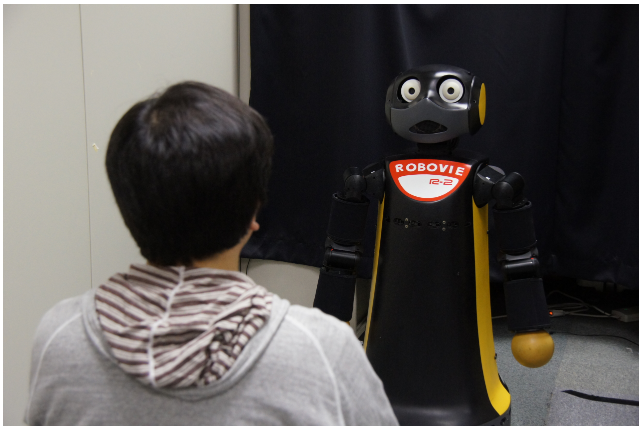

Figure 3: A participant sitting 1.5m in front of Robovie R2.

robot in the pre-interaction phase[1]. During that video the robot introduced itself with the same voice as in the rest of the experiment and described its capabilities (the dialogue was identical for both robots). After the video, participants filled out all the questionnaires.

In the Interaction I phase, they were taken to the interaction area and seated 1.5 m from the robot (Fig. 3). In this phase they were supposed to become familiar with the robot by having a small conversation with it. The robot was introduced as *Robo*, and it asked three neutral questions, such as "Where did you come from?" or "Is it cold today?" After the conversation, participants were taken back to the measurement area and filled out the questionnaires.

Before Interaction II, participants received the CV and papers with information about the job position for which they were applying. The jobs were Bank Manager or Engineer, and their order was counterbalanced between Interaction II and III. The CVs were identical, but the gender of the applicant was chosen to match the participant. Participants were given 5 minutes to read the provided materials and prepare for the interview. When the time ended, the experimenter collected the job descriptions and CVs, and brought the participant to the robot.

First, the robot briefly described the company and job position for which the participant was applying. Afterwards it asked 3 job interview questions. These questions were generic and often encountered during job interviews for various positions, such as "What is your biggest weakness?" or "Please tell me about yourself". After each question the robot thanked the participant and followed to the next one. When all the questions were answered, the robot informed the participant that it will later announce its decision on giving the job (in reality this decision was never announced).

After Interaction II, participants were asked to fill out the questionnaires. This time, dummy questions regarding the interview were added (e.g. "I think that my explanation convinced the robot"). Interaction III was identical to Interaction II, but the job position, CV, and questions asked by the robot were different. The goal of Interaction III was to increase the number of interactions. Its content was slightly modified compared to Interaction II in order to ensure that participants do not have to repeat the exactly same job interview multiple times. The entire experiment took approximately 1 hour.

2.5 Independent variables

In this study there were 3 independent variables: a robot's appearance, behaviour and interaction round. We have manipulated the appearance by assigning participants to either interaction with Geminoid HI-2 or Robovie R2.

The robot's behaviour was expressed by its different responses during the job interview. The robot provided feedback using non-lexical conversation sounds and non-verbal communication. In the positive behaviour condition, it expressed its agreement either by nodding or nodding and uttering "Un" (a Japanese way of approval for what a speaker said). In the negative behaviour condition, it shook its head or nodded and uttered "Asso" (a rather rude way in Japanese of expressing lack of interest in what a speaker says). To ensure natural flow of the conversation, this feedback was initiated by the Wizard of Oz (e.g., when the participant finished a sentence).

Moreover, despite not providing the outcome of the interview, the robot's responses differed between the conditions. In the positive condition the robot indicated that it liked the responses. In the negative condition it hinted that the responses were not particularly impressive. In addition, participants interacted with the robot 3 times. Each interaction was a separate within-subjects measurement.

2.6 Measurements

We measured perceived empathy of a robot with a single statement, "I think the robot understands my feelings," that was rated from 1 (Definitely no) to 7 (Definitely yes). Moreover, we measured trustworthiness with a sin-

1 English translation of the text spoken by robots in pre-interaction videos: "I am *ROBO*. I was developed for communication with people. I can behave as human does using several functions to communicate with people".

gle question “How much do you trust the robot?” that was also rated on a 7-point scale (Not at all - Very much). We used single items for perceived empathy and trustworthiness to decrease the risk of fatigue from repeated measurements. In addition, we used the three subscales of the Robot Anxiety Scale (RAS), which measure state anxiety toward a robot in terms of communication capability, behavioral characteristics, and discourse [30]. Each RAS subscale was measured on a 6-point scale and used in its original Japanese form. The subscales were used independently and measured anxiety towards the robot with which participants interacted.

3 Results

We analyzed the data using 3-way Analysis of Variance (ANOVAs) with appearance and behaviour as between-subjects factors, and interaction round as a within-subjects factor. We used probability p=.05 as a threshold for significance in all analyses. We report effect sizes using generalized eta-squared as it is the recommended effect size measure for repeated measures [31].

3.1 Perceived empathy

First, we looked at perceived empathy. We found a significant main effect of appearance, $F(1,54) = 4.03$, $p = .05, \eta_G^2 = .21$ (Fig. 4). Robovie R2 ($M = 4.02, SD = 1.58$) was rated as more empathic than Geminoid HI-2 ($M = 3.43, SD = 1.26$). We also found the main effect of behaviour, $F(1,54) = 10.16, p = .01, \eta_G^2 = .12$. A robot that had positive behaviour ($M = 4.17, SD = 1.43$) was perceived as more empathic than a robot with negative behaviour ($M = 3.26, SD = 1.33$). The main effect of interaction round was non-significant.

There was a significant interaction effect between appearance and behaviour, $F(1,54) = 8.77, p = .01, \eta_G^2 = .11$. The behaviour of Geminoid HI-2 did not affect its perceived empathy. On the other hand, Robovie R2 was perceived as more empathic when it showed positive ($M = 4.93, SD = 1.11$) than negative behaviour ($M = 3.12, SD = 1.47$), $F(1,26) = 17.44, p < .01, \eta_G^2 = .4$. Furthermore, the interaction effect between interaction round and behaviour was also significant, $F(2,108) = 9.47, p < .01, \eta_G^2 = .04$. During Interaction I robot’s behaviour did not affect perceived empathy. However, for the following interactions the positive behaviour increased robots’ perceived empathy (Interaction II: $F(1,56) = 12.72, p < .01, \eta_G^2 = .19$, positive $M = 4.17, SD = 1.54$, negative $M = 2.86, SD = 1.25$; Interaction III: $F(1,56) = 10.33, p = .01, \eta_G^2 = .16$, positive $M = 4.45, SD = 1.4$, negative $M = 3.24, SD = 1.46$). The interaction effects between appearance and interaction round or 3-way interaction between appearance, behaviour and interaction round were non-significant.

3.2 Trustworthiness

Similarly, trustworthiness was significantly affected by the appearance, $F(1,54) = 5.37, p = .02, \eta_G^2 = .07$ (Fig. 5). Geminoid HI-2 ($M = 4.22, SD = 1.17$) was perceived as less trustworthy than Robovie R2 ($M = 4.86, SD = 1.5$). Moreover, people had more trust in a robot with positive ($M = 4.87, SD = 1.41$) rather than negative behaviour ($M = 4.18, SD = 1.24$), $F(1,54) = 6.88, p = .01, \eta_G^2 = .08$. The main effect of interaction round was non-significant.

There was a significant interaction effect between appearance and behaviour, $F(1,54) = 9.67, p = .01, \eta_G^2 = .11$. Geminoid HI-2’s behaviour did not affect trust, but it mattered for Robovie R2. When Robovie R2 had a positive behaviour ($M = 5.64, SD = 1.03$) it was perceived as more trustworthy than when it had a negative behaviour ($M = 4.07, SD = 1.49$), $F(1,26) = 15.13, p < .01, \eta_G^2 = .37$. Moreover, there was an interaction effect between interaction round and behaviour, $F(2,108) = 5.5, p = .01, \eta_G^2 = .03$. During Interaction I, behaviour did not affect trust. However, during Interaction II a robot’s positive behaviour ($M = 4.86, SD = 1.46$) increased its trustworthiness relative to the negative behaviour ($M = 3.9, SD = 1.18$), $F(1,56) = 7.71, p = .01, \eta_G^2 = .12$. Similarly, during Interaction III a positive behaviour ($M = 5.1, SD = 1.4$) resulted in higher trustworthiness compared with a negative behaviour ($M = 4.14, SD = 1.36$), $F(1,56) = 7.13, p = .01, \eta_G^2 = .11$. The interaction effects between appearance and interaction round or 3-way interaction between appearance, behaviour and interaction round were non-significant.

3.3 Anxiety

The Robot Anxiety Scale (RAS) consists of three subscales that were sufficiently reliable: anxiety toward communication capability of robots (Cronbach’s $\alpha = .91$), anxiety toward behavioral characteristics of robots ($\alpha = .95$) and anxiety toward discourse with robots ($\alpha = .87$). Therefore,

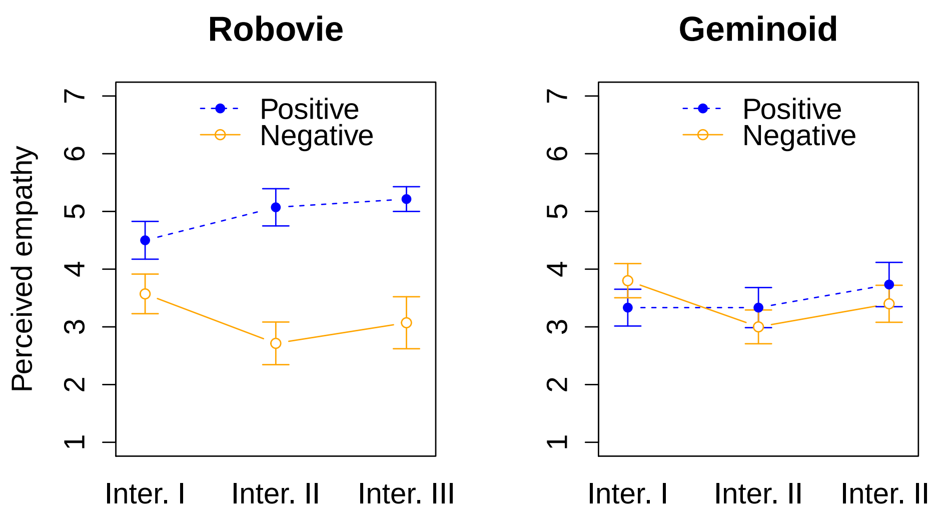

Figure 4: Mean perceived empathy with 95% confidence intervals measured in each interaction round (Interaction I, II and III) for positive and negative behaviour of both robots. Higher scores indicate higher perceived empathy of a robot.

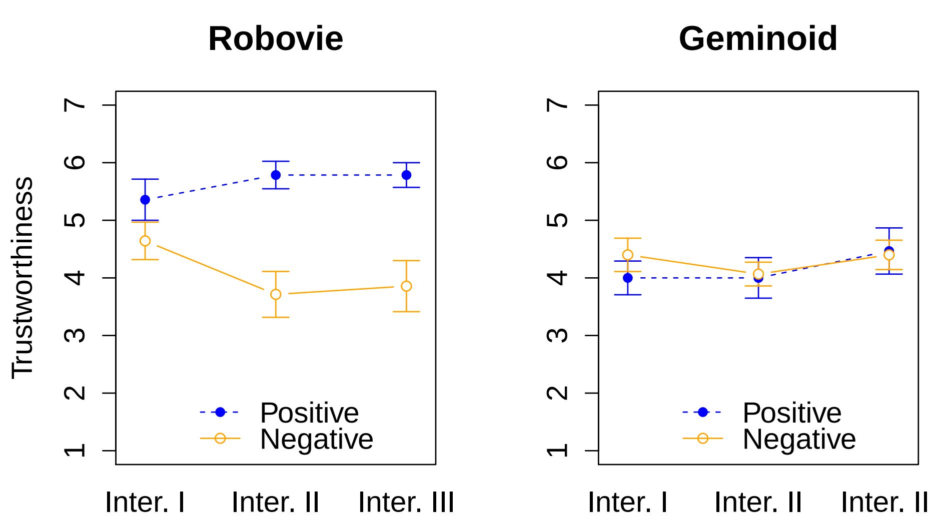

Figure 5: Mean perceived trustworthiness with 95% confidence intervals measured in each interaction round (Interaction I, II and III) for positive and negative behaviour of both robots. Higher scores indicate higher perceived trustworthiness of a robot.

we have conducted separate analyses for each of the subscales.

Anxiety toward communication capability of robots was significantly affected by a robot's behaviour, $F(1, 54) = 5.9, p = .02, \eta^2_G = .07$, see Fig. 6. People were more anxious about a robot's communication capabilities when it had negative ($M = 3.37, SD = 1.12$) rather than positive behaviour ($M = 2.75, SD = 1.22$). No other main or interaction effects were statistically significant.

For the anxiety toward behavioral characteristics subscale we have applied the Huynh-Feldt correction for the main effect of interaction round, because Mauchly's test indicated that the assumption of sphericity was violated ($W = .84, p = .01$). We found a significant main effect of interaction round, $F(1.78, 96.15) = 3.33, p = .05, \eta^2_G = .01$ (Fig. 7). Post hoc tests using the Bonferroni correction revealed that participants felt higher anxiety toward behavioral characteristics of the robot after Interaction I ($M = 2.85, SD = 1.1$) than after Interaction II ($M = 2.56, SD = 1.17$), $p = .02$. No other main or interaction effects were statistically significant.

There were no statistically significant main effects or interaction effects for the anxiety toward discourse subscale.

4 Discussion

In this study we investigated the impact over repeated interactions of a robot's appearance and behaviour on trustworthiness, perceived empathy, and anxiety. Because the findings for perceived empathy and trustworthiness show an identical pattern, we will discuss them together.

Our results clearly emphasize the relevance of interaction between a robot's appearance and its behaviour. Geminoid HI-2 was generally perceived as less trustworthy and empathic than Robovie R2. This is because when Robovie showed positive behavior, it was perceived as more trustworthy and empathic than when it showed negative behaviour; on the other hand even when Geminoid HI-2 showed positive behaviour, its perception did not change.

These results are in line with what Misselhorn [18] hypothesized. A highly humanlike robot was perceived as less empathic than a robot with few humanlike features that were salient. However, our results shed additional light on that hypothesis. The android's behavior did not significantly affect its trustworthiness and empathy. In the case of a more machinelike robot, its behaviour and actions towards a human were determining factors for its perceived empathy and trustworthiness. That suggests that more machinelike robots might be more suitable as companions and the interaction design should allow them to express positive behaviour with a human partner.

Moreover, the results mean that a robot with stronger in-group appearance (Geminoid HI-2 resembling a Japanese person) was perceived as less trustworthy than a robot that does not induce in-group membership. Previous research [21] suggested that for Chinese participants a robot that was presented as an in-group member was perceived as more trustworthy than out-group robot. Since our results reported an opposite pattern, it is possible that the effect of in-group membership on perceived trustworthiness is not characteristic for collectivist cultures, but specific to Chinese culture. Alternatively, it is possible that participants did not perceive Geminoid HI-2's appearance as an in-group member. Potentially, the android's non-perfect resemblance of a human lead to rejection of it as an in-group member.

An alternative explanation for the results on perceived trustworthiness of robots obtained in this study could be due to the use of the identical synthesized voice by both robots. The effects of synthetic voice could be different for each robot. Gong and Nass [32] reported that consistency between voice and appearance can affect an agent's perceived trustworthiness. In their study people trusted more a natural human agent with human voice or humanoid agent with synthetic voice than agents whose appearance did not match their voice. Therefore, it is possible that in our study the highly human-like appearance of Geminoid HI-2 was perceived as inconsistent with its synthetic speech, which led to decreased perceived trust. On the other hand, in case of Robovie R2, the synthetic voice could have been perceived as consistent with its appearance.

The reported interaction effects between the interaction round and behaviour are a result of our manipulation. Interaction I was neutral in both conditions, positive and negative. Therefore, the fact that perceived empathy and trustworthiness were affected by behaviour in Interactions II and III indicates that our manipulation was successful and the difference is not merely due to individual differences between participants assigned to different conditions.

We have also measured anxiety felt by the participants towards various aspects of HRI. We found that participants felt more anxious toward the communication capabilities of a robot when it showed negative behaviour. The positive behaviour led also to perception of a robot as more empathic. Therefore, this result is consistent with work of Ono et al. [28] who showed that empathic behavior in human-

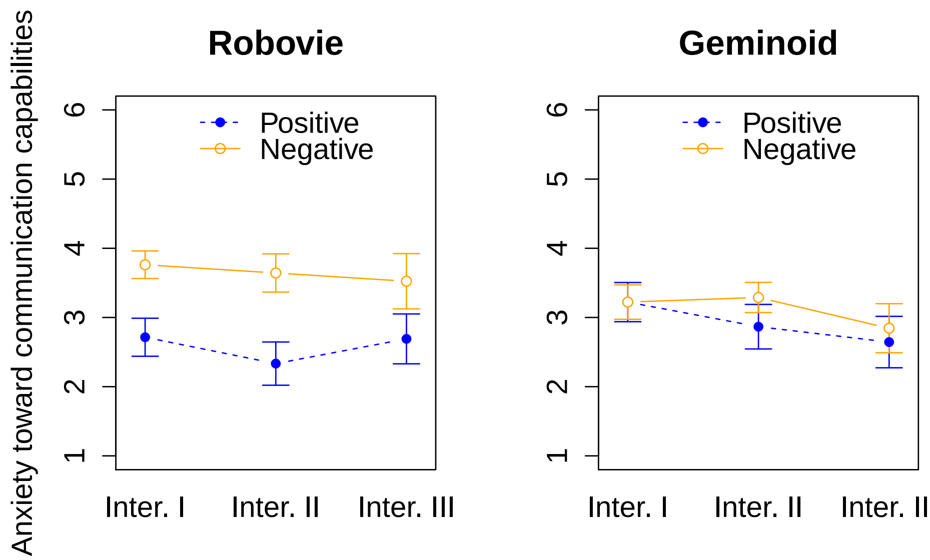

Figure 6: Mean anxiety toward communication capability with 95% confidence intervals measured in each interaction round (Interaction I, II and III) for positive and negative behaviour of both robots. Higher scores indicate higher anxiety toward communication capability of a robot.

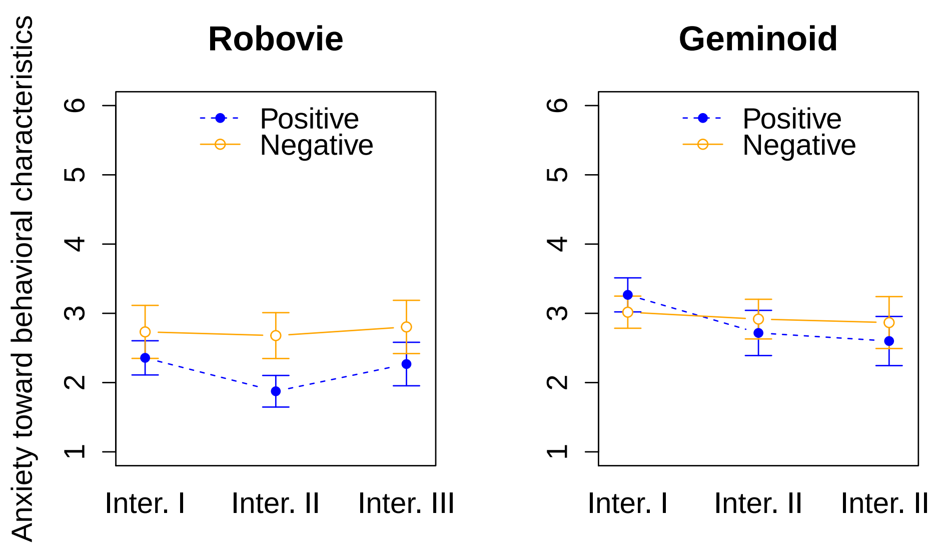

Figure 7: Mean anxiety toward behavioral characteristics with 95% confidence intervals measured in each interaction round (Interaction I, II and III) for positive and negative behaviour of both robots. Higher scores indicate higher anxiety toward behavioral characteristics a robot.

human interaction can reduce stress experienced by a person.

However, this finding could be partially explained as a result of the study setup. In the negative condition, the robot showed disinterest and disapproval of what a human said. Because the goal of participants was to persuade the robot, they might have interpreted its response as a lack of understanding of their persuasive sentences. On the other hand, in the positive condition a robot showed interest in participants' messages. This could have been interpreted as the robot's understanding of complex sentences.

We can find a similar analogy in human interaction when a foreigner speaking a nonlocal language is approached by a local. In such situations the foreigner's nodding is sufficient to be interpreted as her understanding of what is being said irrespective of her language comprehension. In the context of HRI a robot is capable of creating an impression of understanding human speech merely by nodding, which may reduce anxiety regarding its communication capabilities. However, in this study participants had no opportunity to learn whether the robot actually understood what they said. In companion robots such ambiguity in behavior could have profound consequences. A misunderstanding could be introduced by a human's belief that his commands were comprehended by a robot, while it did not understand the message. On the other hand, a disagreeable robot might induce anxiety regarding its communication capabilities.

Therefore, future work should investigate a clearer method of indicating a robot's level of comprehension of human messages. It is important to design robots in a way that enables feedback to a person that its utterance was understood by a robot even if it does disagree with that statement. This additional feedback could reduce anxiety experienced by a human as it will clarify that the source of disagreement is not due to misunderstanding of the provided verbal input.

We did not find any effects of our manipulation on anxiety toward discourse with a robot. However, there was a main effect of interaction round for anxiety towards behavioral characteristic of the robot. People initially were more anxious regarding the appearance of robots. That anxiety vanished during the second interaction, which indicates that participants quickly got used to the appearance of their robotic interaction partners.

4.1 Limitations

In this experiment we used only two robots. Had we chosen a different pair of robots, the results could have been different. Any studies that include multiple robots, potentially face a problem with ensuring that these robots differ only on human likeness dimension, e.g. the robots can also differ on their attractiveness, size, robustness etc. In our study, in the case of Geminoid HI-2 its stern appearance could have caused an increased psychological distance. Physical appearance is an important factor affecting the initial trust attributed to strangers [33]. A more friendly-looking female android, such as Geminoid F, could have been perceived as more trustworthy and empathic as a result of its friendly appearance. Furthermore, future studies should answer a question whether the behaviour of all human-like robots does not affect their perceived empathy and trustworthiness or if it is necessary for a robot to look friendly in the first place for its behaviour to have an effect. In addition, in current study we did not measure perceived gender of Robovie R2. Although, its design resembles a child, we cannot exclude a possibility that it was perceived as a female. Previous research shows that there can be an interaction effect between people and robot's gender [9]. In order to confirm that the results were not due to different perceived gender of the robots future work should verify Robovie R2's perception on that dimension.

5 Conclusions

This paper discussed the role of appearance and behaviour of a robot in repeated interaction on key factors of companion robots: perceived empathy, trustworthiness, and anxiety. We found that a highly humanlike robot is perceived as less trustworthy and empathic than a machinelike robot with some humanlike features. Moreover, an android's behaviour does not significantly affect how it is perceived. For a less humanlike robot, a positive behaviour leads to higher perceived trustworthiness and empathy than negative behaviour. In addition, we found that a robot that disapproves of what a human says can cause increased anxiety towards its communication capabilities.

Our study provides several guidelines regarding design choices for companion robots. Due to higher perceived trust and empathy of more machinelike than highly humanlike robots, the former might be more suitable as companions than androids. Moreover, for these machinelike robots it is important that their behaviour is perceived as positive or their perceived trustworthiness and empathy levels might drop. Our results also suggest that, while synthetic voice is suitable for Robovie R2, its use by an android could negatively impact its perception. Therefore, these highly humanlike robots should speak with a voice that does not sound robotic. Finally, we found that a robot should be able to provide feedback on the comprehension of what a person said, if the robot's behaviour will lead to rejection of that person's opinion. A robot that does not clearly indicate in that situation what it understood can increase anxiety experienced by a person who is unsure of the source of a robot's negative behaviour.

The particular interaction scenario used in this study is not a common scenario for companion robots. However, we believe that the roles of appearance and behaviour are equally important in the context of companion robots. The findings reported in this paper are relevant for the key factors affecting establishing a bond with a robot. We hope that this work will spur further study of the relations among appearance, behaviour, and perception of companion robots.

Acknowledgement: This work was partially supported by JST CREST (Core Research of Evolutional Science and Technology) research promotion program "Creation of Human-Harmonized Information Technology for Convivial Society" Research Area and JST, ERATO, ISHIGURO symbiotic Human-Robot Interaction Project. The authors would like to thank Kaiko Kuwamura, Daisuke Nakamichi, Junya Nakanishi, and Kurima Sakai for their help with data collection.

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