How Humanlike Should a Social Robot Be: A User-Centered Exploration

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Abstract

Robot designers commonly emphasize humanlikeness as an important design feature to make robots social or user-friendly. To understand how users make sense of the design characteristics of robots, we asked 6 participants to classify and interpret the appearance of existing robots in relation to their function and potential usefulness. All the robots had humanlike aspects in their design, and participants most commonly remarked on these humanlike features of the robots. However, the commonsense logic of the "Uncanny Valley" (UV) in HRI design, which suggests that robots should be similar to humans to some degree without being too humanlike, was not supported by participant comments, which did not correlate humanlikeness to user-friendliness in line with the UV hypothesis. Rather, participants related the design features of robots to their everyday contexts, and focused their commentary on context-dependent design implications. As a result, we suggest our understanding of the design characteristics of robots should include the perspectives of users from the earliest stages of design so we can understand their contextual interpretations of different design characteristics. Open and modularized technical platforms could support the inclusion of users in the creation of future social robots.

Introduction

How should social robots be designed so that people find them easy and pleasant to use? A common answer to this question is that they should be lifelike to some degree (Goetz, Kiesler, & Powers, 2003; Hegel, Muhl, Wrede, Hielscher-Fastabend, & Sagerer, 2009; Mori, MacDorman, & Kageki, 2012; Scheeff, Pinto, Rahardja, Snibbe, & Tow, 2002). Lifelike and humanlike qualities are seen as ways to fit robots more naturally into the social expectations and existing categories of users (Vélez, Gallegos, Silva, Tumalli, & Vaca, 2014). At the same time, robotics designers are concerned that a high degree of humanlikeness might have negative effects on user perceptions. These concerns are guided by a popular heuristic for humanlike robot design—the Uncanny Valley hypothesis (Mori et al., 2012).

While anthropomorphic design (Salichs et al., 2006) and the Uncanny Valley (Vélez et al., 2014) have been central to the ways in which robotics researchers and designers make sense of robots, there have been few empirical studies on how users interpret various design rationales and schemes used in existing robots. In this paper, we explore how users make sense of robot designs by asking them to critique and comment on the appearance of several contemporary robots. We first discuss the design features that researchers commonly use in their robot designs and the design guidelines they follow. Then, we use "artifact analysis" (Janlert & Stolterman, 2008; H. R. Lee, Šabanović, & Stolterman, 2014), a method developed to help designers systematically think about the design features of complex technologies, to guide 6 participants in an open-ended critique of existing robots. Our results describe the design features that potential users focused on and the logic they used to interpret the practical significance of robots and specific aspects of their design. In conclusion, we suggest HRI researchers need to be open to different contextually situated categorization schemes that may be brought in by users, rather than following more abstract design schemes.

Related Work

HRI researchers have developed various frameworks for categorizing the salient design features of social robots. These frameworks are generally based on researchers' meta-analysis of existing robots, which are in turn often grounded in researchers' own experiences and scholarly theories of social interaction and design. Researchers have also reported on the design rationales of their robots, which commonly focus on producing lifelikeness in robots, some preferring certain degrees of humanlikeness (Dautenhahn

et al., 2009) while others prefer machinelike qualities (Reiser, Jacobs, Arbeiter, Parlitz, & Dautenhahn, 2013)

Design Framework of Social Robots

Scholars have surveyed existing robots to find possible design frameworks and design taxonomies for social robots. Fong et al. categorized the forms of social robots into four categories: anthropomorphic, zoomorphic, caricatured, and functional (Fong, Nourbakhsh, & Dautenhahn, 2003). Anthropomorphic robots are described as those with a form that leads people to attribute humanlike characteristics to the robot. Anthropomorphism is often used more as a paradigm to facilitate natural and social interaction between humans and robots, than a specific set of design features. Zoomorphic robots imitate living creatures rather than humans (e.g., Sony Aibo, Leonardo). Caricatured robots incorporate simplified or exaggerated representations of lifelikeness, similarly to animated characters (e.g., CERO). Functional robots are those whose form is designed based on the tasks they need to perform (e.g., service robots and toy robots).

From a more holistic viewpoint, Bartneck and Forlizzi suggested a design-centered framework for social robots (Christoph Bartneck & Forlizzi, 2004). The framework consists of five factors: form, modality, social norms, autonomy, and interactivity. All five factors are expected to work together, so that the form and abilities of social robots match. In this framework, form refers to shapes, materials, and behavioral qualities and is categorized into abstract, biomorphic, and anthropomorphic types. To make concrete and practical suggestions, DiSalvo et al. focused on features and dimensions of robot faces that users perceive as more humanlike. They conducted a survey with 48 robots, asking participants how humanlike each robot is (DiSalvo, Gemperle, Forlizzi, & Kiesler, 2002) and using statistical analysis to identify salient factors: the presence of specific features (eyelids, nose, mouth), the dimensions of the head, and the total number of facial features.

Although researchers suggested possible frameworks to design a social robot, the frames for physical design are still quite abstract and rarely examine what categories like anthropomorphic mean in terms of actual design. DiSalvo et al.'s study provided detailed ideas with examples, but focused only on the face. Also, users were rarely included as experts who can help determine what the possible design frameworks of robots should be. In response to the dominance of researcher-defined perspectives and lifelikeness as a guiding idea in social robot design, we invited potential users to comment on what humanlikeness in robots means to them and which traits they see as important for making robots seem social and useful.

Design Features of existing Social Robots

HRI researchers have produced many reports about the rationale of social robot design (Dautenhahn et al., 2009; Ishihara & Asada; M. K. Lee et al., 2009; Reiser et al., 2013; Salichs et al., 2006; Vélez et al., 2014). Lifelikeness was the most commonly discussed design issue (Dautenhahn et al., 2009; DiSalvo et al., 2002; Gee, Browne, & Kawamura, 2005; Ishihara & Asada; M. K. Lee et al., 2009; Reiser et al., 2013) although researchers have different opinions about how humanlike or machinelike their robots should be. Particularly, a number of scholars reported using humanlikeness as a way to promote friendly interactions between humans and robots (Breazeal, 2003; Dautenhahn et al., 2009; M. K. Lee et al., 2009; Salichs et al., 2006; Vélez et al., 2014). Although researchers rarely explain exactly what humanlikeness entails for design, humanlike robots generally have a structure similar to that of the human body (e.g., head, limbs) and a humanlike face as a way to interact with people. Snackbot was made in a humanoid shape so that it would be perceived as friendly and appropriate for close interaction with people (M. K. Lee et al., 2009). Kismet's appearance is described as infant-like, to inspire communication similar to that between infants and caregivers (Breazeal, 2003). Kaspar is described as child-friendly due to its humanlike shape (Dautenhahn et al., 2009).

The logic of the Uncanny Valley, according to which the familiarity of robots increases as the robot looks more like a human, but drops exponentially when it comes too close to a humanlike appearance, is one of the most popular design rationales for social robots. Researchers often refer to the Uncanny Valley in descriptions of humanlike robot design, saying they tried not to fall into the Valley by making robots look abstract (M. K. Lee et al., 2009), less realistic (Dautenhahn et al., 2009), cartoonish (Breazeal, 2003), or removing humanlike body features (Matsumoto, Fujii, Goan, & Okada, 2005). An alternative use of the Uncanny Valley in robot design is expressed by researchers who expect users to favor very humanlike robots (e.g., Geminoid) (Hanson et al., 2005; Ishihara & Asada).

Some researchers have articulated additional design features they considered in the robot design process. One such feature is color (Dautenhahn et al., 2009; M. K. Lee et al., 2009; Osada, Ohnaka, & Sato, 2006). For example, Snackbot's orange color was chosen due to its association with food, in opposition to blue which might connote medical service, or green's connection with sustainable products (M. K. Lee et al., 2009). The size of robots was discussed as well, including height and bulkiness (M. K. Lee et al., 2009; Reiser et al., 2013). For example, Care-o-robot was made more compact so it could fit narrow home hallways. Another group of researchers mentioned minimalism as their design methodology, where only essential features are

implemented instead of building complex humanoids (Dautenhahn et al., 2009; Matsumoto et al., 2005).

Although researchers have divergent ideas on how humanlike their robots should be, humanlikeness is at the center of researchers' discussions about robot design. To add to our understanding of how different robot design features, especially humanlikeness, are perceived, we investigated how potential users critique robots designed for their everyday lives. In the following section, we describe how users construct a design rationale in HRI and how they make sense of existing robots.

Method and Participants

Our method's main aim was to explore how users interpret robot designs and what frames they use to make design decisions, without imposing the frames of researchers on the discussion. We employed an adapted version of Artifact Analysis (Janlert & Stolterman, 2008; H. R. Lee, Šabanović, & Stolterman, 2014) which is a way to focus on objects to evaluate their specific properties and shapes. Artifact Analysis was originally developed for interaction designers as a tool to analyze complex technologies (Janlert & Stolterman, 2008). As technology gets more complex, designers need to analyze how the complexity should be managed and how different features interact with each other and are used in practice to improve their interaction design features. Artifact Analysis provides an analytic tool to scrutinize complicated technologies. In this study, we used it to help users interpret and examine existing robots. Our method was exploratory and aimed to reveal new perspectives on possible design features from users, who are rarely invited to analyze technically complex robots.

Our interviews invited participants to analyze the design features of currently available industrial, research, or commercial robots. First, we asked participants to critique each of the robots with questions about their "first impression," "favorite and least favorite parts," and "possible ways to improve their least favorite parts." Second, we asked them to group similar robots according to any scheme that made sense to them. While grouping the robots, participants compared and contrasted them, which helped us understand the logic according to which they interpreted a robot's design. Finally, we asked what robot participants would or would not buy, and asked them to pick what they saw as the most social robot. The simple procedure of our study was intentionally designed not to reflect the existing categories of social robots in HRI to participants. Rather, participants were able to determine what parts they wanted to discuss and how they would frame the discussion. Our goal was to identify what they saw as important design features and frameworks for interpreting robot designs.

To inspire participants to comment on various design features, we showed them pictures of a diverse set of robots. We used 27 6X6 inch cards with full-body depictions of the robots, gathered from research papers and websites. We included as many different types of robots as we could in terms of their form, context of use, possible users; our set included a spectrum of robots from an industrial arm robot, to an android (Geminoid), humanoid robots (Snackbot, Care-o-bot, Asimo), robots for children (Kaspar, PaPeRo), minimalist robots (Muu), and a robotic car.

Most of our participants (4/6) were over 60 years of age, except for one college student (19) and a bakery worker (43). The age of our participants is roughly representative of the main expected users of social robots in the short term—the elderly. Five of them were retired and three were nursing home residents.

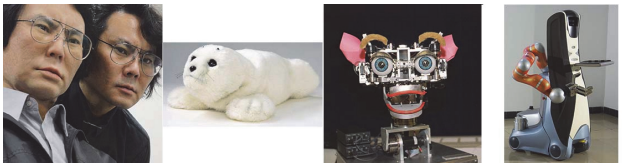

Figure 1 Robot card examples (from Left to Right: Geminoid, Paro, Kismet, Care-O-Robot).

Results

We analyzed the transcripts of our interviews with an inductive coding process, during which we identified 515 unique codes. While "humanlikeness" was the most common theme related to researchers' descriptions of robot designs, participants did not focus on how humanlike a robot was, and humanoid robots were not evaluated most favorably by them. Robots were analyzed in more contextually situated and complex ways, without fitting the Uncanny Valley logic for designing social robots. First, rather than focusing on how humanlike the robot was as a whole, participants commented on specific humanlike features of the robots. Second, their interpretation of the humanlike appearance was closely tied to the social meanings based on perceived gender, race and related social roles of the robots. Below we describe the design rationale and comments of users.

Distributed Humanlikeness

Instead of ascribing humanlikeness to the whole robot, participants identified humanlike qualities in various parts of the robots. The humanlike features identified by participants were different for each robot, except for the Geminoid, which most realistically copied the appearance of an original human. Kaspar's clothes were considered human-

like, although its face was not as humanlike as its clothes. Muu's single eye was referred to as very human, although Muu itself was described as an animal or monster. Asimo's body shape and hands, fingers, legs, and gestures were seen as very humanlike, but its face was considered less so.

Face

Robot faces were the most common part participants described as humanlike, giving empirical support to their emphasis in robot design. The size (proportion of the face), facial expression, and clarity of facial features were important factors to participants. Kaspar's face was critiqued due its relatively large size compared to its height (3/6). P4 (retired, 65) said:

> "It looks miscalibrated. What I don't like about it is the head and the body do not go together to me at all."

In contrast to expectations from the Uncanny Valley hypothesis, all participants pointed out the unpleasant facial expression of Geminoid rather than its overly realistic face. Participants wanted to change its expression rather than focusing on its creepiness as a whole. P5 (retired, 70) explained:

> "This is fairly good (in terms of appearance). What I do not like is that he looks mad. … make him smile!"

Also, the darkness of Asimo's face was considered inappropriate (4/6) for its very humanlike body shape (e.g., joints, hands). P3 (a bakery worker, 43) said Asimo's face is her least favorite part since she cannot see its facial features. P3 called Asimo's face a black hole, where she can see nothing. Although Kismet has clearly defined facial features, no participant described its head as a "face" Instead, each part of the face was described separately as ears, eyes, a mouth, lips, and eyebrows. Also, Kismet was not considered human despite its clear facial features. P6 pointed out its exposed coils and skeleton without a cover, which made it seem not humanlike. P6 said (retired, 68):

> "Since I can't see the rest of this creature… at this point this is the least humanlike robot that I've seen. Even though there is an attempt to make a mouth and handsome blue eye and some kinds of pinky ears."

Limbs, hands, feet, and joints

Figure 2 KASPAR with a large portion of head (Left), Asimo with a dark face (Right)

The limbs, hands, feet and joints of robots represented their practicality or functionality. Participants saw stable and extendable arms as functional (e.g., the arm on Care-o-bot's back, Snackbot's tray (4/6)). 4 out of 6 participants said Snackbot's tray and arm were their favorite parts, despite other less satisfactory design features of the robot. P5 (retired, 70) said:

> "Looks like he is serving supper or something, which would be a good thing for him. He looks kind of blunt in his face… I think it should have better face."

When limbs, hands and feet looked unstable and short (e.g., Papero's arm, Kaspar's feet), participants expected the robot not to be physically functional but to have verbal and cognitive functions.

Figure 3 Snackbot with arms attached to a tray (Left), Papero with no arms and short legs (Right).

Eyes

Participants frequently commented on robots' eyes, saying that eyes were a way for robots to express their thoughts and personality. Large distances between the eyes (3/6), the proportion and size of the eyes (4/6), and the quality of the eyes (4/6) were often examined. Large exaggerated eyes and detailed pupils were considered intimidating or scary (5/6).

Participants (3/6) explained a proper distance between the eyes is necessary for a humanlike effect. P5 (retired, 70) explains:

> "I would make them a little smaller and perhaps make them closely set together. Because our eyes are pretty closely set and that would look more like a human."

P2 (student, 19) complained about Leonardo's big eyes:

> "Ahm… they are just really big. The proportion of its eyes on its head is intimidating."

The big eyes of Kismet (3/6), Muu (3/6), and Papero (2/6) were also negatively evaluated by participants. Muu's large eye made participants feel like they were being watched and spied on. Also, overly realistic and detailed eyes contributed to negative reactions to robots, following the notion of the Uncanny Valley. Leonardo and Muu's realistic eyes with detailed pupils were the least favorite parts of the robots, according to participants. P6 (retired, 68) said:

"Its eyes are pretty kind of startling. They really are staring you down. (laugh) So probably the eyes are the part I like least."

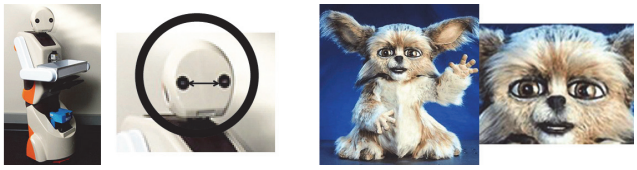

Figure 4 Snackbot with eyes wide apart (Left), Leonardo with big eyes (Right)

Humanlikeness with Social Meaning

Participants' understanding of the robots' humanlike appearance was intertwined with their potential social meanings. It was not important how similar the robot is to a human, but what the meaning of its humanlike appearance implies to the users. Expected social roles, and the perceived gender and race of the robots played an important role in how participants read and anticipated what the robots were for.

Expected Social Roles

Participants used terms related to common social roles to describe robots. Geminoid was mostly referred to as a real human or mad scientist, Asimo as a spaceman, RiMan as a soldier, a housemaid, and a grandmother, Snackbot as a monk, a servant, a waitress, and a housemaid, Care-o-robot and Papero as butlers. Additionally, Snackbot, Kismet and Muu were described as monsters (e.g., "skeleton" for Kismet and "one eye guy" for Muu). Sometimes, robots were described as media characters (e.g., "gremlins" for Leonardo), everyday objects (e.g., Care-o-robot as a vacuum), machines (e.g., Care-o-robot as a computer), and toys (e.g., Asimo as a Lego) as well. Kaspar (2/6) was described as a robot with a Guy Fawkes mask by (student, 19):

"The face looks like the Guy Fawkes mask. But more frightening cause it is more symbolic or very relevant."

Race

Figure 5 Kaspar with Guy Fawkes like face

When explaining features of humanlike robots (e.g., Geminoid, Kaspar), participants also commented on what they perceived to be the race of the robots. P7 (retired, 68) carefully asked whether it is acceptable to talk about race when he told his thoughts of Geminoid. P7 said:

"I am gonna be very honest about it. I might carry some kind of very racial implication. It would be something related to robot racial stereotypes. It's an old idea that Asians are inscrutable. When I say he is a bit sinister, it's because he is Asian. So, if you design a robot like a human, you need to think about racial profiles."

P3 (a bakery worker, 43) also mentioned Kaspar looks like an Asian, although she did not provide any additional thoughts on its race. Race was reflected as a simple indicator, but its meaning was based on the participant's own cultural and social experiences of race.

Gender

Participants (3/6) also discussed the gender of humanlike robots in relation to gendered roles and implicit design features. P5 (retired, 70) explained that Geminoid's gender should be changed according to current social and cultural norms of gendered roles. P5 said:

"To me, if he were selling cosmetics, "she" would be better. But, if he is selling all kinds of things like mechanics, then I think the male would be better. The reason is because we are just used to that."

Two participants described RiMan as a female due to its narrow waist, the skirt-like shape of its base, and its color. P7 (retired, 68) said RiMan reminded him of his grand mother who usually cleaned his room:

"My initial impression is it looks like my grandmother. This robot will be able to clean my room."

Users' alternative design rationale

Although users often mentioned the humanlikeness of the robots, humanlikeness was not their main expectation from robots. The most important point for users was how well the robots can fit into their everyday life. Their preference for or against humanlike features depended on the situation in which they saw the robot being used. Below, we present some examples that show alternative rationales of how social robots could be built. The examples show the importance of understanding the contexts in which robot use might occur and how users interpret those contexts.

Some contexts need unfavorable robots

The Geminoid has been presented as one of the most humanlike robots, which could easily fall into the Uncanny Valley and might thus not be liked by users (C. Bartneck, Kanda, Ishiguro, & Hagita, 2007). However, participants could see themselves actively using the robot in their everyday lives (4/6). Its humanlikeness made sense to them when employed for security purposes, such as guarding the home with its presence. P6 (retired, 68) explained how she could use Geminoid saying that:

"He can sit on the window if you were worried somebody might bother you. You would need to move him

around once in a while. Yes. That wouldn't be too fake."

Geminoid's masculinity was mentioned by P6, who said its masculine presence could be useful to her while driving:

> "He can seat next to me in the car so that it looks like there is a male passenger. It could detract the guys who is hijacking or something like that… I can't tell nothing much about what his limbs are capable of, but that's one use I can think for him."

Whether Geminoid was too humanlike or not was not the main point of their comments. Participants discussed whether its humanlikeness fits certain contexts and needs they had in daily life. In particular, they saw humanlike features could be useful for robots whose function is to provide a feeling of (sometimes intimidating) personal presence.

Big eyes better to watch you with

The exaggerated size of certain parts of the robots was more critical to participants' understanding than whether the robots were humanlike or not. Participants interpreted exaggerated mouths and eyes as having practical implications. Muu's large eye made participants feel watched and spied on, which made them think it could be a mobile security robot to make thieves feel like they were being watched (4/6). P5 (retired, 70) said:

> "I am the volunteer of a library. Every night somebody steals the Wall Street Journals and I've had people complain about it. Because they can't close up the door and they couldn't sleep when they knew it wasn't there. Well, I'd like to make him look and tell me who he is. (laugh)."

Participants were reminded of talking when they saw Kismet's big mouth. P5 (retired, 70) explained:

> "It has a big mouth. So it could tell something like that. …It could remind you that at 10 o'clock you got to go here there something like that."

Discussion

The degree of humanlikeness of robots has been a core focus of discussions about social robot design, although researchers have developed several different viewpoints on the effects of humanlikeness in HRI. However, users had different ways to evaluate and examine robot design, which did not focus on humanlikeness in the abstract. What seemed most important to them was what the robot's humanlikeness might mean in their everyday lives.

Not necessarily a Humanoid robot

Users talked about humanlike features such as head, eyes, and hands, which are all parts of humanoid robots. However, participants did not focus on humanoid robots as a whole. We want to clarify the difference between a humanoid robot developed based on the logic of the Uncanny Valley, and humanlike features which could be added or deleted individually. Participants cared about humanlike features, not humanoid robots. In their mind, humanlike features could be distributed into various parts and the appearance of robots was interpreted based on the social contexts of use and social meanings associated with specific features (e.g. big eyes). In some cases, geometric features of robots (e.g. curves) were more important for determining its use and likeability than the degree of humanlikeness. Most of all, the contexts that users imagined robots being used in were the most critical prerequisite to building user friendly robots. The starting point of social robot design should therefore be understanding the contextual meaning of design features and choosing them appropriately. Humanlikeness is not necessarily a shortcut to acceptance.

Enlarging the role of expected users in robot design

To understand the contextual meaning of robot design features, it is important to find ways in which users can more actively comment on robot design early on. A growing number of HRI studies have invited users into the robot design process (DiSalvo,Nourbakhsh,Holstius, Akin & Louw; Caleb-Solly, Dogramadzi, Ellender, Fear & Heuvel).) We believe the direction of those studies can enlarge the role of users in robot design. Users might be technological novices, but all our participants comfortably analyzed the design features of robots and provided valuable insights based on their contextual knowledge. We suggest this more active role of participants in HRI would provide us with useful insights to find other possibilities for social robot design, and help researchers envision more diverse versions of social robots.

Conclusion & Limitations

Humanlikeness in robot design has been a main design theme of social robotics, based on the belief that humanlike robots would be perceived as more user-friendly and enable natural communication. However, the participants in our study had different ideas about existing robots. What was most important for them was not how humanlike a robot is, but how well the humanlike features fit in their everyday use contexts. Thus, we suggest increasing the participation of users in the robot design process. At the same time, more open technical platforms that could be altered based on the contextual condition of users are essential for further exploration in robot design. Open platforms would enable HRI researchers to reflect the contextual understanding of users into robot design more easily through iterative design processes based on these insights.

Our study is limited by a relatively small number of participants and its exploratory nature. Our goal, however, was not to find users' general preferences for certain design factors, but to examine how people categorize and make sense of design features for social robots, particularly in relation to existing design frameworks from the field. We hope our insights can contribute both methodologically and practically to design oriented research in HRI.

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