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Selecting the Right Robot: Influence of User Attitude, Robot Sociability and Embodiment on User Preferences

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Abstract— **Selecting the suitable form of a robot, i.e. physical or virtual, for a task is not straightforward. The choice for a physical robot is not self-evident when the task is not physical but entirely social in nature. Results from previous studies comparing robots with different body types are found to be inconclusive. We performed a user study to provide a more sound comparison between a virtual and physical robot operating in a social setting. Besides body type, we manipulated the sociability of the robot. Our results show that 1) user preferences indicate that robot sociability is more important than body type for selecting a robot in a non-physical social setting, and 2) the user's attitude towards robots is an important moderating factor influencing robot preference.**

I. INTRODUCTION

An important question for every application in the field of human-robot interaction is: why use a physical robot for this task and not a virtual one? For physical tasks, e.g. being lifted out of bed [1], it is clear that a robot needs to have a physical body [2]. For less physical tasks this is not as obvious. Virtual robots have been successfully developed for example to support people with cognitive disabilities [3]. Virtual robots are cheaper and more flexible in expressing emotions and gestures, because they are not limited by physical constraints [4]. In this study we compare a physical to a virtual robot in a non-physical task in which the advantage of one over the other robot is less obvious, namely when the main function of the robot is to be socially interactive.

In the last 20 years, researchers have been investigating and comparing between physical and virtual robots, but the results are conflicting and inconsistent. In some of these so-called 'embodiment studies', the physical or the virtual robot is favoured, e.g. [5], [6], while in other cases no preference is found, e.g. [2], [7]. The confusing results can partly be explained by differences in embodiment definition and differences in experimental setups.

We argue that most of the previous embodiment studies focused too much on the robot itself instead of including also its position in an environment. As a consequence the social nature of the environment is often overlooked. We expect that a more sound comparison, between physical and virtual, can be made when taking into account the social environment and when controlling for the sociability of the robot. To further investigate this we carried out an embodiment study in which we take these aspects into account.

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This paper is structured as follows. Theory and background is provided in Section II and the method is described in Section III. We present our results and discussion in Section IV and V.

II. BACKGROUND

In this section we first discuss the development of the notion of embodiment over time. Furthermore we give an overview of related work on embodiment and zoom in to investigate the possible influence of robot sociability. The theory and studies discussed lead to the research questions and expectations for our user study.

A. Definition of Embodiment

Dautenhahn reasoned in 1997 that in order for humans to effectively understand another agent, human or artificial, humans need to be able to "place" themselves in the agent's body [8]. In other words an agent, e.g. a robot, needs to have a body to be effectively understood by humans. Pfeifer and Scheier (1999) go even further by stating that intelligence cannot exist without a body. They call a robot embodied when it has an instantiated body, physical or simulated [9](p. 649).

The definition up to this point does not explain the significance of 'having a body'. Dautenhahn et al. (2002) introduced a broader, more quantitative, notion of embodiment to account for that. They argue that embodiment is defined by the relationship between a robot and its environment. A robot is embodied in an environment when there exists a mutual ability to perturb each other. The larger the impact a robot can have on its environment, and vice versa, the more embodiment the robot is. This is what Dautenhahn and colleagues call *the degree of embodiment* [10].

It is clear that a robot arm would be seen as more embodied, i.e. having a higher degree of embodiment, than a face on a screen given the task to make a fresh pot of coffee. This however becomes more complex when the environment has a social character. For example when we have two socially assistive robots, who are identical apart from their ability to be empathic: the one who can show empathy will be favoured by the user [11]. The ability to be emphatic enables this robot to perturb more in the social environment than without that ability. In other words, it has a higher degree of embodiment. But is this also the case when the emphatic robot is virtual and the non-emphatic robot is physical? Put differently, what is the influence of a robot's sociability on its degree of embodiment when comparing

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between a physical and virtual robot? We discuss several attempts addressing this question in the next section.

B. Related Work - Embodiment Studies

We reviewed various embodiment studies carried out in the last 10 years and summarized these in Table I. The results of previous studies indicate that selecting the body type (physical or virtual) of a robot is not straightforward. Where for example [12] and [5] find that users give a higher rating to a physical robot, [13] find that users give a higher rating to a virtual robot when no touch is involved.

When taking the relationship between the robots and their respective environments into account the following becomes evident: when the environment has a physical component, the physical robot has the upper hand. For example, in [12]-(1), [5], [14], [15], [16] and [19] (task-oriented), the physical robot is preferred in a physical task. The same holds for [13] when the user is allowed to touch the robot. When no physical element is present in the environment the results remain inconclusive: both physical and virtual robots are either rated as equal, e.g. in [2], [12]-(2), [17], [7], or the virtual robot is preferred, e.g. [6], [13] (no touch) and [19] (persuasive-conversational). In none of the listed studies the physical robot is preferred. When asked explicitly, the users think they prefer the physical robot in a non-physical environment but implicit ratings indicate no distinction [18].

The physical nature of the task seems to be a good explanation for why physical robots are preferred in some cases. It is still unclear which robot is preferred when there is no physical component involved in the environment. An important observation is that all these studies are set in a social environment. Yet in few of these studies the sociability of the robot is explicitly controlled for. We are continuing our review by revisiting the studies of [13] and [19] in more detail to investigate a possible influence of robot sociability.

C. Related Work - Influence of Sociability

Lee et al. (2006) [13] found an inverse result for the evaluation of two robots. Participants were allowed to touch the robot in the first experiment but not in the second one. The ability to touch was given as the most important factor influencing user ratings. Post-experiment interviews revealed that participants in the second experiment expected some kind of social interaction with the physical robot. This was included in the first experiment but absent in the second one. An alternative explanation would be that the robot in the no-touch condition was socially unequipped to meet the expectations and therefore the virtual robot was preferred. In other words: the physical robot had a lower degree of embodiment than the virtual robot. This was the other way around in the touch condition.

Another example is the research by Hoffmann and Kramer (2013) where they compared a physical and virtual robot operating in a task-oriented scenario or a persuasive-conversational scenario. An interaction effect between body type and scenario was found. The physical robot was viewed as more competent in the task-oriented scenario while the virtual robot was viewed as more competent in the conversational scenario. The researchers reasoned that not the robot itself but the scenario was the main factor of influence [19]. An alternative explanation lies in the response time of the robot. The physical robot needed between 15–20 seconds to reply where the virtual robot needed 5 seconds. In both scenario's the participants talked with the robot but in the conversational scenario this was the only activity while in the task-oriented scenario the participants were focused on solving a (physical) Tower of Hanoi puzzle. The difference in response time was more crucial for the evaluation of the robot in the conversational scenario. The virtual agent was socially more equipped to keep the conversation going and was rated as more competent than the physical robot. When the participants were solving the physical puzzle they favoured the physical agent. The delay in response time was less relevant because participants talked less frequent with the robot. In other words, the physical robot has a higher degree of embodiment in the task-oriented scenario while the virtual robot, quicker in replying, has a higher degree of embodiment in the persuasive-conversational scenario.

D. Research Questions and Hypotheses

We have identified sociability as a possible important factor influencing the degree of embodiment of an agent. Hence, we conducted a user study investigating the role of sociability when comparing a physical to a virtual robot. We manipulated the level of sociability while keeping other aspects of the degree of embodiment the same which will yield a more sound comparison between the physical and virtual robot. We aimed to answer the following questions:

Question 1: is a more sociable robot favored by its users in a social setting compared to a less sociable robot?

Expectation: in the previous section we have seen that more socially equipped robots are better received by users. We expect that a more sociable robot is preferred by its users.

Question 2: are robots that have a different body type, i.e. physical versus virtual, evaluated differently?

Expectation: we intend to construct two robots with different body types with an equal as possible degree of embodiment. If we succeeded there should per definition be no effect of body type on user evaluation.

Question 3: is the influence of sociability on user ratings different for the two body types?

Expectation: in the previous section we have seen that the more sociable robot is preferred independent of body type. We expect no interaction effect of sociability and body type.

In the coming sections the design, methods and results for this study are discussed.

III. METHOD

We have compared four robots with varying sociability (neutral versus social) and body type (physical versus virtual). To keep the comparison as fair as possible no physical or virtual specific actions were required in the selected conversational (chitchat) task. The virtual robot was an exactly as possible copy of the physical robot in terms of

TABLE I

OVERVIEW OF EMBODIMENT STUDIES IN A SOCIAL SETTING*.

Author	*Result*	*Measurement*	*Task*
Bartneck et al., 2004 [2]	Physical = virtual	Perceived intensity and recognition accuracy	Identifying emotional facial expressions agent
Kidd & Breazeal, 2004 [12]-(1)	Physical = human $>$ virtual	Perception and engagement	Following instructions given by agent to manipulate wooden blocks
Kidd & Breazeal, 2004 [12]-(2)	Physical = remote (physical via TV screen)	Perception and engagement	Desert survival task and teaching task
Shinozawa et al., 2005 [6]	Physical $<$ virtual	influence of decision	Color-name selection
Lee et al., 2006 [13] (touch)	Physical $>$ Virtual	Positiveness of evaluation	Open and playful interaction with touch
Lee et al., 2006 [13] (no touch)	Physical $<$ Virtual	Positiveness of evaluation	Open and playful interaction without touch
Wainer et al., 2006 [5]	Physical $>$ virtual	Enjoyment and watchfulness	Solve tower of Hanoi
Komatsu & Abe, 2008 [14]	Physical $>$ virtual	Acceptation to play and looking duration	Puzzle video game
Pereira et al., 2008 [15]	Physical $>$ virtual	Enjoyment	Chess game
Bainbridge et al., 2010 [16]	Physical $>$ video-displayed	Fulfill unusual requests & interaction enjoyment	Book-moving task
Hasegawa et al., 2010 [17]	Physical = virtual $>$ none	Natural, enjoyment and present	Listening to agents giving directions
Segura et al., 2012 [18] (explicit)	Physical $>$ virtual	preference to interact with	Role-play of secretarial tasks
Segura et al., 2012 [18] (implicit)	Physical = virtual	perceived capabilities and acceptance	Role-play of secretarial tasks
Wrobel et al., 2013 [7]	PC = Physical = Virtual	Enjoyment and engagement	Play a game of trivia
Hoffmann & Kramer, 2013 [19] (task-oriented)	Physical $>$ Virtual	Perceived competence	Solve tower of Hanoi
Hoffmann & Kramer, 2013 [19] (persuasive-conversational)	Physical $<$ virtual	Perceived competence	Talking with robot about health habits

* Only the relevant finding from the original papers are reported in this summary. The core of this table is from the work of [7] and [19]

appearance and behavior. We manipulated the sociability of the robot, i.e. neutral vs. social, while trying to minimize the difference in the degree of embodiment between the physical and virtual robot. In this section, we describe the design, participants, task, materials, experimental set-up and procedure.

A. Design

A two-by-two between subject user study was performed varying over sociability and body type (see table II). After the interaction, participants rated the robot on a number of subjective scales. In the remainder of this section these scales are discussed in more detail.

1) Dependent variables: The robot was rated on its ability to change the affective state of the participant, its social presence, its social attraction and the interaction in general.

TABLE II

EXPERIMENTAL DESIGN OF THE TWO-BY-TWO BETWEEN SUBJECT USER STUDY WITH TWO SOCIABILITY LEVELS AND TWO LEVELS FOR BODY TYPE.

Body type		Sociability: Less (-)	Sociability: More (+)
	Physical	Physical & neutral	Physical & social
	Virtual	Virtual & neutral	Virtual & social

To be able to compare this study with the literature we used questionnaires similar to those used in the research of [13] and [19]. For each scale the internal consistency was calculated separately for every condition using a Cronbach's α analysis. Unless specified otherwise, the final scales were calculated by taking the mean of all selected items.

Participants' affective state. The affective state of the participants before and after the interaction was measured with the Positive and Negative Affect Schedule (PANAS) [20]. This schedule consists of 20 items (words) measured on a 5-point Likert scale (1: Very Slightly or Not at All to 5: Extremely). The change in positive and negative affect state were measured separately. The positive scales before and after had a Cronbach's α between .557 and .946. Positive affect change was calculated by subtracting the mean 'before' score from the mean 'after' score. The negative scale was deemed too inconsistent to use (average Cronbach's α of 0.563).

Social presence. To test whether a more sociable robot would be perceived as more socially present two subscales from the Networked Minds Questionnaire of Social Presence[21] were used: co-presence and behavioral engagement. They were slightly adapted to fit better with the experiment e.g. 'Other individual' was replaced with 'the (virtual)[1] robot'. A 7-point Likert scale (1: Entirely disagree to 7: Entirely agree) was used. A Cronbach's α analysis

[1] The text in the questionnaires spoke of 'the virtual robot' in the virtual conditions where in the physical conditions the robot was referenced as 'the robot'.

revealed that the items addressing the dependence of the robot, the feeling of isolation and pretended attention by the robot were reducing the internal consistency of the scale. A plausible explanation was the scripted fashion of the conversation because it forced the participant and robot in a dependent role. These items were removed leaving 5 out of 12 items in the scale with a Cronbach's α varying between .651 and .863.

Social attraction. To measure the social attraction towards the robot a modified version of the Interpersonal Attraction Scale [22] was used. The modifications by [13] were used where 'Aibo' was replaced with 'the (virtual)* robot'. It consisted of 3 items measured on a 7-point Likert scale. The scale scored a Cronbach's α of at least .780 in all conditions.

General evaluation of the interaction. A holistic evaluation of the interaction was carried out using an adapted version of the questionnaire used by [19]. It contained 5 (two removed) items measured on a 5-point Likert scale. The general evaluation scale did not have a sufficient internal consistency (average Cronbach's α of 0.608) to be useful for further analyses.

2) Manipulation checks: In order to verify whether the manipulation of sociability was successful, a manipulation check was performed. This check was a combination of the perceived sociability scale by Heerink et at. (2009) [23] (4 items) and a different sub-measure in Biocca's social presents questionnaire: psychological involvement [21] (4 items). Both scales had a Cronbach's α of at least .707 in all conditions.

3) Moderating variables: Effects of gender [24], age [25], general attitude towards robots [26], novelty and culture [27] have been reported to influence the way robots are perceived by participants. To check for such interfering effects the gender, age, culture and previous experience with robots of participants were registered after the experiment. Furthermore, to measure the general attitude towards robots the Negative Attitudes towards Robots Scale (NARS) was used [28]. The scale had a Cronbach's α of .830 when the item about robots dominating the future was left out. This left 13 items in total.

B. Participants

40 (31 female; 9 male; median: 23; range: 18-44) participants were recruited from the Radboud University's participant pool (5) or signed up after messages on on-line social networks (35). The participants from the pool participated for course credits while the others did it pro bono publico. All participants were novel to the task, although some have seen the robot before. Three participants were identified as significant outliers and ruled out from the analyses.

C. Materials

For this experiment the Nao robot (version 1.14.5) from Aldebaran[2] was used (see figure 1a). We used Webots for Nao 7.1.2 from Cyberbotics[3] to host a virtual Naoqi instance. The Naoqi instance available in Choregraph, standard software delivered with the Nao, could not be connected to the remote control. Choregraph however was used to render an exactly as possible virtual copy of the Nao (see figure 1b) and to model the gestures. The speech was generated using the standard text-to-speech engine available in the Nao. The speech instances were saved to .wav files and played through a speaker (placed behind the screen) in the virtual conditions. A custom-made remote control[4] gave the experimenter the opportunity to easily select the right response for the robot. A Foscam FI9821W IP camera was used for observation.

D. Task

The participants engaged in a scripted conversational interaction with the robot. They received a list containing 16 chitchat items they had to tell to the robot in the given order. The robot started the conversation. Turns alternated after that. When participants (accidentally) went off script the robot asked them to go back to the script. This was necessary in two occasions. The participants were told that the robot was learning to recognise the listed sentences from different speakers in order to build a speaker-independent language model. This was to make sure every participant had the same interaction apart from the intended manipulations.

All replies of the robot had two parts: a core that was the same in every condition and a variable part that varied in the level of sociability. Several factors that have been found in the literature to influence the (perceived) sociability were used to model the social parts of the robot and left out in the neutral version. The implemented factors were: praise [29], empathy [11], politeness [30], humor [31] and solidarity [32]. The neutral robot was modeled to be more ego-centric and shallow. Additionally, the sociability of the robot was also manipulated using the frequency and intensity of gestures [33]. The social robot had at least one gesture in each reply while the neutral robot used gestures only 37.5% of the time. In the social condition the gestures had a high intensity for positive replies and a low intensity for negative replies. In the neutral condition all gestures had an equal low intensity. This is an excerpt from the complete conversation[4]:

Participant: "It's really cold. I don't like the winter. Especially when I have to be outside a lot."

Robot: CORE: "It can get quite cold indeed.", NEUTRAL: "Robots cannot feel cold." [OR] SOCIAL: "I don't like that either." *Shake head* (solidarity).

Participant: "Do you have a new year's resolution?"

Robot: CORE: "[...] I want to learn new movements. Maybe even join the robot football team!", NEUTRAL: *Right hand move slowly forward* [OR] SOCIAL: *Both hands go energetically up in the air*.

E. Experimental Set-up and Procedure

Participants were escorted from the front-desk to the lab room by the experimenter. They were instructed to sit at the questionnaire desk (see figure 1c & 1d) where they

[2]http://www.aldebaran.com/en
[3]http://www.cyberbotics.com
[4]Code and full conversational script: https://github.com/mikeligthart/NaoWizardOfOz

Fig. 1. Experimental set-up where the top row depicts the interaction desk and the bottom row the questionnaire desk. Furthermore, the left shows the physical condition and the right shows the virtual condition.

first needed to sign the consent form. Before participants were given the instructions they had to complete the pre-PANAS questionnaire. Participants in the physical condition answered the questions on paper (see figure 1c) and in the virtual condition on a laptop (see figure 1d). After the instructions participants were seated before the robot (see figure 1a & 1b) where the conversation took place. At the end the robot instructed the participants to go back to the questionnaire desk to complete the post-questionnaire. The whole procedure took about 25 min. and the conversation lasted about 5 min. Participants were alone in the room while filling out the questionnaires and during the conversation. They were unable to see the robot upon entering the room and sitting at the questionnaire desk.

IV. RESULTS

An inspection for moderating effects (MANOVA) revealed a main effect of the initial negative attitude towards robots (NARS) on user evaluations (F(5,31) = 5,674 p = 0,0008, η_p^2 = 0.478). For that reason the data was split in two groups, positive (N_p = 16) and negative (N_n = 21), where the mean of the NARS was taken as threshold. Participants with a score below the mean were assigned to the positive group and above the mean to the negative group. All further analyses were performed with two-way (sociability and body-type) ANOVAs. The p-values were corrected with the Bonferroni correction to compensate for the multiple tests. Perceived sociability and psychological involvement were used to check the effectiveness of the manipulations while positive affect change, social presence and social attraction measure the user evaluation.

1) Check: Perceived sociability: A main effect of sociability on perceived sociability was found in the positive group (F(1,12) = 15.302, p = 0,0020, η_p^2 = 0.560). A social robot was indeed perceived as more social ($M_{sociability}$ of 4.250 (social) versus 3.219 (neutral)). No other effects were found (All $F's \leq$ 1.138 and $p's \geq$ 0.3070).

2) Check: Psychological involvement: A main effect of sociability on physiological involvement was found in the positive group (F(1,12) = 17.783, p = 0.0011, η_p^2 = 0.597). Participants rated the social robot ($M_{involvement}$ = 4.299) as more involved than the neutral robot ($M_{involvement}$ = 2.656). No other effects were found (All $F's \leq$ 1.028 and $p's \geq$ 0.3249).

3) Positive affect change: There was a significant main effect of body type on positive affect change in the positive group (F(1,12) = 7.021, p = 0.0212, η_p^2 = 0.369). Participants interacting with the virtual robot had on average a decline in their positive affect ($M_{p-change}$ = -0.112) where after an interaction with the physical robot an increase in positive affect was found ($M_{p-change}$ = 0.433). No other effects on positive affect change were found (All $F's \leq$ 3.241 and $p's \geq$ 0.0969).

4) Social Presence: No effects on social presence were found (All $F's \leq$ 2.752 and $p's \geq$ 0.1229).

5) Social Attraction: A significant main effect of sociability on social attraction was found in the positive group (F(1,12) = 9.346, p = 0.0099, η_p^2 = 0.438): the social robot ($M_{attraction}$ = 6.167) was found to be more attractive than the neutral robot ($M_{attraction}$ = 5.083). Furthermore, a near significant main effect of body type on social attraction was found in the negative group (F(1,17) = 4.367, p = 0,0519, η_p^2 = 0.204): the virtual robot ($M_{attraction}$ = 4.016) was found to be more attractive than the physical robot ($M_{attraction}$ = 2.622). No other effects on social attraction were present (All $F's \leq$ 2.710 and $p's \geq$ 0.1256).

V. DISCUSSION AND CONCLUSION

Results show that how users evaluate a robot strongly depends on their initial attitude towards robots. Where the relative positive participants have no significant preference for either a physical or virtual robot, the relative negative participants find the virtual robot more socially attractive. Furthermore, where positive participants perceived the social robot as more social and involved, the negative participants perceived no significant difference between social and neutral robots. Interesting trends were observed in the negative group: the social virtual robot was preferred over a neutral virtual one, but a social physical robot was less favoured than the neutral physical one. This body type and sociability interaction trend was not observed in the positive group. The power for these observations were too low to report as significant. This is mainly caused by the splitting of the data. These observations are left to explore in future research.

The other results are only found in the group of relatively positive participants. As a consequence, the inferences made from these results are only generalizable to people with a relatively positive attitude towards robots. A more sociable robot is indeed favoured by its users in terms of social attraction compared to a less sociable robot. No significant differences between a virtual and physical robot were reported apart from one. After interacting with the virtual robot participants reported to be less positive where after an interaction with the physical robot participants reported to more positive instead. A possible explanation for this difference could be that participants expected that the interaction would be more fun. A possible novelty effect of the physical robot might mask a lack of fun of the task itself. Multiple participants in the virtual condition reported that they missed facial expressions or that the script they had to follow was to distracting to really watch the robot. These remarks were not made by participants in the physical condition. We have to note that answering on paper in the physical condition compelled participants less to give an optional comment than on a laptop in the virtual condition. Finally, no significant interaction effect was found.

Although, as expected, no effect of body type nor an interaction effect have been found it is important to note that the observed power was too low to make any claims on the absence of such effects by itself. However, the study presented shows us two things. The first is that sociability is more important than body type for selecting a robot that has to operate in a non-physical social setting. Our literature review revealed a preference for physical robots in a physical task. Our user study showed an effect of sociability on user preference, in a non-physical social setting, where no effect of body type is found. The second point is that people's initial attitude towards robots has a strong influence on user preference. The exact consequences of that influence are left to investigate in a follow-up study with a larger sample size.

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