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## Speech and Language for Acceptance of Social Robots: An Overview

**Judith A. Markowitz**

J. Markowitz Consulting  
5801 N. Sheridan Road  
#19A  
Chicago, IL 60660  
USA  
judith@markowitz.com

**Abstract**

We are entering the age of robots in which social and personal robots will become part of our daily personal and professional lives. This paper explores two major ways in which speech and language contribute to user acceptance of social and personal robots: as tools to identify and examine user anthropomorphism and as user-centric features of robots. Both ongoing research and directions for future work are highlighted.

**Keywords**

social robots, anthropomorphism, uncanny valley, computers as social actors, CASA, speech, voice, language

## Introduction

We are on the cusp of the age of robots. Most analysts looking at robotics report that, very soon, robots will not only be commonplace, they will be part of our daily lives. Robotics is attracting so much interest that it has spawned a multitude of market reports. Frank Tobe of *The Robot Report* described 62 such reports on various segments of the marketplace (Tobe, 2016).

Companies involved in research in this area range from start-ups to multi-national corporations. Governments have joined that chorus of voices. In 2006, for example, the government of South Korea, which is funding its robotics program, announced it wants to put "a robot in every home by the year 2020" (Lovgren, 2006). The Japan Robot Association, which also provides active support and funding for its robotics program, has estimated that the market for robots in Japan will exceed 6 trillion yen (around 54 billion USD) in sales by 2025 (Nirmala, 2015).

This future is not limited to Asia (Jozuka, 2016; Markets and Markets, 2015; Tobe, 2016). A few examples of government-funded and public-private projects are:

- The European Commission's development of personal robots, including robots for eldercare (<https://ec.europa.eu/digital-single-market/en/robotics-ageing-well-current-research>) the funding of which includes projects focused on natural-language processing (Mirnig & Tscheligi, 2015);
- Canada, whose projects include HitchBot, a hitch-hiking, humanoid robot (<http://mir1.hitchbot.me/>);
- Israel's Ministry of Foreign Affairs that is funding development of robots for security and space exploration (<http://mfa.gov.il/mfa/aboutisrael/Pages/default.aspx>); and,
- Several agencies of the United States government that fund robot development, including the National Science Foundation which has the National Robotics Initiative 2.0: Ubiquitous Collaborative Robots (NRI-2.0; [https://www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=503641](https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503641)).

Many of the projects and projections cited above involve *social robots*, a rapidly-expanding category of robots. Social robots are designed to interact with humans in a humanlike manner. These robots are already finding places in education, training, healthcare, and as playthings. In the near future, they may become *personal robots* capable of providing eldercare, childcare, and comparable services for other humans of all ages.

Their success in these roles relies as much on acceptance by the humans with whom they work as on their ability to fulfill the tasks with which they are charged. Such acceptance is especially important for personal robots since they will work closely with humans. This paper discusses ways in which speech and language contribute to user acceptance.

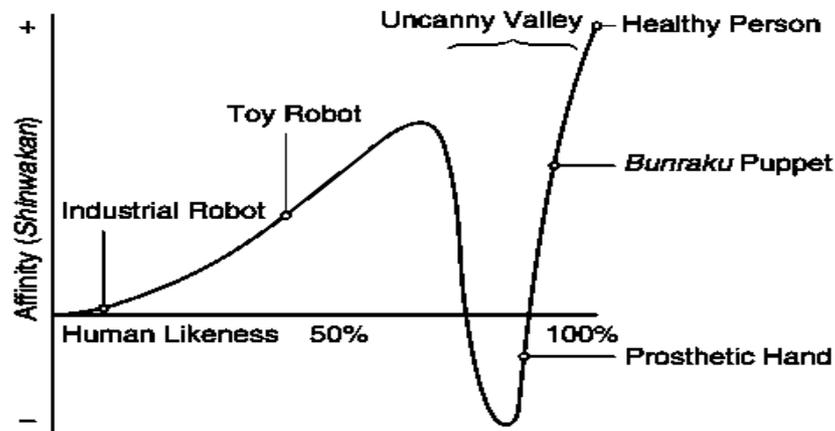
## Simulation

The most obvious path to acceptance is to simulate human appearance and behavior. That has been a direction taken by some roboticists leading to androids whose appearance and movements are remarkably like those of humans. Even so, some differences between human and robot physiology and function make accurate simulation difficult.

The most well-known challenge to the simulation path to acceptability of robots is the "Uncanny Valley" identified by Masahiro Mori (Mori, 2012). Figure 1 shows Mori's graph of human responses to artifacts of increasing similarity to humans.<sup>1</sup> The uncanny valley provides an explanation for strongly-negative responses to humanlike artifacts. It holds that humans are repelled by simulations of humans (and human body-parts) that are not completely true. According to the theory, once the appearance of a simulation is isomorphic with that of a healthy human the response becomes extremely positive.

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<sup>1</sup> Prosthetic hands are singled out as lying deep within the uncanny valley. Later in his paper Mori identifies zombies, corpses, and myoelectric hands as provoking the uncanny-valley response, as well.



**Figure 1.** Graph of the Uncanny Valley (Mori, 1970). The y axis is the degree to which an artifact resembles a human. The x axis represents the positive and negative reactions of humans to the artifact.

Mori's hypothesis addresses the uncanny valley with regard to appearance and movement but not to other behaviors, such as speech. Yet speech poses an especially knotty problem that could be considered a stumbling block for the kind of simulation that would move an android out of the uncanny valley.

The challenge arises from the difference between how speech is produced by humans vs. robots. For humans, speech production is a single, straightforward process. It is effected by pushing air from the lungs, past the vocal cords, into the resonating cavities of the mouth and nose, and out the lips and/or nose. The configurations of the soft palate, tongue, teeth, and lips in the oral cavity form the phonetic sequences the speaker wants to generate.

Speech generation in robots is entirely different. In most speech-enabled robots, speech is generated by a text-to-speech system (TTS) and fed to speakers. Following the demands of simulation, the robot also needs a mobile mouth – or, at least, movable lips. Since there is no direct link between sound production and lip movement, the robot's mouth must be manipulated by a controller that translates auditory output of the TTS into movements of the robot's lips (Hyung, Cruz, & Lee, 2016). With few exceptions (Hanson, 2007; see [https://www.youtube.com/watch?v=W0\\_DPiOPmF0](https://www.youtube.com/watch?v=W0_DPiOPmF0)), androids that are remarkably humanlike in appearance and behavior speak with flapping lips. Among them is an android that has been touted as the first robot TV anchor (Ruptly TV, 2014).

### Beyond the Uncanny Valley

Although a great deal of robot design has been influenced by Mori's hypothesis, researchers disagree about whether the uncanny valley actually exists and, if it does, what triggers the effect. (Bartneck, Kulic, Coft & Zoghbi, 2009; Blow, Dautenhahn, Appleby, Nehaniv, & Lee, 2006; Brenton, Gillies, Ballin, & Chatting, 2005; Ho & MacDorman, 2010).

Some studies have found uncanny-valley responses to robots which are not androids or to cartoonish images. Others point to factors that are unrelated to a robot's appearance. Gray and Wegner (2012), for example, found that "perception of mind" – a feeling that a robot can think, feel emotions, and experience things – unnerves humans more than humanlike appearance.

Both supporters and detractors of Mori's hypothesis have moved from testing the uncanny-valley hypothesis to identifying specific aspects of robot behavior as well as appearance that enhance acceptance of social and personal robots. Dufty (2015) and Hanson et al. (2005) accept the validity of the uncanny valley but have contended that negative responses to androids result from a failure to extend the simulation to behavioral and social aspects of design, including speech and language.

*We feel that for realistic robots to be appealing to people, they must attain some level of integrated social responsivity and aesthetic refinement ... In our experiments, our robots have demonstrated clearly, once and for all, that we can better understand social intelligence by rendering the social human in all possible detail. (Hanson et al. 2005, p. 1729)*

Their research has focused on rendering the social human with an emphasis on verbal skills. Their Philip K. Dick android is an example of that work (Dufty, 2015; Hanson, 2007).

One of the most active areas of post-uncanny-valley research involves anthropomorphism: the attribution of human qualities, such as emotions, planning, and intention to animals and inanimate things. (Baron, 2013; Bartneck et al., 2009; Dalibard, Magnenat-Talmann, & Thalmann., 2012; Ho & MacDorman, 2010; Riek, Rabinowitch, Chakrabarti, & Robinson, 2013). Speech and language have proven to be valuable for this research both as tools for understanding humans' responses to social/personal robots and as features of robots that enhance acceptance.

## The Roles of Speech and Language

### *Language as a Tool*

Anthropomorphism as a psychological phenomenon is well known. Researchers have documented the ease with which both adults and children establish affective and social bonds with robots (Breazeal, 2002; Fussell, Kiesler, & Setlock, 2008; Koerth-Baker, 2013; Tung & Chang, 2013; Weingartz, 2011). Even soldiers have been known to risk their lives to "save" a disabled robot or to weep when their robot colleagues are destroyed (Hsu, 2009). Our responses are so automatic that even those who fully understand that affective or social behavior by social robots is no more than bits of programming, still experience anthropomorphism. For example, in *God in the Machine*, Anne Foerst, founder of MIT's God and Computer Project, wrote

*Why would it make me happy if Kismet smiled at me when I knew that it was a programmed reaction? Why would I be disappointed when Cog was ignoring me, even if I knew that – at the time – it could hardly see anything in its periphery? (pp. 9-10).*

Language has proven to be an invaluable tool for understanding anthropomorphism. In their groundbreaking study, for example, Heider and Simmel (1944) reported that a large majority of their subjects characterized the movement of geometric forms using anthropomorphic language. Similarly, language is the tool for identifying and categorizing anthropomorphism of personal robots. Friedman, Kahn and Hagman (2003) examined the language in more than 6,000 postings on online user-forums for AIBO, Sony's robotic dog shown in Figure 2.



**Figure 2.** AIBO, Sony's robotic dog. (Sven Volkens (Own work) [CC BY-SA 4.0 (<http://creativecommons.org/licenses/by-sa/4.0>)], via Wikimedia Commons)

They categorized the postings into the five overarching “essences” shown in the left column of Table 1. The only essence that is not anthropomorphic is the technical essence.

**Table 1.** Anthropomorphic user language from postings in online user-forums for AIBO – adapted from the findings reported by Friedman, Kahn and Hagman, 2003: 277

<b>Essence</b>	<b>Pct. Members Posting</b>	<b>Sample</b>
technical: focuses on AIBO as an inanimate object	75	AIBO has batteries; AIBO is a toy
life-like: attributes animacy to AIBO (e.g., biological descriptors and/or processes)	48	I like to think of AIBO as a kind/breed of its own
mental states: attributes emotions and other mental processes to AIBO	60	My dog would get angry when my boyfriend would talk to him.
social rapport: mentions ways in which AIBO evokes or engages in social interaction	59	So this morning I asked him 'Do you want a brother?' Happy eyes !
moral standing: accords AIBO respect, rights, and responsibilities for its own actions	12	I can't believe they'd do something like that?! That's so awful and mean...that poor puppy...

Fink, Mubin, Kaplan, & Dillenbourg (2012) examined language in postings from online user-forums for the social robot AIBO, for the iPad, and for the Roomba vacuum cleaner (a disk-shaped, non-social robot). Posts to the AIBO forum contained the most anthropomorphic language. Anthropomorphic posts for the two robots exhibited far more anthropomorphic language than those on the non-robotic iPad forum. The iPad posts contained little anthropomorphism.

Fink (2014) and Forlizzi (2007) studied the impact of introducing Roomba vacuums to families. They studied the floor-cleaning patterns over time using interviews and diaries. They found anthropomorphic language and reports of anthropomorphic behavior (e.g., talking with the Roomba, giving the Roomba a name). In the same study, Forlizzi (2007) gave other families a Hoover Flair, a standard, upright vacuum. Families with the Hoover exhibited little anthropomorphic language and, unlike the Roomba, the Hoover had little impact on the floor-cleaning practices of the families involved.

### **Speech and Voice as Features**

There is a burgeoning volume of research on the impact of speech and language on acceptance of social and personal robots. This section touches on a few areas that illustrate the diversity of that work.

Studies on the impact of voices of artificial agents on anthropomorphism and acceptance provide a foundation for research on robot voices – notably the work of Nass and Brave (2005) which addressed a broad spectrum of aspects of spoken interactions between humans and computers. One such area is perception of a robot's gender and its impact on a human's response to that robot. For example, Eyssel, Kuchentrandt, Bobinger, de Ruiter, and Hegel (2012) varied robot voices to indicate both voice type (humanlike vs. robotic) and the gender of the robot. They found greater anthropomorphism and acceptance when the gender expressed by the robot's voice matched that of the human subject. Acceptance was further enhanced when the robot had a humanlike voice of the same gender as the subject. Walters, Syrdal, Koay, Dautenhahn, and Boekhorst (2008) assessed the influence of voice type and gender (expressed solely by voice) on proxemics: how close humans will approach a non-humanoid robot. The voice types were humanlike (female and male), robotic (androgynous), and no voice (the control condition). Subjects remained farthest from the robot using the robotic voice but were willing to approach the robot using a humanlike voice or no voice even closer than human strangers tend to approach each other.

Such behavior is not limited to adults. Paetzel, Peters and Nyström (2016) found that the perception of a robot's gender by children aged eight to thirteen depends more on the gender expressed by its voice than by its face. Furthermore, the children in their study did not experience "uncanniness" when there was a mismatch between the apparent gender of the robot's face and voice. Okita and Ng-Thow-Hing (2015) studied the effect of different robot voices on children from another perspective. A humanoid robot with either a machine-like or humanlike voice gave information and instruction to children aged four to eight. They found that the humanlike voice produced superior retention for younger children (four and five years old). Children six to eight years old showed a somewhat better performance with the humanlike voice but the difference was not as striking as for the younger children. Furthermore, younger children were more likely to engage in conversation when the humanlike voice was used. Age did not appear to affect engagement with the robot using the machine-like voice. Looking specifically at child-robot interaction, Sandygulova and O'Hare (2015) used a variety of child-like voices with Irish children ages eight to eleven. They found that the children enjoyed interacting more with a robot whose child-like voice spoke in an accent similar to their own.

Speaking styles have also been found to affect a human's cooperating with a robot providing advice or instruction. Goetz, Kiesler, and Powers (2003) used a humanoid robot to give exercise instructions and to participate with a human in a jellybean-sorting task. The same humanoid robot was used but it differed in demeanor: playful or serious. The demeanor was expressed primarily through playful or subdued language. They found that the congruence between the task and the robot's demeanor strongly influenced the subjects' willingness to respond to the robot's instructions. The playful demeanor produced more willingness to perform the light-hearted jellybean-sorting task but the serious demeanor engendered greater willingness to perform the more serious exercising task. When it used the playful demeanor the robot was seen as being enjoyable and witty, albeit sometimes obnoxious. When the robot used the serious demeanor it was seen as being more intelligent and much more conscientious.

Scheutz et al. (2006) examined the impact of adding affect to a robot's speech. They gave human-robot pairs a series of operational goals to achieve within a specified amount of time. The robot always complied with the human's instructions. In one condition the robot was allowed to express urgency in its voice when time was running short in the same way a human would communicate urgency (the affect condition); in the other condition the robot's voice was neutral (the no-affect condition). Objective metrics of team performance were better in the affective condition and the humans in that condition were more inclined to accept the robot's autonomy and other human-like attributes.

### ***Language as a Feature: Dialogue***

A social robot must be supplied with the language and dialogue skills required to effectively perform the tasks for which it was built. One successful example is the Philip K. Dick android built by researchers at the University of Memphis and Hanson Robotics. It did little more than respond to questions like the science-fiction author on whom it was modeled. Performance of that sole task entailed development of a multi-layered dialogue model that included multiple response strategies, an extensive database of actual responses Dick had given to questions, error-correction strategies, and a world model (Dufty, 2015; Hanson, 2007).

Robots designed to assume more complex roles with humans will often need to possess social-interaction skills as well as task-related dialogues to gain acceptance. There is, for example, a push to deploy robots capable of collaborating with humans in a variety of settings. In addition, dialogue and dispute-resolution strategies vary depending upon whether the robot is a superior, subordinate, or peer of the human (Azhar, 2015; Bahn et al., 2015; Black and Sklar, 2016; Jennings et al. 2014; Kahn et al., 2014; Salem, Ziadee, & Sakr, 2014). ArgMAS (<http://www.mit.edu/~irahwan/argmas/>) is an annual conference dealing with disputes and differences of opinion in multi-agent systems. These issues are applicable to educational, caretaking, and personal relationships as well as in business and professional environments. For example, a robot caretaker needs strategies for handling disagreements and refusals by their charges to cooperate with instructions (e.g., to take their medication). Developing dialogues of these types is a challenge but the situations involved are also difficult for relationships between humans.

## Additional Considerations

The success of social and personal robots depends upon user acceptance. This paper discussed two ways in which speech and language contribute to acceptance of social and personal robots.

One is that the content of user language can promote anthropomorphism which has been shown to increase user acceptance. This paper has presented evidence supporting that view but, as with many other aspects of design, there are counterbalances to consider.

1. Some researchers contend that designs that promote anthropomorphism encourage users to prefer interaction with robots over human contact. Sherry Turkle of MIT is one of the strongest voices supporting this view. In her 2011 book *Alone Together*, Turkle argues not only against designing to promote anthropomorphism but against creating social robots (Turkle, 2011). Total elimination of social robots is not feasible. It is also not desirable for populations that need social and emotional support, such as children in hospitals or institutions and elderly with dementia or other afflictions that limit meaningful contact with other humans.
2. A related position, and one that emphasizes interface design principles, is that of Bruce Balentine (2007). One significant point he makes is that efficient, effective, and satisfying design (in that order) lies at the heart of any interface. Although Balentine was discussing IVRs, this position can be extended to the need for designing speech and language for social robots. Design that enhances anthropomorphism is appropriate only when it meshes with the other attributes of the robot and contributes to making the robot more efficient, effective, and satisfying.
3. Anthropomorphism may occur whether or not the robot is a social robot. As indicated earlier in this paper, most of the subjects in Heider and Simmel (1944) studies used anthropomorphic language to describe geometric shapes. Hsu's report on robots in the military includes examples of soldiers who refused identical replacements of their robot brethren. The soldiers in Hsu's story had spent considerable time with the robots in question and, perhaps more importantly, those robots had saved their lives on more than one occasion (Hsu, 2009). This is not to say that practitioners should abandon speech and language design that encourages anthropomorphism. As this paper has argued, language is pivotal for making social robots truly social. Language that promotes anthropomorphism is likely to lead to faster bonding which can be an important factor in the ability of a robot to provide services it was built to deliver. Contexts that fall into this category include caretaking, tutoring/training, and collaborative work in business settings.
4. Some populations do not do well with highly-anthropomorphic robots. A notable example is autistic children who, unlike other children, have been found to respond better to humanoid robots that are not highly social. Kim (2013) provides an in-depth analysis which includes speech and language.
5. Regarding the "similarity attraction" effect of voice gender discussed earlier, several practitioners argue that, "... this research sounds compelling on its face ... [but] when you examine the details, it [becomes] much less solid" (J. R. Lewis, personal communication, 5/5/2017). Furthermore, the studies of Nass and Brave (2005) demonstrate a "social effect from the lab and not from actual use in the field" and have proven difficult to replicate (Lewis, 2011). This problem has led some to note, "Why such strong effects of humanizing cues are produced in laboratory studies but not in the field is an issue for further investigation (Couper, Singer, & Tourangeau, 2004, p. 567)." They continue, "Across these studies, little evidence is found to support the "computers as social actors" thesis, at least insofar as it is operationalized in a survey setting."

The other contribution discussed involves how effective design choices of robot speech, voice, and language can contribute to the commercial success of social robots. The work regarding the second contribution is still emerging but research has already provided pointers towards implementations that support acceptance of social robots in a variety of roles.

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### About the Author



**Judith Markowitz** is president of J. Markowitz Consultants. She has a doctoral degree in linguistics from Northwestern University and has served as an industry analyst in speech-processing for more than thirty years. She is a senior member of the Institute of Electrical and Electronics Engineers (IEEE).