Anthropomorphism and Human Likeness in the Design of Robots and Human-Robot Interaction

Julia Fink

CRAFT, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland
julia.fink@epfl.ch

Abstract. In this literature review we explain anthropomorphism and its role in the design of socially interactive robots and human-robot interaction. We illustrate the social phenomenon of anthropomorphism which describes people's tendency to attribute lifelike qualities to objects and other non lifelike artifacts. We present theoretical backgrounds from social sciences, and integrate related work from robotics research, including results from experiments with social robots. We present different approaches for anthropomorphic and humanlike form in a robot's design related to its physical shape, its behavior, and its interaction with humans. This review provides a comprehensive understanding of anthropomorphism in robotics, collects and reports relevant references, and gives an outlook on anthropomorphic human-robot interaction.

Keywords: anthropomorphism, design, human-robot interaction, literature review, social robots, social factors in robotics.

1 Anthropomorphism and the Role of Anthropomorphic Design

Soon more and more robots will be used in everyday environments, and an important aspect of developing "socially interactive robots" [1] is the design for effective human-robot interaction (HRI) as well as acceptance. One approach to enhance people's acceptance of robots is the attempt to increase a robot's familiarity by using anthropomorphic (humanlike) design and "human social" characteristics. This implies humanlike parts of a robot's physical shape, the usage of facial expressions and other social cues, as well as natural humanlike interaction and communication (e.g. speech, gaze, gestures). However, the role of anthropomorphism in robotics is not to build an artificial human but rather to take advantage of it as a mechanism through which social interaction can be facilitated [2]. An underlying assumption is that humans prefer to interact with machines in the same way that they interact with other people [1]. The idea combines "anthropomorphic design" and the phenomenon of "anthropomorphism" – when people attribute human characteristics to objects. Researchers have found that whenever artifacts show intentional behavior (e.g. when animated), people tend to perceive them as characters or even as creatures [3] [4].

1.1 Anthropomorphism

"Anthropomorphism" originates from the Greek "*anthropos*" for "human" and "*morphe*" for "shape" or "form" [2]. It describes people's tendency to attribute

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human characteristics to non-lifelike artifacts. The phenomenon of ascribing intentions [5] and animacy to simple shapes based on motion has been intensively studied in (developmental) psychology. But why do humans ascribe intentions and emotions to objects? One interpretation is that attributing familiar humanlike qualities to a less familiar non-humanlike entity can serve to make the entity become more familiar, explainable, or predictable [6]. In the design of socially interactive robots [1], anthropomorphism plays an important role and is reflected in the robot's form (appearance), behavior (e.g. motion), and interaction (e.g. modality). Robotics uses the mechanism to increase acceptance of robots and facilitate interaction.

1.2 Anthropomorphic Forms in Robot-Design: Shape, Behavior, Interaction

Anthropomorphic design means an imitation of human (or natural) form [7]. Fong et al. classify four categories of a robot's aesthetic form: anthropomorphic, zoomorphic, caricatured, and functional [1]. In robotics, "anthropomorphic design" refers to three parts: a robot's shape, behavior, and interaction/communication with the human [8] [9]. Social robots make further use of "human social" characteristics, such as express/perceive emotions, communicate with high-level dialogue, learn/recognize models of other agents, establish/maintain social relationships, use natural cues (gaze, gestures, etc.), exhibit distinctive personality and character, learn/develop social competencies [1]. One may ask how much human-likeness we want to have in non-human objects. How will people react to a robot that resembles a human? In 1970, Mashiro Mori formulated a theory called the "uncanny valley" [10]. It describes people's reactions to technologies that resemble a human too close while still not being one. Mori hypothesized that a person's response to a humanlike robot would abruptly shift from empathy to revulsion as it approached, but failed to attain, a lifelike appearance [10].

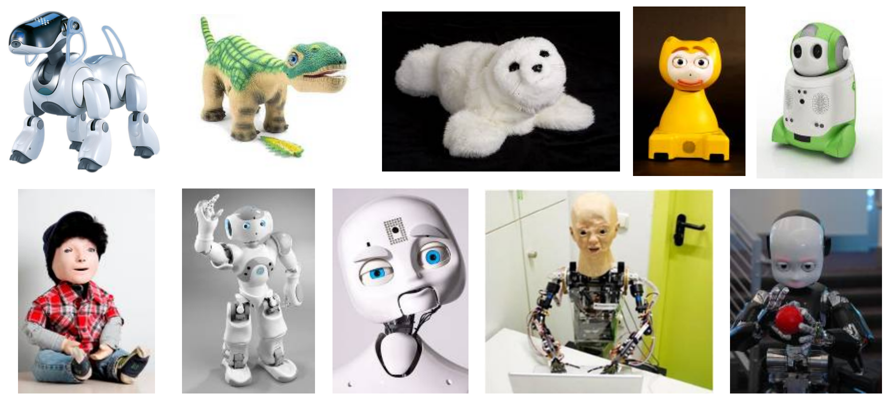

Fig. 1. Examples for bio-/anthropomorphic robots; top row: AIBO, Pleo, Paro, iCat, Papero; bottom row: Kaspar, NAO, Nexi, Barthoc, iCub, NAO

1.3 Why Is Anthropomorphism Relevant for (Social) Robotics?

What brings together anthropomorphic design and social robotics is the fact, that the appearance and function of a product impacts how people perceive it, interact with it, and build long-term relationships with it [11]. On one hand, robots with humanlike design cues can elicit social responses from humans which in turn can have a positive impact on acceptance [12] [13] [14]. People responded more positively to an artifact that displayed humanlike behavioral characteristics (emotions, facial expression) in contrast to a purely functional design [3] [15] [16] [17]. However, user preferences were task and context dependent [18]. Thus, the appearance of a robot should match its capabilities as well as the users' expectations [13] [19]. Anthropomorphizing a technological agent appears to create some social connection to it, aids in learning how to use it [6], and how pleasant and usable it is perceived [20] [16]. People preferred to collaborate with a robot that was able to respond socially [14] [18]. On the other hand, robots that overuse anthropomorphic form, such as humanoids that almost perfectly resemble a human but still remain unnatural copies, can have a contrary effect and evoke fear or rejection [10]. Though the point of when this negative effect can be observed is not yet identified, studies showed that especially humanoid robots evoked more reluctant and negative responses than robots with a pet-like or more functional shape [21]. Interestingly, the phenomenon seems to be culture sensitive [22] and based on Epley et al.'s psychological determinants likely to be related to other person-related factors, such as expertise/experience with a system [23] [24].

2 The Social Phenomenon and Socially Interactive Robots

2.1 Explaining the Social Phenomenon of Anthropomorphism

According to [25], there are two main perspectives when seeking to explain people's tendency to anthropomorphize artifacts. First one explains anthropomorphism from the design of the artifact. It is assumed that humans directly respond to life-like or social cues that an object or system emits, without thoughtful mental processing, by simply applying stereotypes and heuristics to it. Schmitz [26] describes that within the visual scope for design, the outer appearance can have an important impact on the overall perception of an object. If this explanation of anthropomorphism is correct, people may respond automatically to social cues emitted by a robot, and apply human-human social schemas and norms to these interactions [25].

A second explanation applies a human-centered, cognitive viewpoint where anthropomorphism is described through people's specific mental model [25] they have about how an artifact works the way it does. If a system behaves much like a human being (e.g. emits a human voice), people's mental model of the system's behavior may approach their mental model of humans, but this model may differ in important respects from their models of humans [25]. People's estimation of a robot's "knowledge" and its capabilities/abilities affects the way they relate to it. Research examined the validity of the mental model concept with various kinds of robots [25] [27]. Findings suggest that people tend to hold richer mental models about anthropomorphic robots in contrast to mechanic ones [27] .

As an alternative to the two explanations given above, one can explain people's tendency to attribute human qualities to objects based on social psychology. As mentioned earlier, Epley et al. [6] established a three-factor theory of when people are likely to anthropomorphize based on psychological determinants. Namely, the theory describes that some people are more likely to anthropomorphize, so when (i) anthropocentric knowledge is accessible and applicable to the artifact (elicited agent knowledge), (ii) they are motivated to explain and understand the behavior of other agents (effectance motivation), and (iii) they have the desire for social contact and affiliation (social motivation) [6]. Some work also discusses the inverse process to humanizing artifacts, namely, dehumanization [6], or mechanomorphism [23].

2.2 Classification and Evaluation of Social Robots

Socially interactive robots can be classified in terms of (1) how well the robot can support the social model that is ascribed to it and (2) the complexity of the interaction scenario that can be supported [1]. Breazeal [28] and later extended by Fong et al. [1] suggest seven classes of social robots: socially evocative, social interface, socially receptive, sociable, socially situated, socially embedded, socially intelligent (for more details, see Fong et al. [1]). This classification is based on Dautenhahn and Billard's [29] definition of social robots, as *"embodied agents that are part of a heterogeneous group: a society of robots or humans. They are able to recognize each other and engage in social interactions, they possess histories (perceive and interpret the world in terms of their own experience), and they explicitly communicate with and learn from each other."* Since the time when the Turing Test was drafted, one of the benchmarks for success in AI and HRI has been how well a system can imitate human behavior. Several measurements and methods have been suggested for the evaluation of anthropomorphic robots: psychological benchmarks [30], as well as properties of a social robot rated by humans [19] [31]. From a methodological point of view, questionnaires and content analyses [32] [33] have been used to analyze anthropomorphism in robotics but also more implicit measures (e.g. psychophysical onses), such as gaze cues [34], motor/perceptual resonance [35], and neurologic metrics [4].

3 How Anthropomorphism Impacts Human-Robot Interaction

3.1 Impacts of Anthropomorphic Shape of a Robot

A robot's physical embodiment is one of the most obvious and unique attributes and thus of high importance for interaction. The role of the physically visible design of robotic products has been discussed and investigated by designers [8] [19] [36]. HRI studies have so far verified that there are differences in how people interact with anthropomorphic and non-anthropomorphic robots [37] especially in terms of social interaction. However, while no real evidence exists, theory suggests a negative correlation between the robot's physical realism and its effectiveness in HRI [37]. A human shaped robot can raise specific expectations from the user side [25], which can lead to a negative effect when the robot's behavior does not meet these expectations.

In general, many studies so far, contribute (partly) to the “uncanny valley” effect, however, one has to take a more detailed look at which dimensions of the interaction are affected: Kanda et al. conducted a study with two different humanoid robots (ASIMO and Robovie) and showed that different appearance did not affect the participants’ verbal behavior toward the robot but did affect their non-verbal behavior such as distance and delay of response [38]. Similarly, comparing a pet-robot (AIBO) to a humanoid robot (ASIMO), people seem to prefer the pet-shaped robot [21]. While there was no significant difference in how people gave verbal commands to both robots, the way participants gave positive and negative feedback to AIBO and ASIMO differed significantly [21]. While AIBO was treated similarly to a real dog and petted to give positive feedback, the humanoid ASIMO was touched far less [21].

In evaluating how humanlike a robot appears, especially a robot’s head and *face* receives considerable attention, since this body part is crucial in human-human communication (most non-verbal cues are mediated through the face). DiSalvo et al. [8] found that particularly the nose, the eyelids and the mouth increase the perception of humanness in robotic heads. Further, the width of the head had a significant effect.

Also, a robot’s *physical embodiment* and presence has been investigated in terms of anthropomorphic interactions compared to robot-like agents or a remote robot [39] [40]. Kiesler et al. [39] conducted a study where a robot-like agent interviewed participants about their health. People were either present with the robot/agent, or interacted remotely with it, projected life-size on a screen. Results indicated that participants were more engaged, disclosed less undesirable behavior, and forgot more with the robot versus the agent [39]. People viewed the robot as more dominant, trustworthy, sociable, responsive, competent, and respectful than the agent and rated it more lifelike. The collocated robot was anthropomorphized the most [39].

In conclusion, studies suggest a positive effect of embodied robots that use anthropomorphic shape. However, there is the tendency that participants prefer a pet-shaped robot to a human-shaped robot. Overall, research confirmed that the physical shape of a robot strongly influences how people perceive it and interact with it, thus visible design is crucial. However, demographic, cultural factors [22] [41], individual preferences, and the context of use need to be considered as well. This makes it hard to identify concrete universal guidelines for how to design an acceptable social robot.

3.2 Impacts of Robots Using Human Social Cues / Social Interaction

Besides the shape, a robot’s effectiveness in HRI is also related to its behavioral social success which is a fundamental component of the interaction. Studies showed that the social identity of the robot (both the personality and the role of the robot) [37] has an effect on the user’s task performance. The use of social interaction in HRI is expected to make the interaction more natural and thus more effective. Efforts have been made in making a robot’s behavior social by giving it a personality, letting it display facial expressions, making it communicate in a polite way, or even making it cheat [42], for example. Also the ability of recognizing and being aware of the human counterpart’s emotional state was used as one possibility for socially intelligent machines. In the following we present results of studies with robots that used human social cues to interact with people and outline how this affected the interaction.

A considerable amount of studies investigated the effect of a robot's ability to exhibit *facial expressions* during interacting with a human. Eyssel et al. [15] examined the effects of a robot's emotional nonverbal response on evaluations of anthropomorphism. Using the iCat robot they found that when the robot provided emotional feedback, people perceived it as more likeable, felt closer to it, and rated the interaction as more pleasant compared to when the same robot responded neutrally. Participants evaluated the emotionally expressive robot more humanlike and anthropomorphized it more, due to the fact that it displayed two emotional states (happiness and fear) during the interaction [15]. Gonsior et al. [43] could show a similar effect, measuring people's *empathy* toward the robot head EDDIE when (1) it was neutral, (2) displayed the subject's facial expression, and (3) when it displayed facial expressions according to its internal model, indirectly mirroring the subject's expression (labeled as the "social motivation model") [43]. People's ratings on empathy, subjective performance, trust, and likeability significantly differed between the three conditions and were most positive for the robot using the social motivation model.

A robot's *social awareness* can also be expressed in the way it communicates verbally. The presence of voice is another strong trigger for anthropomorphic perception. Different kinds of voices have been evaluated as well as dialogue and turn-taking in HRI. For example, Fussell et al. [44] could show that people view a robot that responds politely as less mechanistic than an impolite one, which contributes to the hypothesis that social robots are perceived as more humanlike.

In conclusion, human social behavior, such as facial expression or the sound of voice [45], shape not only the way we interact with each other but also how a robot is evaluated. It is still a challenge to model human social characteristics in robots and most systems can only be used in short-term interaction or are operated by a "wizard", where still the robot is not autonomous but a human is operating it in the background.

3.3 Anthropomorphic Human-Robot Interaction

What would be the advantages of "anthropomorphic" interaction? First of all, the actual world is quite well suited for humans. Everything is well adapted to the size of a human; it's physical abilities and limitations, and so forth. Secondly, humans usually know how to interact with each other. They use natural cues, gestures, emotions, speech and the interaction is characterized through multimodality. For HRI however, multimodal interfaces are challenging [37]: computer vision to process (optimally in real time) facial expression and gestures; speech recognition for language understanding and dialog systems; sensory processing to combine visual and linguistic data toward improved sensing and expression. Still, to add meaning to facial and physical expressions and speech, and combining all of those capabilities in real time on a mobile, self-contained robot platform, is an open research problem in robotics [37]. In addition, for social interaction body pose, movement, and other subtle cues are important sources of information. In recent years there have come up interesting new ways for interacting with technology that could be transferred to robotics [46]. Haptic or tangible interfaces and affective computing exploit anthropomorphic design to facilitate interaction and make the user experience more pleasant. Anthropomorphic interfaces attempt to build on established human skills (e.g. physical manipulation of tangible objects [26]), learned in daily social encounters. Another technical trend is to augment everyday objects with sensing, computing, and actuation power. Lifelike movements in everyday objects can be beneficial for interaction [36]. The attempt with anthropomorphic interfaces is to exploit both the naturalness of conversational and social interaction, and the physicality of real world objects.

4 Conclusion

Anthropomorphic and socially interactive robots are certainly a very interesting field in HRI and extensive research has been carried out to investigate the impact of human-shaped robots and robots using humanlike behavior in the interaction with people. One strives hard to draw a general conclusion especially since some findings seem to be contradictory and highly sensitive to the human individual in the loop. Overall, due to its broad understanding and usage in a variety of disciplines, the phenomenon of anthropomorphism seems to be more difficult to grasp than expected. Further, experiments do not always use robots or manipulate their properties in a way that it is actually valid for comparison and thus not all results are meaningful. However, that anthropomorphism is of complex nature has already been pointed out by others [13]. However, we like to mention here, that anthropomorphic design, though it holds some very promising approaches, is not the "one and only" solution to design meaningful HRI. There are equal good reasons to not design humanlike robots. This has for example been recognized by DiSalvo et al. [8] who suggest that in the design of robots, a balance needs be found that takes into account three considerations: *"the need to retain an amount of robot-ness so that the user does not develop false expectations of the robots emotional abilities but realizes its machine capabilities; the need to project an amount of humanness so that the user will feel comfortably engaging the robot; and the need to convey an amount of product-ness so that the user will feel comfortable using the robot."* [8] Alternatives to pure anthropomorphism can also be found in new interfaces for HRI [47]. We still believe that robots – as well as humans – need to be authentic in the way they are, to be "successful" in a variety of dimensions. "The best way is just being oneself."

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