Effects of Lateral Head Tilt on User Perceptions of Android and Humanoid Robots

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Abstract

Human responses to android and humanoid robots have become an important topic to social scientists due to the increasing prevalence of social and service robots in everyday life. The present research connects work on the effects of lateral (sideward) head tilts, an eminent feature of nonverbal human behavior, to the experience of android and humanoid robots. In two experiments ($N = 402$; $N = 253$) the influence of lateral head tilts on user perceptions of android and humanoid robots were examined. Photo portrayals of three different robots (*Asimo*, *Kojiro*, *Telenoid*) were manipulated. The stimuli included head tilts of -20°, -10° (left tilt), +10°, +20° (right tilt) and 0° (upright position). Compared to an upright head posture, we found higher scores for attributed human-likeness, cuteness, and spine-tinglingness when the identical robots conveyed a head tilt. Results for perceived warmth, eeriness, attractiveness, and dominance varied with the robot or head-tilts yielded no effects. Implications for the development and marketing of android and humanoid robots are discussed.

Keywords: human-robot interaction, nonverbal communication, head tilt, uncanny valley, anthropomorphism

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1. INTRODUCTION

1.1 Overview and Issue Relevance

Do you own a robot? Possibly you get your living room parquet vacuumed by an autonomous cleaner or your front lawn is cut by a mower robot, but otherwise you most likely answer “no” to this question. This could be quite different in 10 years. We are approaching an age in which robotic creatures will be turning up in more and more places in our professional and private life. “Rise of the robots” read recent cover stories in magazines (e.g. Fine, 2013). And Microsoft founder Bill Gates called robotics “the next hot field” after the PC revolution (Gates, 2007). This trend does not stop at industry-focused applications. Driven by ageing populations and ever more efficient, integrated and affordable technology, the field of social and service robots is growing as well (Japan Robot Association, 2001; Japan External Trade Organization, 2006; Kranenburg-de Lange, 2012). Especially on the Asian market, roboticists are already testing various types of robotic day-to-day assistants. They range from communication companions and autonomous housekeepers to care bots intended to support the elderly at home or to dispense medicine to hospital patients.

Regarding their visual appearance, some of these service robots do not differ all that much from the C-3POs or WALL-Es we have become familiar with in movies and literature. Many contemporary robot designs mimic human beings to a greater or lesser extent. At the same time, robots with humanlike looks are reported to elicit particularly negative responses in human observers or interaction partners. They have even been associated with a strong feeling of eeriness—a psychological phenomenon referred to as the *uncanny valley* (Mori, 1970).

Despite the growing relevance of humanlike robots, comparatively little is known yet about the factors that influence the experience of them. Accordingly, this paper is focused on users' responses to humanoid and android robots. Beyond the realism of their external appearances, we posit that features of nonverbal behavior of humanlike robots can increase the attributed anthropomorphism. More specifically, this paper argues that a head tilt conveyed by a robot, i.e. a shift of the head toward the left or right shoulder (e.g. Costa & Ricci Bitti, 2000; Goffman, 1976), affects users' perceptions of human-likeness and variables related to user acceptance.

1.2 On the Human-Likeness of Android and Humanoid Robots

A glance at the digital collection of contemporary robot developments provided by the Institute of Electrical and Electronics Engineers (IEEE, 2012) demonstrates that about 70 out of the 158 robots shown are constructed to look or behave humanlike. Depending on how easily they can be distinguished from real people, humanlike robots are typically either referred to as *humanoids* or *androids*. Whereas *humanoid* robots often come with extremities like arms, legs or a head but still have an overall mechanical look, *android* robots are intended to mimic human beings as realistically as possible, e.g. by covering the mechanical body with silicon skin (cf. Hirai, Hirose, Haikawa, & Takenaka, 1998; IEEE, 2012; MacDorman & Ishiguro, 2006; Nishio, Ishiguro, & Hagita, 2007).

Why would you build humanoids or androids in the first place? One reason often given by roboticists is that humanlike extremities are necessary to operate in an environment that originally was built for human beings (e.g. Hirai, Hirose, Haikawa, & Takenaka, 1998). Other researchers hold that only robots that are perceived as real people and therefore treated as such will be able to elicit natural responses in human communication partners (e.g. MacDorman & Ishiguro, 2006). The degree to which users actually attribute human-likeness—or more far-reaching: anthropomorphism—to androids and humanoids therefore constitutes a variable of high interest in the study of human-robot interaction.

Following Epley, Waytz, & Cacioppo (2007), the essence of anthropomorphism is described as "imbuing the imagined or real behavior of nonhuman agents with humanlike characteristics, motivations, intentions, and emotions" (p. 864). Anthropomorphic inferences thereby go beyond the observable looks and behavior of an artificial agent. They include the ascription of intentionality or traits that distinctly imply human nature (Eyssel, Hegel, Horstmann, & Wagner, 2010). When it comes to android robots and users' perceptions of human-likeness, there is one phenomenon that has received widespread attention among academicians, practitioners and the general public: the *uncanny valley* (Mori, 1970). The uncanny valley phenomenon represents the assumption of a curvilinear relationship between a robot's human-like features and the user's evaluation and acceptance of that robot. If a robot displays a rather high degree of human similarity in its appearance but at the same time still acts or looks somewhat "inhuman," perhaps as a result of "missing" limbs or imperfect motion, it is associated with a negative feeling of "uncanniness" (Ho & MacDorman, 2010; Mori, 1970). Recent empirical results indicate that such eerie feelings might arise from uncertainty or a meaning conflict that users have to deal with when being confronted with a blend of humanlike and machine-like qualities (Burleigh, Schoenherr, & Lacroix, 2013; Mara & Appel, 2015; Yamada, Kawabe, & Ihaya, 2013).

In this paper, we argue that not only the visual design of a humanlike robot but also its behavioral attributes can influence the intensity of anthropomorphic inferences and related impressions by human observers. We put an emphasis on nonverbal communication cues because their role in the experience of humanoid and android robots has rarely been explored to date (see 1.3). Our particular interest lay in the question of whether even a minimal change of a robot's head posture could have a significant impact on how this robot is perceived by human raters. We decided to focus on the study of lateral head tilt displays for three reasons: first, the head tilt is reported to be a very widespread and frequently occurring nonverbal cue in interpersonal communication; second, a comparably large body of empirical literature has dealt with its meaning in human-human interaction; and third, the manipulation of head tilts is a minimal and yet a potentially effective intervention in applied robotic contexts.

1.3 Nonverbal Cues and Head Tilt

A substantial part of human communication is nonverbal. Many of the things individuals try to learn about each other in social interactions—e.g. emotional states or intentions of a person—are conveyed not only through words (Ambady & Weisbuch, 2010; Mehrabian, 1972). In recent years, the posture of the human head has been identified as an intriguing nonverbal cue. Much attention has been dedicated to the *head tilt* (or *head cant*), which refers to "cocking" the head toward the left or right side so that the horizontal line connecting the eyes is no longer parallel to the horizontal line connecting the shoulders (cf. Goffman, 1976; Halberstadt & Saitta, 1987; Henley, 1977). When asked to pose for a photograph, nearly three-fourths of people were shown to exhibit head tilting (Costa & Ricci Bitti, 2000). Even in historical portrait paintings, head tilts are a prevalent feature. In an examination of 1,498 works by painters from the 14th to the 20th century, head canting was present in almost half of all portraits (Costa, Menzani, & Ricci Bitti, 2001). Observations of natural interaction settings, e.g. chats in the street, reveal that about 40% of people cock their heads (Halberstadt & Saitta, 1987).

By shifting our heads sideways we dampen the arousal brought about by eye contact in friendly face-to-face communication, as suggested by Eibl-Eibesfeldt (1988). Several authors described lateral head tilting as a subtle determinant for flirting or courtship behavior (Eibl-Eibesfeldt 1970; Givens, 1978). Head tilts were further characterized as an indication of shyness (Givens 1978; McGrew, 1972) or conciliatory behavior (Otta, Lira, Delevati, Cesar, & Pires, 1994) and it was correlated with higher attractiveness ratings (Costa & Ricci Bitti, 2000; Krumhuber, Manstead, & Kappas, 2007; Otta et al., 1994).

Interestingly, in Costa and colleagues' (2001) analysis of historical paintings, the social role of the depicted persons predicted how pronounced their head cant was. Whereas tilt angles of up to 20 degrees could be found in portraits of characters who expressed an adoration of God, aristocrats were rather shown with upright heads. This finding supports the assumption that head tilting is associated with submission, appeasement, ingratiation, or a request for protection. This meaning might have developed because head tilts expose a highly vulnerable part of the human body (the carotid artery) and reduce the overall height of a person (Goffman, 1976; Henley, 1977; Morris, 1977).

It is hardly surprising that the relation between head tilt and the perception of human-likeness has never been examined in the context of interpersonal communication. In general, you could justifiably call anthropomorphism a variable of negligible relevance in the study of human beings[1]. Regarding human-robot studies, no experimental research to date has examined head tilts conveyed by android or humanoid robots and their impact on anthropomorphic inferences made by human users.

However, there are empirical studies that have dealt with robotic nonverbal behavior. Most of them either tried to answer applied questions having to do with the

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[1] The study of *dehumanization effects* (see, e.g., Haslam, 2006) might be an exception.

effective integration of a robot's speech, gaze and deictic gestures, or they examined user impressions on a broader level of mixed behavioral cues. The former type of research includes case studies in which robots indicate directions by gaze, head movements, or pointing gestures and human interaction partners need to understand where the robot wants them to look or go (e.g. Breazeal, Kidd, Thomaz, Hoffman, & Berlin, 2005; Brooks, & Breazeal, 2006; Hegel, Gieselmann, Peters, Holthaus, & Wrede, 2011). This is of particular interest for the use of humanlike robots in practical scenarios, e.g. when they are deployed to serve as shopping assistants or museum guides (Kuno, Sadazuka, Kawashima, Yamazaki, Yamazaki, & Kuzuoka, 2007; Yamazaki, Yamazaki, Burdelski, Kuno, & Fukushima, 2010).

Other studies examined the impact of various nonverbal cues other than lateral head tilt on the acceptance and impression formation by human users. In comparison to speech-only conditions, humanlike robots that combined verbal and mixed nonverbal stimuli were found to induce higher user engagement (Moshkina, Trickett, & Trafton, 2014). Also, human-robot dialogues in which the robot exhibited nonverbal behavior were perceived as more natural and comfortable (Liu, Ishi, Ishiguro, & Hagita, 2012; Salem, Eyssel, Rohlfing, Kopp, & Joublin, 2013) and humanlike mimics led to higher likeability ratings of a robot (Eyssel, Hegel, Horstmann, & Wagner, 2010). Not least of all, human interaction partners were more likely to anthropomorphize robots when they made arm and hand gestures while talking (Salem et al., 2013).

1.4 Study Overview and Predictions

As part of the very broad spectrum of nonverbal communication cues in human-human interaction, the lateral head tilt is a particularly frequent one and is associated with impressions of friendliness, submissiveness, and attractiveness. However, what happens if a robot adapts this typically human cue?

We conducted two online experiments that addressed this question in a comprehensive empirical fashion. To get a highly structured yet extensive set of stimuli, we manipulated photo portrayals of three different humanlike robots, resulting in five different conditions of head posture for each robot. By doing so, we could not only identify head tilt as a variable that might affect the perception of a range of android and humanoid robots, but also examine the potential moderating role of robot type. Ratings of human-likeness, warmth, cuteness, attractiveness, dominance, eeriness, and spine-tinglingness served as our dependent variables.

We predicted robotic head tilt to increase anthropomorphic inferences by human raters for two reasons: First, the mere fact that a robot is capable of moving its "head" in an apparently organic way could be associated with something like "creatureness" and thereby lead to higher human-likeness ratings. Second, humans interpret head tilts on a daily basis during interactions with other humans. Participants may unconsciously deduce human nature whenever such a nonverbal cue is used—even if by a mechanical being. To get more specific, we hypothesized that a robot that exhibits a head tilt in a photo portrayal would more likely be ascribed human-likeness than a robot that is pictured with an upright head.

As mentioned earlier, the link between the perceived human-likeness and the "uncanniness" of a robot is a field of high interest in robotics. With a manipulation of head tilt, conflicting outcomes are imaginable. On one hand, higher human-likeness of robots has been reported to result in higher eeriness (Mori, 1970). If we predicted a rise of anthropomorphism through the head tilt, a rise of eeriness could therefore follow. On the other hand, empirical evidence suggests that interactions with robotic agents are perceived as particularly comfortable when the robot exhibits humanlike gestures or mimics (e.g. Eyssel et al., 2010; Salem et al., 2013). Moreover, humans with cocked heads have been rated more attractive and less dominant than those with upright heads in interpersonal communication (e.g. Krumhuber et al., 2007; McGrew, 1972; Otta et al., 1994). If we expected equivalent effects for our tilted robot portrayals, a decline of eeriness ratings would be in line with previous literature in which a negative correlation between attractiveness and the uncanny valley experience has been found (Ho & MacDorman, 2010). As both directions of effects therefore seemed to be reasonable, we decided to look into the impact of head tilt on a robot's eeriness in an explorative manner.

There are few theory-guided experiments on the influence of robots' nonverbal behavior. The present research is the first to examine head tilt cues as a determinant of impression formation in the context of human-robot interaction, anthropomorphism, and the uncanny valley.

2. EXPERIMENT ONE

2.1 Method

2.1.1 Participants.

In our first experiment, 402 US residents (63% male) volunteered to participate in the study. All participants accessed the experiment via Amazon's Mechanical Turk platform[2] and received a compensation of $ 0.35 for their time spent. We excluded 38

[2] Previous research conducted with this platform in the context of experimental research corroborates its validity (see Berinsky, Huber, & Lenz, 2012; Buhrmester, Kwang, & Gosling, 2011; Mason & Suri, 2012).

participants from further statistical analyses who knew the robot that was assigned to them before starting the survey, 16 participants who reported having insufficient language skills, and 5 who stated that they did not answer all items completely truthfully. The final sample consisted of 343 participants with a mean age of 31.77 years (*SD* = 11.64, range from 18 to 73).

2.1.2 Stimuli.

We decided to test our assumptions by using pictures of three actually existing robot types varying with respect to the human-likeness of their visual appearance. The robots were not required to be technically capable of head tilting in reality, but for the purpose of our experiments, they needed to come with parts likely to be identified as head and chest. From the *IEEE Robots* collection (IEEE, 2012), which provides photographs of more than 150 contemporary robots, we selected the android *Telenoid* (developed by the Hiroshi Ishiguro Lab at Osaka University), the rather humanlike *Kojiro* (developed by the JSK Robotics Laboratory at the University of Tokyo) and the mechanical-humanoid *Asimo* (developed by Honda Robotics) as stimuli for our experiments. Telenoid is a telepresence robot designed to transfer a human sender's voice, facial expressions, and gestures in real time to a distant place (Ogawa et al., 2011). Kojiro is a detailed musculoskeletal robot whose artificial muscles, bones, and tendons are created to mimic the human anatomy (Mizuuchi et al., 2007). Asimo is the world's most advanced two-legged robot, created to assist humans in real-world environments and able to recognize moving objects, faces, gestures, and sounds (Hirose & Ogawa, 2007).

The original photos of the selected robots were first checked for their suitability: in an upright position, the lines between their "eyes" and "shoulders" had to be parallel. After some minor angle modifications, this condition was satisfied in all three cases. Our experimental manipulation, the actual tilting of the robots' heads, was conducted with the help of the open source software *Gimp*, which allowed us to rotate the head part separately from the body part on each photo. Head positions then were fixed at 0° or tilted with -20° or -10° (left-tilt from observer's point of view) or +10° or +20° (right-tilt from observer's point of view). Finally, we adjusted the size of the images in a way to create comparable "half-bust" portraits of all three robots (see Figure 1).

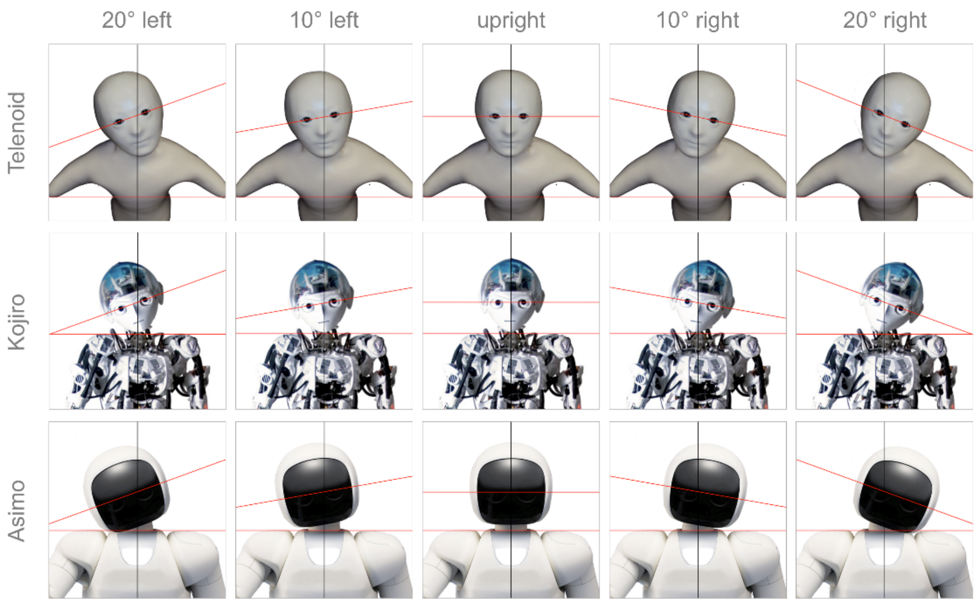

Figure 1. For the generation of our stimulus materials, the experimental factor head posture was manipulated by using photo portrayals of three different robot types. With the help of an image manipulation software, robot heads were presented either in a 20° left tilt, 10° left tilt, an upright, a 10° right tilt, or a 20° right tilt condition (angle lines were not visible for our participants).

2.1.3 Dependent Measures.

In study 1, we examined four dependent variables: human-likeness, attractiveness, eeriness, and dominance ascribed to the robot stimuli. To assess the first three of those criteria, we used the humanness, attractiveness and eeriness scales of the *uncanny valley indices* developed by Ho and MacDorman (2010). Each of the scales is composed of several semantic differential items that were rated on 7-point scales. *Human-likeness* was assessed with six pairs of attributes (artificial–natural; synthetic–real; inanimate–living; human-made–humanlike; mechanical–biological; without definite lifespan–mortal; Cronbach's $\alpha = 0.80$). *Attractiveness* judgments were measured with the help of five items (unattractive–attractive; ugly–beautiful; repulsive–agreeable; crude–stylish; messy–sleek: Cronbach's $\alpha = 0.88$). For the assessment of the robots' *eeriness*, we followed Ho and MacDorman's differentiation between two subcomponents; *eeriness-eerie* consisting of three items (reassuring–eerie; numbing–freaky; ordinary–supernatural: Cronbach's $\alpha = 0.74$) and *spine-tingling* consisting of five items (unemotional–hair-raising; uninspiring–spine-tingling; boring–shocking; predicable–thrilling; bland–uncanny: Cronbach's $\alpha = 0.76$).

In addition, we wanted to find out whether a manipulation of head tilt cues would determine how dominant a robot is perceived to be. For measuring *dominance* as a dependent variable, we presented eight bipolar adjective pairs, which were adapted from Mehrabian and Russell's "dominance" component of their semantic differential scale (7-point scale, controlled–controlling; important–awed; strong–weak; influential–influenced; guided–autonomous; submissive–dominant; bossy–respectful; cared for–in control: Cronbach's $\alpha = 0.77$; cf. Mehrabian & Russell, 1974; also see Bradley & Lang, 1994).

2.1.4 Procedure and Design.

Each participant was asked to rate his or her experience of only one randomly assigned robot picture. The pictures varied with respect to the robot shown (Telenoid, Kojiro or Asimo) and the head-tilt angle (upright position was slightly oversampled). No significant differences were found between the left-tilt versus right-tilt conditions. Thus, left- and right-tilt conditions with equivalent angles were collapsed. As a consequence, Experiment 1 followed a 3 (robot shown: Telenoid, Kojiro or Asimo) x 3 (head-tilt: 0°, 10° or 20°) between-subjects design.

2.2 Results and Discussion

We first inspected the zero-order correlations of the user ratings (Table 1). Human-likeness was positively related to eeriness-spine-tingling and to dominance. Positive correlations were further identified between both eeriness components (eerie and spine-tingling). A negative relationship was found between attractiveness and eeriness-eerie and between attractiveness and dominance.

		M	*SD*	1	2	3	4
1	Human-likeness	2.64	1.09				
2	Eeriness: eerie	4.29	1.25	.02			
3	Eeriness: spine-tingling	3.96	1.01	.30***	.49***		
4	Attractiveness	4.36	1.27	.09	-.61***	-.06	
5	Dominance	3.71	0.93	.21***	.37***	.35***	-.34***

Table 1. Zero-order correlations of the robot perceptions (Experiment 1). Notes. *** = $p < .001$

We predicted that an increase in head tilt could lead to a considerable increase in the human-likeness ascribed to the robots. Moreover, we were interested in the differential effect for the three robots examined. A between-subjects ANOVA with head tilt as the independent variable and human-likeness as the dependent variable revealed a significant main effect of head tilt, $F(2, 340) = 5.82$; $p = .003$; $\eta_p^2 = .033$ (see Figure 2). As expected, robots presented in the upright head position were experienced as less humanlike (M = 2.39; SD = 0.97) than robots presented with a 10° head tilt (M = 2.62, SD = 1.09), or robots presented with a 20° head tilt (M = 2.89; SD = 1.15). This result suggests that, on average, a minimal human behavioral cue conveyed by a robot can indeed make the robot appear to be more human, even if it remains otherwise identical. The robot itself yielded no main effect, $F(2, 340) = 2.17$; $p = .116$; $\eta_p^2 = .013$. We did, however, find a significant interrelationship between robot and head tilt, $F(4, 334) = 3.76$; $p = .005$; $\eta_p^2 = .043$. Simple main effects indicated that the head tilt yielded a significant effect on the human-likeness of the Telenoid (upright: $M = 2.18$; $SD = 0.90$; 10°-tilt: $M = 3.05$; $SD = 1.26$; 20°-tilt: $M = 3.06$; $SD = 0.93$), $F(2, 334) = 8.21$; $p < .001$; $\eta_p^2 = .047$, as well as a significant influence on Kojiro (upright: $M = 2.37$; $SD = 1.00$; 10°-tilt: $M = 2.56$; $SD = 1.04$; 20°-tilt: $M = 3.12$; $SD = 1.27$), $F(2, 334) = 4.63$; $p = .01$; $\eta_p^2 = .027$. Head tilt yielded no significant effect on the human-likeness of Asimo (upright: $M = 2.59$; $SD = 0.99$; 10°-tilt: $M = 2.35$; $SD = 0.91$; 20°: $M = 2.50$; $SD = 1.15$), $F(2, 334) = .52$, $p = .60$; $\eta_p^2 = .003$.

Next, we looked at *eeriness* ratings as a function of the robots' head postures. Our analyses showed different outcomes for the two sub-dimensions proposed by Ho and MacDorman (2010). The head tilts resulted in robot impressions that were significantly more *spine-tingling* for our participants, $F(2, 340) = 6.83$; $p = .001$; $\eta_p^2 = .039$. The head-tilted robots induced a stronger spine-tingling experience than the robots in an upright position (upright: $M = 3.71$; $SD = 1.15$; 10°-tilt: $M = 3.93$; $SD = 0.93$; 20°-tilt: $M = 4.21$; $SD = 0.92$). Moreover, we found a significant effect for the robot presented $F(2, 340) = 6.58$; $p = .002$; $\eta_p^2 = .037$ (Asimo: $M = 3.70$; $SD = 1.00$; Kojiro: $M = 4.03$; $SD = 0.77$; Telenoid: $M = 4.16$; $SD = 1.20$). The interaction between both predictors was trend-significant, $F(4, 334) = 2.22$; $p = .067$; $\eta_p^2 = .026$. A separate look at the robots showed that head-tilt affected spine-tingling scores of the Telenoid, $F(2, 334) = 7.68$; $p = .001$; $\eta_p^2 = .044$ (upright: $M = 3.64$; $SD = 1.23$; 10°-tilt: $M = 4.40$; $SD = 1.08$; 20°-tilt: $M = 4.45$; $SD = 1.12$) but not the scores of the other two robots (Fs < 2.99, ps $> .05$).

Regarding eeriness-eerie, the Telenoid was considered to be most eerie ($M = 5.22$; $SD = 1.17$), Asimo to be least eerie ($M = 3.67$; $SD = 0.97$), with Kojiro in between ($M = 4.09$; $SD = 1.10$), $F(2, 340) = 62.37$; $p < .001$; $\eta_p^2 = .268$. Head-tilt had no significant influence, *F*(2, 340) = 0.16; *p* = .856; η_p^2 = .001; neither did the head-tilt by robot-interaction, *F*(4, 334) = 1.09; *p* = .360; η_p^2 = .013.

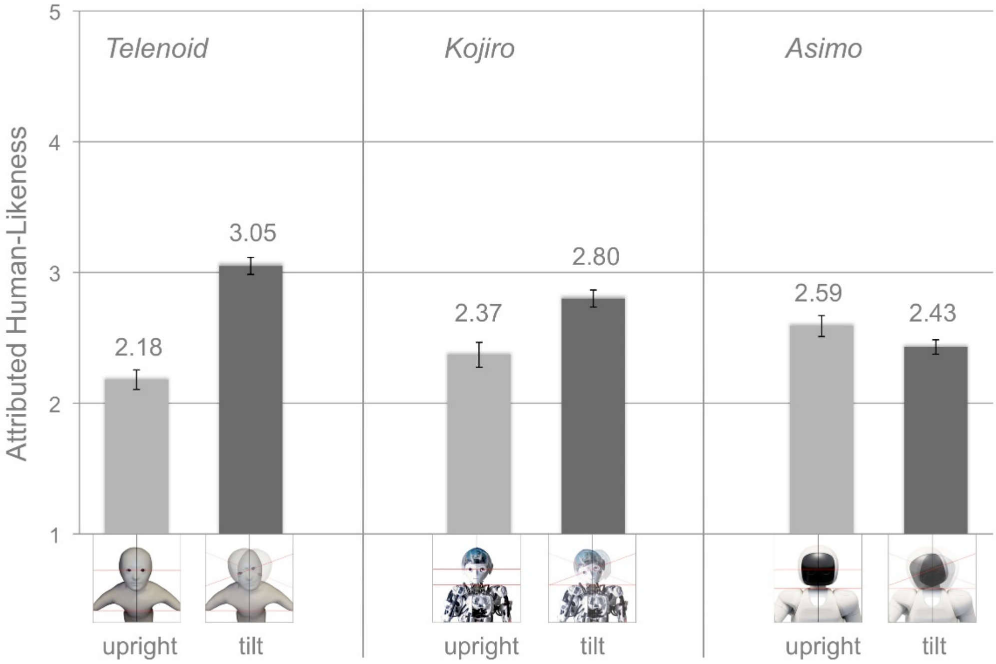

Figure 2. Results from Experiment 1 on human-likeness scores attributed to the three different robots by upright versus tilted head posture (-20°, -10°, +10°, and +20° collapsed).

A parallel ANOVA on *attractiveness* ratings yielded a large main effect of the robot displayed, *F*(2, 340) = 62.92; *p* < .001; η_p^2 = .27, with Asimo rated most attractive (*M* = 5.01, *SD* = 1.04), Kojiro in second place (*M* = 4.53, *SD* = 1.08), and Telenoid least attractive (*M* = 3.43, *SD* = 1.15). Regarding head tilt, descriptives point in the expected directions (upright: *M* = 4.17; *SD* = 1.34; 10°-tilt: *M* = 4.45; *SD* = 1.23; 20°-tilt: *M* = 4.45; *SD* = 1.23), but the main effect was non-significant, *F*(2, 340) = 1.80; *p* = .166; η_p^2 = .010; neither was the robot by head-tilt-interaction, *F*(4, 334) = 0.39; *p* = .814; η_p^2 = .005. Finally, no significant effect was discovered for a robot's head posture and the *dominance* ascribed to it, as indicated by a non-significant main effect *F*(2, 340) = 0.54; *p* = .583; η_p^2 = .003. The robots themselves yielded a significant effect, *F*(2, 340) = 4.91; *p* = .008; η_p^2 =

.028. Ascribed dominance was highest for the Telenoid (*M* = 3.94; *SD* = 1.03), followed by Asimo (*M* = 3.64; *SD* = 0.85), and Kojiro (*M* = 3.57; *SD* = 0.88). The interaction was non-significant, $F(4, 334) = 1.65$; $p = .161$; $\eta_p^2 = .019$.

In line with our assumptions, Experiment 1 indicated that head tilts increase the attributed human-likeness of robots. This main effect was revealed to be moderated by the type of robot, with a most pronounced increase of attributed human-likeness in the head tilt condition for the android robot Telenoid. Similar results were obtained for the spine-tingling subcomponent of eeriness. Both main effects are significant at the $p = .001$ level, i.e. below the significance level of $p =.01$, which would be advisable after Bonferroni alpha adjustment due to five dependent variables. Head tilt had no effect, however, on the eeriness-eerie, attractiveness and dominance scores.

We found it notable that the Telenoid, which we considered to be the robot with the highest anthropomorphic realism due to the organic shape of its body and its silicon skin, was rated as least humanlike in the upright head condition. Interestingly enough, when the Telenoid was presented with a tilted head, its human-likeness scores caught up or even surpassed the two other robot types. This result supports our initial assumption that perceived human-likeness of a robot is not only a function of its optical appearance, but also of its behavioral attributes. A fit between these two levels of impression might be of particular importance for creating a coherent overall image of an android robot.

In summary, we found support for the hypothesized influence of a minimal manipulation of head posture on the perceived human-likeness of a robot. However, based on the findings in Experiment 1, we decided to conduct another study to examine the concept of anthropomorphism in greater depth—namely, by testing for the attribution of distinct human nature traits. In contrast to the human-likeness scale from Experiment 1, which corresponds more with a general conception of aliveness and would be applicable to animals or plants as well, we included interpersonal warmth as a new variable in the follow-up experiment. Moreover, as we found only small and non-significant differences in general attractiveness ratings between the head-tilt conditions in Experiment 1, we decided to integrate a more specialized cuteness measure in Experiment 2.

3. EXPERIMENT TWO

3.1 Method

3.1.1 Participants.

253 participants (57% male) from the US took part in the follow-up experiment. As in Experiment 1, the participants were recruited with the help of Mechanical Turk, and they received $ 0.25 as compensation. 37 participants were excluded from further analysis (26 because they knew of the robot beforehand, 8 reported their language skills to be insufficient, and 3 reported that they didn't answer the survey completely truthfully). Thus, our final sample consisted of 216 participants with a mean age of 31.39 years (SD = 10.33; range from 18 to 67 years).

3.1.2 Stimuli and Dependent Measures.

As in Experiment 1, photos of the robots Asimo, Kojiro, and Telenoid were presented. The photos were identical to the stimuli of Experiment 1 with the exception that there was no 10°-tilt condition in Experiment 2. Thus, the photos displayed the robot either in upright position, with a pronounced left-tilt (-20°) or with a pronounced right-tilt (+20°). To measure *interpersonal warmth*—a trait that usually is considered as uniquely human—we asked participants to rate the portrayed robot in terms of five characteristics on 7-point scales ("How helpful; [sensitive]; [polite]; [generous]; [humble] do you expect [this robot] to be?", cf. Cuddy, Fiske, & Glick, 2006; Eyssel & Kuchenbrandt, 2012). A reliable index with Cronbach's $\alpha = 0.88$ could be constructed. In order to score the perceived *cuteness* of the robot shown, participants answered two questions that were taken from studies on baby schema effects, again on 7-point scales ("How cute do you find this robot?"; "How much does this robot make you feel that you would like to care for it?"; cf. Glockner, Langleben, Ruparel, Loughead, Gur & Sachser, 2009). The items formed an index with good reliability, as indicated by Cronbach's $\alpha = 0.88$. Warmth and cuteness judgments were positively correlated, $r(236) = .38$, $p < .001$.

3.1.3 Procedure and Design.

As was the case in Experiment 1, each participant was requested to rate his or her experience regarding the picture of one randomly assigned robot portrait. No significant differences emerged between leftward versus rightward tilts. Thus, the two tilt conditions were collapsed. As a consequence, Experiment 2 followed a 3 (robot shown: Telenoid, Kojiro or Asimo) x 2 (head tilt: upright position or 20°-tilt) between-subjects design.

3.2 Results and Discussion

After a significant effect of head tilt cues on attributed human-likeness was detected in Experiment 1, we included a more far-reaching measure for anthropomorphic inferences in Experiment 2. The variable *interpersonal warmth* clearly goes beyond perceptions of sheer lifelikeness because the concept is focused on the attribution of distinct human nature traits. Overall, only a small non-significant difference could be found between the perceived interpersonal warmth of a robot in the tilt conditions (M = 3.84, SD = 1.39) and the upright condition (M = 3.59, SD = 1.52), $F(1, 230) = 1.21$; p = 0.272; $\eta_p^2 = 0.005$. The main effect of the robots was significant $F(2, 230) = 3.73$; p = .025; $\eta_p^2 = 0.031$, with Asimo (M = 4.03, SD = 1.44) eliciting greater warmth scores than Kojiro (M = 3.74, SD = 1.42) and Telenoid (M = 3.53, SD = 1.41). The interaction between robot and head tilt was not significant, $F(2, 230) = 1.83$; $p = .163$; $\eta_p^2 = .016$. For exploratory purposes, we nonetheless inspected the head tilt effects for all three robots separately. A significant simple main effect was revealed for the warmth ratings of the android Telenoid (upright: *M* = 3.00, *SD* = 1.34; tilted: *M* = 3.76, *SD* = 1.38), $F(1, 230) = 4.66$; $p = 0.032$; $\eta_p^2 = 0.020$. For the other two robots, no such effect could be found, *F*s < 0.23; *p*s > .60.

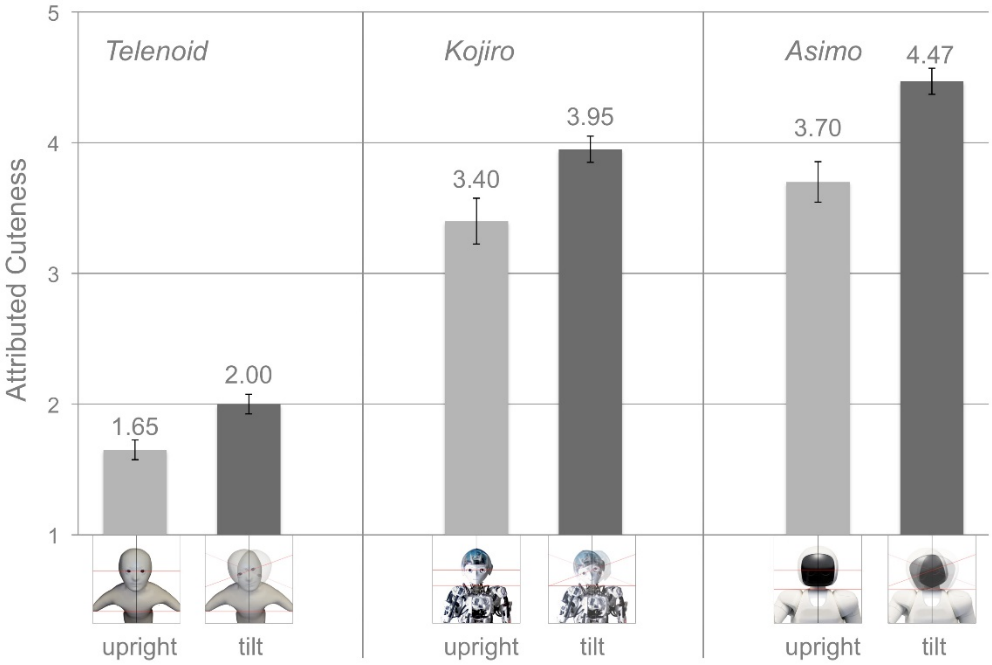

Figure 3. Results from Experiment 2 on cuteness ratings of the three different robots by upright versus tilted head posture (-20° and +20° collapsed).

In line with our expectations, an ANOVA revealed a main effect of the head tilt on the perceived *cuteness* of the robots (Figure 3). On average, the robot portrayals were rated significantly cuter when exhibiting a tilted head (*M* = 3.50, *SD* = 1.74) than an upright head (*M* = 2.89, *SD* = 1.63), $F(1, 230) = 7.65$; $p = .006$; $\eta_p^2 = 0.032$. Furthermore, robot type was a significant and strong predictor of cuteness, $F(2, 230) = 48.07$; $p < .001$; $\eta_p^2 = 0.295$, with Asimo scoring highest (*M* = 4.27, *SD* = 1.51), followed by Kojiro (*M* =

3.78, *SD* = 1.59), and Telenoid (*M* = 1.89, *SD* = 1.02). The interaction between both independent variables was not significant, $F(2, 230) = 0.38$; $p = .683$; $\eta_p^2 = .003$.

Recapitulating the findings of Experiment 2, the manipulation of the robots' head postures did not result in a significant general effect on how much interpersonal warmth was attributed. An explorative look nonetheless indicated a trend that was in line with the findings in Experiment 1: an increase of perceived warmth as a function of head tilt was particularly pronounced again in the case of the android robot Telenoid, whereas effects for both other robot types were insignificant. In line with our assumptions, we found a significant positive relationship between head tilt and cuteness ratings in Experiment 2.

4. GENERAL DISCUSSION

From the gynoid *Maria* that starred in Fritz Lang's 1927 film *Metropolis* to Isaac Asimov's robot stories or *Star Trek*'s commander *Data*, humanlike automata have long played major roles in science fiction. For the first time in history, we are now approaching an era in which humanoid and android robots might no longer just be fictional characters, but also start to appear in real-life situations, e.g. as assistants in households or medical care. Therefore, the study of human-robot relationships and particularly the factors that drive a user's perception, experience, acceptance, and rejection of robotic interaction partners is a field of growing relevance in psychology.

In this paper, we have argued that user impressions of human-likeness are not only a function of a robot's visual appearance (e.g. how realistically it imitates the human form). To a considerable extent, they might also depend on behavioral attributes exhibited by the robot. We hypothesized that even a tiny manipulation of a nonverbal communication cue represented in photographic portrayals of android and humanoid robots would lead to significant effects on their perception by human observers. To summarize the results of our two online experiments, robots that exhibited a head tilt were found to be perceived as significantly cuter, more human-like and also more spine-tingling by our participants. For the latter two variables, robot type turned out to serve as a moderator. Head tilt yielded most pronounced effects on human-likeness and spine-tinglingness for the android robot Telenoid. In contrast, our manipulation of head posture did not influence how eerie, dominant, attractive, or warm-natured the robots were rated collectively; neither could we find significant interaction effects. However, regarding the attribution of warmth—an indicator for the attribution of human nature traits—descriptive results point to a similar pattern as shown for human-likeness. Head tilt significantly increased the warmth ratings for the Telenoid, but not for the two other robots (which were rated as more warm-natured overall).

Intriguingly, it was precisely the robot that mimics human appearance in a nearly photorealistic way that was generally perceived as less human-like and less warm-natured than the two other more mechanical-looking robots. A possible explanation for this could lie in different frames of reference that were automatically activated for the different types of robots. Participants might have (unconsciously) based their evaluations of human-likeness on a comparison with real humans in the case of the android Telenoid, whereas the less realistic humanoids Kojiro and Asimo might not have triggered such a reference. However, scores for perceived human-likeness and warmth of the Telenoid greatly increased when it was presented with a tilted head. This might be due to a higher perceived coherence between humanlike looks and humanlike behavior in the experimental conditions. A harmonious balance between visual appearance and behavioral features of a robot has been described as an important determinant for user acceptance (Goetz, Kiesler, & Powers, 2003; Minato, Shimada, Ishiguro, & Itakura, 2004) and might be particularly relevant for androids (cf. Mori, 1970).

It is noteworthy that the results for eerieness-eerie and eeriness-spine-tingling, which are both components of the eeriness construct of the uncanny valley scales (Ho & MacDorman, 2010), diverged as a function of head tilt. Whereas there was no effect found for the eeriness-eerie scores, ratings for eeriness-spine-tingling were significantly higher in the head tilt than in the upright conditions. Spine-tinglingness implies that something is thrilling, exciting, and not at all boring for the recipient. In contradistinction to pure eeriness, it therefore has a partially positive connotation.

Contrary to our assumptions, head tilt did not lower dominance perceptions. This is not in line with previous research on interpersonal impression formation, where head tilting repeatedly was associated with shyness and submissiveness (Costa, Menzani, & Ricci Bitti, 2001; Goffman, 1976; Henley, 1977; Morris, 1977). Possibly, our frontal stimuli portraits gave an impression of gaze fixation by the robots, which would have counteracted the meaning of head tilt. Gaze fixation has been linked to dominance and expression of power in the literature (cf. Costa, Menzani, & Ricci Bitti, 2001). Aside from that, our measure for dominance perception might have corresponded less with participants' conception of dominance than autonomy (based on Mehrabian & Russell, 1974, adjective pairs such as "autonomous vs. guided" or "controlled vs. controlling" were part of our scale).

User perceptions in our two experiments were more strongly affected by robot type than by head posture. The visual design of a robot type is an important factor but, as our research shows, not the only one that determines user perceptions. Given that user perceptions are subject to a number of factors (including stable individual differences on the users' part or situation-specific factors), it is notable that a minimal intervention such as the change of a static head posture in our experiments can have a relevant impact on anthropomorphic inferences by human observers and other related variables.

This research adds to the social psychological literature on nonverbal behavior and impression formation, and extends its scope to human-robot interaction. It further adds to the corpus of work on the effects of humanlike virtual avatars (e.g. Bente, Krämer, & Eschenburg, 2008; Cassell & Thórisson, 1999). Aside from that, our findings provide many new and applicable insights for robotics as well as for the marketing of artificial agents. Nonverbal communication is a very powerful tool for the achievement of intersubjective understanding. Empirical results on the occurrence and the meaning of behavioral cues in interpersonal communication can play a relevant role in improving future interactions between humans and humanoid or android robots.

In addition to the contributions made by our research, its limitations and prospects for future inquiry deserve attention. First, in the frame of our experiments, we concentrated on the meaning of lateral head tilts and had no chance to examine the role of nonverbal head posture cues apart from that. Studies on human-human interaction have reported associations between backward head tilt and pride (cf. Tracy & Robins, 2004) as well as downward head tilt and shame (Izard, 1971; Keltner, 1995), to name just two examples. Which role such other nonverbal cues play in the perception of robots therefore remains an open question for further exploration.

Second, we did not focus on combinations of lateral head tilt with other behavioral features, e.g. gaze directions or facial expressions. In natural social settings, a nonverbal cue usually occurs and is interpreted in interplay with other behavioral attributes. Based on manipulations of the famous Mona Lisa portrait, Frey, Hirsbrunner, Florin, Daw, and Crawford (1983) have shown, for instance, that observers' impressions of the depicted lady's smile changed with the posture of her head. Future studies could take up this point or even investigate interactive effects of nonverbal and verbal cues by robots. As Ekman and colleagues (1974, 1980) suggested, a discrepancy between spoken expressions and nonverbal behavior can lead to a particularly disturbing experience.

A third limitation of this research is that we did not explore cultural differences. All of the participants in our experiments resided in the US, and to a very great extent reported "Caucasian" as their main ethnic identification. Possibly there are diverging meanings of head tilt in different regions of the world, and cultural differences may play a crucial role in many fields of human-robot interaction.

Fourth, the potential limitations arising from the use of static photo portrayals need to be discussed. In terms of external validity, a field experiment incorporating real-life interactions with robots would have been advisable. Moreover, with a functional robot actually present, the role of head tilting could be examined in motion, including temporal and procedural aspects. Nevertheless, we think that our results are transferable to the lived reality of a majority of the population. Today, most people have not confronted a real humanoid or android. Even if such encounters are on the rise, mass media and the Internet are still where most recipients experience their first contact with robots or—more precisely—see pictures of them. Alas, people often form their first impressions of robots on the basis of photos or videos. For this reason, our research might be of particular relevance for representations of robots in the media or in marketing.

Finally, the development of humanlike robots gives rise to many ethical questions that are beyond the scope of this research project. This includes whether or not it is generally desirable (or acceptable) to mimic human beings by means of technology as well as whether the fields of application that are intended for such robots are indeed suitable. These are questions of high social relevance, which both the scientific community as well as the public will need to face.

5. CONCLUSION

In the near future, robots may assist humans in hospitals, retirement facilities and their homes. Our research shows that androids and humanoids are perceived to be more human when they engage in head tilting, an important non-verbal cue in human nonverbal communication. Roboticists and robot marketers may consider head tilts to improve the experience of these new technologies. But as robots become more human, new ethical questions will have to be considered.

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