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The Evaluation of Different Roles For Domestic Social Robots

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***Abstract*— Robotics researchers foresee that robots will become ubiquitous in our natural environments, such as our homes. For a successful diffusion of social robots, it is important to study the user acceptance of such robots. In an online survey, we have investigated the acceptance of three different possible roles for domestic social robots and the preferred appearance. The results show that, although most people prefer a humanoid robot for domestic purposes, the role for which a social robot is build affects the choice for a robotic appearance made by potential future users. When comparing the acceptance of the three different roles, people evaluate the companion robot more negatively on the different acceptance variables. Implications of these results are discussed.**

I. INTRODUCTION

Today, people have busier lives than ever before with increasingly less time to spend with family and friends. Socially assistive robots are designed to be our servants and companions and can relieve especially families where both parents are working. However, the development of the increasing presence of such robots in our everyday lives will not simply be accepted without reservation on the part of the human users. Research in social robotics suggests that the mere presence of robots in everyday life does not automatically increase acceptance of these robots and the willingness to interact with them [3]. A challenge for the success of social robots is its acceptance by future users. And the inclusion of future users at the early stages of design is important for developing socially robust, rather than merely acceptable, robotic technologies [28]. To make the diffusion of social robots successful, it is important to study the user acceptance of social robots in an early stage of their development process, so that future social robots can be adapted to the desires and requirements of users. This paper describes our findings on the acceptance evaluation of three different possible roles for domestic social robots and the preferred appearance.

II. THEORETICAL BACKGROUND

Robots are expected to increasingly enter our everyday lives. To increase the acceptance of robots, they are designed to interact socially to simplify the interaction between humans and robots [4]. However, if social robots are to be introduced successfully into people's homes, we need to understand how people perceive possible future purposes of domestic social robots. Social robotics research is increasingly paying attention to the domestic environment as a context of use. However, domestic social robot that can perform a combination of tasks efficiently, accurately and robustly do not yet exist, which is why this area of research is still in its infancy. Yet, we aimed to study the evaluation and acceptance of consummate domestic social robots that might exist in the (near) future with a large sample size. Both reasons prompt that employing actual human-robot interactions are impossible, which causes us to focus on text-based scenarios of future roles of social robots and their anticipated acceptance by potential users in this study. Additionally, employing research based on use scenarios entails that actual use cannot be evaluated. Instead, use intention will be administered as the outcome variable. The following parts will elaborate on these two requisites for this study.

A. Anticipated Acceptance

Focusing on behavioral intention rather than system use is a common method in adoption research [21]. Moreover, prominent theories, such as the theory of planned behavior [1], imply that behavioral intention is a strong predictor of actual behavior, which validates use intention as a vital focus of research. Existing behavioral intention theories and models of technology acceptance, such as the theory of planned behavior [1.] or the unified theory of acceptance and use of technology [29] could provide insight into the adoption of domestic social robots. Therefore, we have completed an extensive literature review of technology acceptance and human-robot interaction research as well as general communication and social psychology literature [14]. This literature review resulted in a long list of possible explanatory factors of social robot acceptance, from which we identified the key factors of usefulness, adaptability, self-efficacy, enjoyment, sociability, and companionship. Similar key factors have been used before in the evaluation of human-robot interaction studies. For example, Heerink et al. [16] found similar factors both directly and indirectly influencing use intention of a robotic system among older users. Broadbent et al. [5] stress the importance of appearance and ability of robots to adapt to individual needs. And Young et al. [31] point to practical benefits (e.g. usefulness), fun (e.g. enjoyment) and social influence as aspects to focus on when evaluating human-robot interaction.

B. Utilizing Text-Based Use Scenarios

A scenario is a description of the activities of one or more persons together with the information about the user goals, actions and reactions [27]. Moreover, external factors, such as the environments, background or situation, mediate the interactions [32]. While direct interactions between robots and users are preferable in the evaluation of human-robot interaction, there are many practical factors (e.g.,

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privacy, cost, time, and safety) that may restrict this ideal form of evaluation [8]. Moreover, direct evaluations are more useful in summative studies than in formative evaluations where the robot of interest has not yet been developed [23]. To overcome this problem, use scenarios can be deployed in other forms such as text, video, virtual reality, acted demo, and so forth. Xu et al. [32] explored the effects of deploying these different media to evaluate human-robot interaction scenarios. The authors concluded that exploring of the users' instrumental needs or cognitive attitudes could be assessed without great details that faithfully convey the human-robot interactions scenarios, and that the deployment of both video and interactive video leads to biased user attitudes. As this study focuses on anticipated acceptance by administering people's use intention (i.e., cognitive attitude) of three different possible roles for domestic social robots and the preferred appearance (i.e., instrumental need), the application of text-based use scenarios is believed to be appropriate.

C. Evaluating Robotic Appearances

Most human-robot interaction researchers use either humanoid or caricatured robots in their studies [18, 26]. The reason for this may be that some researchers argue that robots need some amount of humanness to make users feel comfortable to interact with robots [12]. However, other research shows that a robot's appearance should match its intended purpose or the functional role for which it is designed [13]. Thus, including all four types of robotic appearances in the evaluation of robots design for domestic purposes could provide a more holistic view on people's preferences for robotic appearances.

III. Method

A. Questionnaire and Procedure

The questionnaire started with collecting the demographic data (i.e., gender, age and educational level). Next, a short description of a domestic social robot in the home was given (i.e. can perceive and react to social situations, and can interact naturally with humans using verbal and nonverbal communication). The technology acceptance literature argues that varying aspects could play a dominant role in the acceptance of different technologies with different applications [7, 17]. It is expected that this will be similar for different appearances of robots with various roles for domestic use. For this reasons, three different potential future scenarios of the domestic social robot were implemented for the questionnaire: butler, information source, or companion.

The participants were randomly assigned to one of three future roles for domestic social robots: butler, information source, or companion. The butler robot was described as a servant that can do several chores in and around the home according to one's personal preferences. The information source robot was portrayed as a talking internet connected database that answers all your questions. The companion robot was defined as a sociable intellect that builds on online shared stories and with whom users can talk when feeling down or lonely. Then, the participants were provided with pictures of the four types of robotic appearances defined by Fong et al. [12]. Humanoids which have a humanlike appearance, zoomorphic robots which have an animal-shaped appearance, caricatured robots which have an immediate association with an existing animal or human, and functional robots which shape is determined by its function. The used pictures are displayed in figure 1. The participants were asked to choose the robot appearance that would be most suitable for the role as described in the assigned condition, and provide a rationale for this choice in an open field.

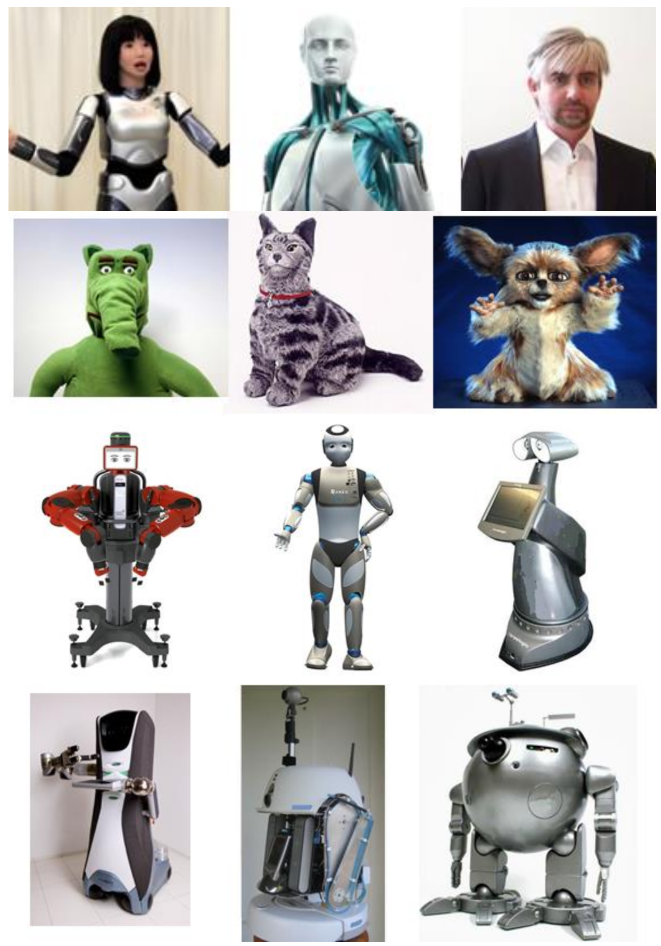

Figure 1. Used Pictures for Humanoid, Zoomorphic, Caricatured and Functional Robots Respectively.

TABLE I. DESCRIPTIVE STATISTICS OF THE VARIABLES

	Butler		Companion		Information		
Construct	***M***	***SD***	***M***	***SD***	***M***	***SD***	**α**
Use Intention	4.22	1.00	4.20	0.97	4.25	0.96	.95
Usefulness	4.14	1.85	3.74	1.79	3.22	1.70	.89
Ease of Use	4.48	1.03	4.52	0.97	4.42	1.00	.86
Adaptability	3.65	1.40	3.79	1.45	3.65	1.36	.82
Enjoyment	3.95	1.74	3.15	1.65	3.67	1.66	.92
Social Presence	4.40	1.43	3.92	1.44	4.35	1.31	.92
Sociability	3.56	1.57	3.09	1.59	3.54	1.53	.75
Companionship	3.19	1.48	3.09	1.59	3.37	1.52	.94
Social Influence	4.05	1.45	3.60	1.47	3.97	1.38	.88
Self-Efficacy	4.17	1.19	4.25	1.31	3.76	1.42	.83

After the description of the domestic social robot, the participants responded to the items of seven key variables of social robot acceptance as indicated in the theoretical background. The items for usefulness, ease of use, adaptability, enjoyment were adopted from Heerink et al. [16]. Other items came from other research disciplines and were adapted to the robot context, such as use intention [22], social influence [19], and self-efficacy [2]. All items were translated to Dutch. The translation was completed by two bilingual speakers using the back-translation process. This process ensures that meaning and nuance are not lost, and that the translated versions of the constructs remain as true to the original as possible [24]. The items were presented on 7-oint Likert scales. Table I (see previous page) presents the standard descriptive statistics of the constructs, including internal consistency.

B. Data Analysis

Most parts of the online questionnaire consisted of items presented on 7-point Likert scales. This quantitative data gathered was using the statistical package of SPSS 20. Qualitative data was obtained from the open field question about the participants rationale for their preferred appearance. Based on the data entries from the participants, key concepts were identified and translated into a coding scheme by the primary coder. Next, for each entry, both the primary and a secondary coder independently applied one code from the coding scheme to each entry. Intercoder reliability, which involves testing the extent to which the independent coders agree on the application of the codes, has found to be substantial with a Cohen's Kappa of .79 [20]. In total, 17 reasons for the participants' preference of a robot appearance were sorted from the data entries. Table II displays these reasons and their distribution among the three conditions (i.e., butler, companion and information source robot).

C. Participants

A Dutch panel sample was asked to voluntarily participate in our online survey. A total of 1162 participants (34,7% response rate) completed the survey. Table III displays the demographics of the participants, which are quite similar to those of the Dutch population [4].

IV. RESULTS

A. Robot Roles and Appearance Preferences

When examining the results in table IV, it can be observed that, regardless of the condition, most participants preferred a humanoid appearance (*n*= 622). Regardless of the condition, more than half of the participants who choose a humanoid robot stated that they favored this robot because it looked most humanlike (*n*= 315). Other frequently mentioned reasons were that a humanoid appearance looks familiar (*n*= 64), that such an appearance suits best when a robot is built to be social (*n*= 62), and that such an appearance is the most attractive one (*n*= 51). Unfortunately, quite some participants did not provide a reason for choosing a humanoid appearance (*n*= 67). The caricatured

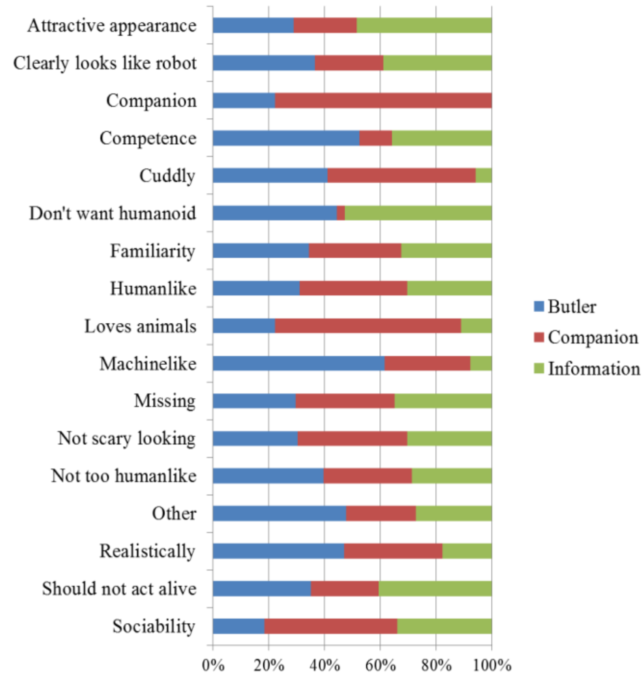

Figure 2. Provided Reasons for Chosen Appearance in the Conditions

TABLE II. SAMPLE VS. DUTCH POPULATION

	Sample (in %)	Population (in %)
Gender		
Male	51.1	49.5
Female	48.9	50.5
Age		
18-29	20.9	22.1
30-44	26.9	29.6
45-59	27.5	26.5
60+	24.7	21.8
Education		
Low	22.8	23.1
Middle	47.8	48.2
High	29.4	28.7

TABLE III. EFFECT OF CONDITION ON PREFERRED APPEARANCE

		Condition		
		Butler	Companion	Information
Humanoid	Count	204.0	213.0	205.0
	Expected	213.3	119.8	208.9
	z	-0.6	0.9	-0.3
Zoomorphic	Count	24.0	68.0	23.0
	Expected	39.4	36.9	38.6
	z	-2.5	5.1	-2.5
Caricatured	Count	81.0	45.0	94.0
	Expected	75.4	70.7	73.9
	z	0.6	-3.1	2.3
Functional	Count	87.0	45.0	66.0
	Expected	67.9	63.6	66.5
	z	2.3	-2.3	-0.1

and functional appearance were almost equally chosen (e.g., *n*= 220 and *n*= 198 respectively). The reason to choose for a caricatured appearance was either because this appearance does not look all too humanlike (*n*= 50), because this appearance clearly looks like a robot (*n*= 45), or because they thought this appearance was the most competent for its purpose (*n*= 30). The choice for a functional appearance made by the participants was either because this appearance clearly looks like a robot (*n*= 36), because robots should not act as if they are alive or resemble in their home (*n*= 25), or because they thought this humans (*n*= 27), because they do not want a humanoid robot in their home (*n*= 25), or because they thought this appearance would be most competent (*n*= 25). A smaller number of participants choose a zoomorphic appearance (*n*= 115). The most provided reason for choosing this appearance was because the participants thought such a robot looks cuddly (*n*= 17). Other reasons provided by the participants were either that a zoomorphic appearance looks attractive (*n*= 10), that it looks friendly (*n*= 9), or that they just love animals in general (*n*= 9). Unfortunately, a comparatively large group of participants in this condition (*n*= 19) did not provide a reason for their choice. The provided reasons for the robotic appearances are presented in figure 2.

A Chi-square test was performed to see if the condition (e.g. butler, companion or information source robot) had an effect on the appearance of robot the participants preferred (again see table III). The results show that there is a significant association between the assigned condition (i.e., the robot's role as butler, companion or information source) and chosen appearance of robot ($\chi^2(6)= 62.689$, $p < .001$). The values of the standardized residuals (z) are used to further interpret the results of the Chi-square test. The standardized residuals represent the error between the observed frequency (i.e., what the data actually observes) and expected frequency (i.e., what the model predicts). A positive value indicates an overrepresentation and a negative value points to an underrepresentation. A value higher than 1.96 or lower than -1.96 for either the over- or underrepresentation is considered to be significant at $p < .05$ [10].

In the butler condition, the results show that there is a significant underrepresentation for the zoomorphic appearance (*z*= -2.5) and a significant overrepresentation for the functional appearance (*z*= 2.3) of the robot. The reasons why the participants choose a functional appearance (total *n*= 87) was either because this one looked most competent (*n*= 11), because this clearly looks like a robot (*n*= 11), because they do not want a human-shaped robot (*n*= 11), or because they thought that robots should never resemble human beings (*n*= 10). However, quite some participants in this group did not provide a reason (*n*= 12). In the companion condition, there is a strong significant overrepresentation for the zoomorphic appearance (*z*= 5.1) and a significant underrepresentation for both the caricatured appearance (*z*= -3.1) and the functional appearance (*z*= -2.3). From all participants who choose a zoomorphic appearance (*n*= 68), some did this because they thought this appearance looked cuddly (*n*= 9) or just attractive in general (*n*= 9). Other participants connected this appearance to the familiarity with pet companions (*n*= 6) or they just loved animals in general (*n*= 6). However, again, quit some participants did not provide a reason for their choice (*n*= 10). Finally, in the information source condition, there is a significant underrepresentation for the zoomorphic appearance (*z*= -2.5) and a significant overrepresentation for the caricatured appearance (*z*= 2.3). The reasons why the participants choose a caricatured appearance (total *n*= 94) was either because with this appearance clearly looks like a robot (*n*= 18), because this appearance is not too humanlike (*n*= 16), because this appearance looked most competent for its purpose (*n*= 14), or because this appearance was the most attractive one (*n*= 11).

B. Evaluating the Acceptance of Robot Roles

To determine existing differences in the evaluation of acceptance variables of the three robot roles, we performed a one-way ANOVA on the acceptance variables including use intention. For an overview of the means of the acceptance variables for each condition, please see table III. The participants showed higher intentions to use either the butler ($p < .001$) or information source robot ($p < .001$) as compared to the companion robot ($F(2,1152)= 18.34$, $p < .001$). For usefulness, all robot roles were evaluated significantly different ($F(2,1152)= 23.85$, $p < .001$). The butler robot was evaluated as most useful, second came the information source robot, and the least useful was the companion robot ($p < .01$ between all pairs). The participants evaluations of all roles were equal on ease of use ($F(2,1152)= 0.94$, $p= .392$), as well as for adaptability ($F(2,1152)= 1.33$, $p= .265$). For enjoyment ($F(2,1152)= 22.17$, $p < .001$), the participants indicated that they would enjoy a butler and an information source robot more than a companion robot ($p < .05$ between all pairs). Similar results were found for social presence ($F(2,1152)= 13.39$, $p < .001$) and sociability ($F(2,1152)= 10.68$, $p < .001$), with the participants indicating that they would perceive a butler and an information source robot as more socially present and more sociable than a companion robot ($p < .05$ between all pairs). The participants evaluations of all robot roles were equal on companionship ($F(2,1152)= 2.64$, $p= .072$). For social influence ($F(2,1152)= 10.62$, $p < .001$), the participants reported that they would experience more social influence to use a butler robot or an information source robot than a companion robot ($p < .05$ between both pairs). Finally, for self-efficacy ($F(2,1152)= 3.33$, $p= .036$), the participants indicated that they would feel more competent ($p < .05$ between all pairs) to use an information source robot than a butler robot.

V. Discussion

This study evaluated three different possible roles for domestic social robots (i.e., butler, companion and information source robot) by studying their acceptance and preferred appearance. For all the three roles, most participants favored a humanoid appearance over the other types of appearances for a social robot that would operate in their own homes. This result is similar to earlier findings in an earlier study by us in which humanoid robots were evaluated more positively [15]. The main reason for choosing a humanoid appearance as provided by the participants in this study was that such an appearance looks most like human, which they found more attractive and better suited for robots build for social interactions with their users. This is in line with earlier statements that a robot designed for social interaction with humans must project some amount of humanness to make the user feel comfortable to socially engage with the robot [12]. The results presented here enhance the importance of other human-robot interaction research exploring more detailed design features of humanoid robots, such as the one from Hwang et al. [18]. Future human-robot interaction research could further investigate why humanoid appearances are more positively evaluated.

However, the findings presented here show that the role for which a social robot is built affects the preference for a robotic appearance made by potential future users. When a social robots is built for the role as butler, people seem to find a functional appearance more suitable and a zoomorphic appearance less suitable for this purpose. The division of the choice for appearance of a robot in the butler role showed an overrepresentation for the functional appearance, because the participants found this appearance more competent and more clearly looking like a robot. Some other participants specifically stated that they did not want a human-shaped robot or that robots should never resemble humans. When a social robots is built for the role as companion, people seem to find a zoomorphic appearance more suitable and a functional and caricatured appearance less suitable for this purpose. The division of the choice for appearance in the companion role showed an overrepresentation for the zoomorphic appearance, because the participants found this appearance cuddly and attractive. Some other participants related this appearance to the familiarity with human-pet relationships or they just loved animals in general. When a social robots is built for the role as information source, people seem to find a caricatured appearance more suitable and zoomorphic appearance less suitable for this purpose. The division of the choice for appearance in the role as information source showed an overrepresentation for the caricatured appearance, because the participant found this appearance not too humanlike and clearly looking like a robot. Some other participants found this appearance more competent and more attractive.

These findings support other researchers that people expect robots to look and behave appropriately, given the task in context [13]. Thus, a robot's appearance should match its intended purpose or the functional role for which it is designed. Additionally, these results also reflect the findings of Nomura et al. [25] who found that people assume humanoid robots to perform concrete tasks in society and that zoomorphic robots will serve pet- or toy-like roles. Examining the acceptance evaluation of the three different roles for social robots, it is shown that overall the companion robot is evaluated more negatively on the different acceptance variables. Earlier findings also indicate that only a few people would like to see future robots as friends, as people could perceive robots as not possessing a humanlike personality or character traits [9]. Rather surprising was that the participants even evaluated the companion role for social robots as less sociable. An explanation for this findings could be that people expect robots to be social enough for the role as butler of information source, but not for the role as companion.

A. *Limitations*

This exploratory study has revealed findings that could be relevant for future research ideas and robotic designs. However, some potential drawback of the study could be found in the text-based use scenarios, the chosen pictures and the employed sample.

The application of text-based use scenarios combined with robot pictures was believed to be an appropriate research method for our current goal [31]. However, other results can be expected with live human-robot interaction scenarios. As emotional responses to robots also affect the acceptance [30] and use behavior [11] of potential users, and because these emotional responses are likely to be bigger when confronted with real robots than with robot pictures [18], it is important to verify our current findings in the context of live human-robot interaction.

Although the robot pictures intended to be as neutral as possible, the robot's pose or colors could have had an effect. Therefore, some researchers argued for the inclusion of robot pictures with neutral background and information about the height of the robot [26]. Further research is necessary to investigate the existence of differences in the evaluation between altered pictures of the same robot.

Another limitation is that this study included only participants from The Netherlands. As nationality or cultural differences are found to have an effect on the evaluation of robotics systems [3], the same study conducted in another country could result in different findings. Therefore, replication of this study among other nationalities or cultures is recommended to validate the current findings.

B. *Conclusion*

This study investigated the evaluation of three possible future roles of domestic social robots (i.e., butler, companion and information source robot) by studying their acceptance and preferred appearance. Most participants, regardless of the designated role, indicated that they would prefer a humanoid robot for domestic purposes. Nevertheless, the results of this study showed that role for which a social robot is built affects the preference for a robotic appearance made by potential future users. More understanding is needed about the potential users' evaluations of possible future roles of domestic social robots. Broadening this understanding could be used to increase the acceptance of domestic social robots and help improve robotic designs for domestic purposes in the future.

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