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Now you feel it, now you don't: How observing human-robot interactions and human-human interactions can make you feel eerie

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Abstract

Robots seemingly in possession of an experiential mind, as well as humans allegedly incapable thereof, have been reported to elicit feelings of eeriness in their perceivers. The current work re-examined this claim, asking participants to rate both robots and humans in various social situations regarding their mind capacities (e.g., emotional capability, intelligence), non-mind qualities (e.g., animacy, usefulness), and overall appeal (e.g., eeriness, likeability). It was found that feelings of eeriness towards both targets formed a distinct emotional response that was separable from simple dislike. Yet, unexpectedly, eeriness towards both targets intensified, the less they were seen as possessing a typical human mind. For robots, however, this association was less consistent. Moreover, eeriness towards robots, but not towards humans, was most strongly predicted by a lack of perceived usefulness. These results indicate that mind attributions affect people's attitudes towards each other more strongly than their attitudes towards humanoid robots.

Keywords: impression formation, person perception, robot companion, social robotics, Uncanny Valley

Biographical Note

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Now you feel it, now you don't: How observing human-human interactions and human-robot interactions can make you feel eerie

In recent years, robotic agents have begun to provide domestic, educational, and medical support to humans in everyday settings (Breuer et al., 2012; Broadbent, Stafford, & MacDonald, 2009; Reiser, Jacobs, Arbeiter, Parlitz, & Dautenhahn, 2013; Robins, Dickerson, Stribling, & Dautenhahn, 2004). In light of these developments, understanding human responses towards so-called companion robots has become a pressing issue of investigation (Amirabdollahian et al., 2013; Dautenhahn, 2007; Hindriks, Neerincx, & Vink, 2012; Mavridis et al., 2012; Nourbakhsh, 2013). Despite its contemporary relevance, scientific inquiry on the topic dates back over forty years ago. As early as in 1970, the Japanese scientist Masahiro Mori hypothesized that robots would elicit increasingly positive feelings, the higher their human likeness, until they reached a level of realism that would make perceivers uncomfortable. This discomfort would only disappear, Mori argued, once robots would fully resemble their human counterparts.

Since Mori's original hypothesis, many researchers have tried to understand the occurrence of discomfort towards robots. While some have studied the *likeability* of robots (e.g., Bartneck, Kanda, Ishiguro, & Hagita, 2009), others have focused on the experience of *eeriness* in their presence (e.g., Hanson, 2006). Eeriness towards robots has frequently been defined as a sense of strangeness and disquiet that is accompanied by feelings of fear, anxiety, and/or disgust (Cheetham, Suter, & Jäncke, 2011; Ho, MacDorman, & Pramono, 2008). As robots may occasionally be disliked without appearing eerie, however, some scientists have even begun to study both likeability and eeriness in concert (MacDorman & Entezari, 2015; Zlotowski, Sumioka, Nishio, Glas, Bartneck, & Ishiguro, 2015). Importantly, the scientific attempt to understand these different aspects of discomfort towards robots is fueled by observations that both may reduce people's willingness to engage with or approve of them (Syrdal, Dautenhahn, Koay, & Walters, 2009; Young, Hawkins, Sharlin, & Igarashi, 2009).

Based on these concerns, engineers around the world have tried to reduce discomfort around robots by optimizing their human-like shape or way of movement (e.g., Piwek, McKay, & Pollick, 2014; Prakash & Rogers, 2015; Rosenthal-von der Pütten & Krämer, 2014; Thompson, Trafton, & McKnight, 2011; Walters, Syrdal, Dautenhaun, te Boekhorst, & Koay, 2008). Less work, in contrast, has examined the effects of robots' psychological human likeness by manipulating their (alleged) mental abilities (e.g., Breazeal & Scassellati, 1999; Cangelosi, 2010; Dominey & Warneken, 2011; Ge & Han, 2008; Kamide, Takubo, Ohara, Mae, & Arai, 2014; McShane, 2014; Sytsma & Machery, 2010; Zlotowski, Bartneck, & Strasser, 2014). Yet, some of the latter studies suggest that discomfort arises and intensifies specifically when robots are perceived as possessing a humanoid mind (Gray & Wegner, 2012; Waytz & Norton, 2014).

The current project further elucidates this fascinating finding, building upon the assumption (cf. Gray, Gray, & Wegner, 2007; Robbins & Jack, 2006) that human minds are generally expected to have the capacity to feel (i.e., *experience*) and to think (i.e., *agency*). During social interactions, people frequently judge each other's experiential and agentic capacities in order to understand the invisible motivations that may underlie visible human behavior (Jack & Robbins, 2012; Knobe & Prinz, 2008; Waytz, Gray, Epley, & Wegner, 2010). But even encounters with non-human entities, such as objects or robots, can elicit so-called mind attributions (Chammat, Foucher, Nadel, & Dubal, 2010; Epley, Akalis, Waytz, & Cacioppo, 2008a; Krach et al., 2008; Meltzoff, Brooks, Shon, & Rao, 2010). The more a robot acts in a goal-directed manner, for instance, the more it may be seen as possessing a human-like mind, especially when perceivers long for a sense of predictability and control (Fink, 2012; Vogeley & Bente, 2010; Waytz, Gray, Epley, & Wegner, 2010; Zlotowski, Proudfoot, Yogeeswaran, & Bartneck, 2015).

But what evidence is there to suggest that attributing human-like minds to robots may result in discomfort towards them? The psychologists Gray and Wegner (2012) recently demonstrated that a humanoid robot compared to a mechanical-looking one was not only seen as more capable of emotions, but also as eerier. In addition, their work revealed that the same mechanical looking super-computer was perceived as eerier, when it was described as possessing an experiential rather than an agentic mind. Based on these findings, the authors concluded that feelings of eeriness towards robots do not only depend on whether a mind is perceived to be present, but also on the type of mind a robot seems to possess. These comprehensive claims deserve further empirical consideration.

First and foremost, as acknowledged by the authors themselves, it is of pivotal importance to replicate the original findings with a broader array of robots which “provide nuanced differences in [mind] capacities” (p. 129). Second, the specificity of the proposed link deserves further investigation. Researchers interested in robot-related eeriness have traditionally asked perceivers to judge robots more broadly, for instance, regarding their human likeness, animacy, or usefulness (cf. Bartneck, Kulić, Croft, & Zoghbi, 2009; Ho & MacDorman, 2010; Lee, Lau, & Hong, 2011). Are these non-mind judgments less relevant for predicting feelings of eeriness than the newly proposed mind attributions? Third, do mind attributions exclusively impact feelings of eeriness or do they affect a robot’s general appeal, such that seemingly mind-possessing robots are also perceived as less likeable and unsafe (cf. Ho & MacDorman, 2010; Syrdal, Nomura, & Dautenhahn, 2013)? Fourth, do mind attributions trigger feelings of eeriness towards robots per se or does the effect dependent on whether perceivers find such attributions unbelievable based on their preconceived notions about robots (Bartneck, 2013; Gray & Wegner, 2012; Kaplan, 2004)? Finally, it remains to be explored to which degree the link between mind attributions and feelings of eeriness may also depend on characteristics of the perceiver. For instance, people highly familiar with robots may hold more positive views about seemingly agentic robots (e.g., robots that guide, direct, and motivate subordinates) than those less familiar with them (Ju & Takayama, 2011). To address these questions, we conducted two studies that examined the patterns of associations between perceived mind capacities, non-mind qualities, and target evaluations in response to sociable robots.

Study 1

Considering that present day robots are far from showing truly human-like social abilities, we adopted a ‘life as it could be’ approach to explore the cognitive principals that govern contemporary attitudes towards companion robots (cf. Harder, Polani, & Nehaniv, 2010; Walters et al., 2011). Thus, a series of images portraying dyadic interactions between humans and robots was created and presented in an online survey (see Figure 1A). It was predicted that displaying the same type of robot but in a wide range of social scenarios and in numerous communicative postures would induce varying impressions regarding its mind capacities (Beck, Stevens, Bard, & Caǹamero, 2012; Cohen, Looije, & Neerincx, 2014; Erden, 2013; Le, Hanoune, & Pelachaud, 2011; Mitchell & Hamm, 1997; Sciutti et al., 2013; Shaw-Garlock, 2009; Tomasello, Carpenter, Call, Behne, & Moll, 2005). By experimentally inducing fluctuating impressions of mind capacities across the different interactions, we aimed to address the following questions: Are feelings of eeriness and mind attributions linked in a nuanced manner (Q1)? Does the link occur for both attributions of experience and attributions of agency (Q2)? Are feelings of eeriness more closely associated with mind attributions than with non-mind judgments (Q3)? Do changes in attributions of mind and non-mind judgments specifically affect feelings of eeriness or do they generalize to reports of likeability and perceived safety (Q4)? Is there an association between participants' mind attributions, their non-mind judgments and the degree to which they find that a robot acts in an (un)believable manner (Q5)? Finally, do perceiver characteristics modulate the link between mind attributions and feelings of eeriness towards robots (Q6)?

Method

Participants

155 valid survey replies were obtained. Participants were between 18 to 54 years of age (*M* = 29.7 years, *SD* = 8.39; 4 non-responders). The sample comprised 51.0% males and 47.7% females (2 non-responders). Participants were of a diverse national background (42 different nationalities, 5 non-responders) and had a high proficiency in English (1 non-responder; 12.9% native English speakers, 78.7% proficient non-native English speakers, 7.7% non-proficient non-native English speakers). They reported a range of educational qualifications (9.7% high-school graduates, 2.6% technical school graduates, 15.5% had attended some college, 23.9% were college graduates with bachelor degrees, 29.0% were college graduates with master degrees, 17.4% held a doctorate degree; 3 non-responders). All participants provided informed consent before survey completion and followed a study protocol approved by the Institutional Review Board (IRB) of New York University Abu Dhabi (NYUAD).

Procedure

Participants were recruited via various internet forums (e.g., http://psych.hanover.edu/research/exponnet.html; http://beta.in-mind.org/online-research; http://www.wexlist.net; http://www.dubizzle.com), Facebook groups (e.g., *Psychological*

Research on the Net), and email lists (such as departmental email lists). All announcements invited English speaking individuals of at least 18 years of age to participate in an online survey (via www.qualtrics.com) in exchange for a prize draw (€20.00). After reading about the study's goal (i.e., to learn about people's responses to human-robot interactions), participants could give their consent to participate by ticking a dedicated box. They were then asked to rate a set of forty human-robot interactions (HRI) in randomized order. They were also asked to consider each robot as a unique exemplar throughout the study by judging each interaction without being influenced by the preceding images.

In order to elicit a wide range of mind attributions, images of forty different HRI were used. The interactions ranged from primarily instrumental exchanges (e.g., giving directions) to largely affective exchanges (e.g., giving a hug), with some interactions combining instrumental and affective aspects (e.g., donating money to a beggar) or lacking either (e.g., having a chat). Importantly, all interactions had previously been found to engage neural networks of person perception and impression formation in the human brain, confirming their ecological validity (cf. Wang & Quadflieg, 2015). For each interaction, participants rated a robot's overall appeal by rating the degree to which each robot appeared likeable (=1) vs. not likeable (=7), reassuring vs. eerie, safe vs. unsafe, as well as believable vs. not believable (cf. Bartneck et al., 2009; Ho & MacDorman, 2010). In addition, participants provided two non-mind judgments by rating whether each robot appeared animate vs. inanimate and human-like vs. machine-like (cf. Bartneck et al., 2009). Finally, participants provided two mind attributions by rating the degree to which each robot appeared intelligent vs. unintelligent (to assess agency) and able to have emotions vs. unable to have emotions (to assess experience; based on Bartneck et al., 2009; Wojciszke & Abele, 2008). All rating scales appeared in randomized order below each image. Participants were only able to proceed to a new image once they had completed all scales.

Upon completion of the rating task, participants were asked about their familiarity with robots, proficiency in English, demographics (i.e., sex, age, nationality, education), and their distraction during survey completion (in this order). Familiarity with robots was assessed on a 6-item scale asking participants to rate the extent to which each of the following statements applied to them (1 = *not at all* to 7 = *very much*): '*I have technical knowledge about robots'*, '*I am familiar with robots as toys*', '*I am familiar with robots at the workplace*', '*I am familiar with robots at museums*', '*I am familiar with robots in books/magazines/comics*', '*I am familiar with robots in movies/TV series*'. Proficiency in English was probed by asking 'Is English your native/first language?' with three possible responses: 1 = *Yes*, 2 = *No, but I am a proficient English speaker*, 3 = *No, and I sometimes struggle to understand it*. Education was assessed by asking participants to choose 'their highest degree or highest level of schooling completed at this time [1= *no formal qualifications*, 2 = *less than high school graduate*, 3 = *high school graduate*, 4 = *technical school*, 5 = *some college*, 6 = *college graduate (Bachelor)*, 7 = *college graduate (Master)*, or 8 = *doctorate*]. Distraction was probed by asking how focused participants were during survey completion (1 = *I was focused on the survey and did not get distracted*, 2 = *I was focused on the survey but got occasionally distracted*, 3 = *I got repeatedly distracted*, or 4 = *I did not take the survey seriously. Please consider disregarding my data*).

Data Screening and Preprocessing

The survey was visited 429 times. All data were reviewed according to the following criteria: Only participants of at least 18 years of age who rated the entire set of forty interactions and who refrained from asking us to disregard their data by the end of the survey (*n* = 169) were considered for analyses. We also excluded participants (*n* = 14) who provided the exact same judgment on at least one dimension across the entire set of interactions (e.g., who rated the perceived intelligence of all targets as 1). The latter criterion ensured that a) our participants used all dimensions to differentiate among the presented interactions and b) that within-person associations between the different dimensions of judgments could be computed for all participants. Thus, a final sample of 155 responses was obtained. In a next step, we computed each participant's average familiarity-with-robots score. Before averaging the replies from the corresponding items, a missing values analysis was run. One participant failed to complete the familiarity-with-robots scale and four participants skipped one of the relevant items. Missing values on single items were replaced with the respondents' average score derived from their completed items. A reliability analysis for the familiarity scale demonstrated high internal consistency (α = .88). Descriptive statistics revealed a wide range in familiarity with robots in the current sample (*M* = 3.67, *SD* = 1.61, *Min* = 1.00, *Max* = 7.00; 1 non-respondent).

Results

We first aggregated all data across individuals and interactions (see Table 1, column 2). Keeping in mind that lower scores reflect enhanced mind attributions (i.e., emotional capability and intelligence scores), these averages revealed that the interactions induced reliable mind attributions (i.e., as they generally fell below the scales' midpoints). We then aggregated all data across individuals only, computing the average rating for each interaction. This analysis showed that, as intended, mind attributions varied substantially across the different interactions (see Table 1, columns 3 and 4 for minimum and maximum values). Subsequently, patterns of associations between perceived mind capacities, non-mind qualities, and ratings of appeal were analyzed through a series of multi-level regressions (level 1: number of interactions per perceiver, level 2: number of perceivers) to account for variance in ratings within and across individuals in a non-aggregated manner (Raudenbush & Bryk, 2002).

Before investigating the associations of interest, a series of no-predictor models was specified to partition the variance of each outcome variable (i.e., of eeriness, likeability, safety, and believability) for each interaction *i* in individual *j* (Y_{ij}) into its within-unit and between-unit components (Heck, Thomas, & Tabata, 2014). The four corresponding models provided a mean score for each outcome variable across individuals and interactions (i.e., the fixed-effect value for the intercept $\gamma_{00,}$ as displayed in Table 1) and estimated the between-interaction variation in intercepts (u_{0j}), the between-individual variation in intercepts (v_{0j}), and residual within-individual error variance (ε_{ij}). It was found that for all four outcome variables significant variation emerged across interactions (Wald *Z* for eeriness: 4.28; likeability: 4.12; safety: 4.26; believability: 4.30; all *ps* < .001), across individuals (Wald *Z* for eeriness: 8.48; likeability: 8.41; safety: 8.50; believability: 8.42; all *ps* < .001), and within individuals (all Wald *Zs* = 54.80, all *ps* < .001), justifying the multi-level regression approach.

In line with our main question of inquiry, we then specified a within-person predictor model with eeriness as the outcome variable and the grand-mean centered (cf. Enders & Tofighi, 2007) predictor variables emotional capability (W1) and intelligence (W2). The model estimated two random effects (the interaction intercept, the individual intercept) as well as three fixed effects (the overall intercept, W1, and W2), adopting a default covariance structure (variance components, VC). It was found that robots appeared less eerie (i.e., more reassuring), the more intelligent [*ß* = .19, *SE* = .01, *t*(6189.29) = 12.81, *p* < .001] and the more emotionally capable [*ß* = .07, *SE* = .01, *t*(6147.12) = 5.28, *p* < .001] they seemed [with γ_{00} = 3.39, SE = .13, $t(95.39) = 27.22$, $p < .001$]. Including these two mind capacity predictors reduced the variance in eeriness across (Wald *Z*: 8.43; $p < .001$) as well as within individuals (Wald *Z*: 54.79; $p < .001$), resulting in enhanced model fit, such that Schwarz's Bayesian Criterion (BIC) was reduced for the within-person predictor model (BIC1 = 21100.94) compared to the no predictor model (BIC0 = 21368.41).

In a next step, we further included the traditionally used non-mind ratings as within-person predictors. Thus, we specified a model with eeriness as the outcome variable and the grand-mean centered predictor variables emotional capability (W1), intelligence (W2), animacy (W3) and human-likeness (W4). This time, the model estimated two random effects (the interaction intercept, the individual intercept) as well as five fixed effects (the overall intercept, W1, W2, W3 and W4). In this combination, ratings of perceived intelligence, animacy, and general human likeness, but not ratings of emotional capability, predicted feelings of eeriness towards robots (see Table 2). Including the non-mind predictors enhanced model fit further (BIC2 = 21005.38), reducing the variance to be explained across (Wald *Z*: 8.41; $p < .001$) and within individuals (Wald *Z*: 54.78; $p < .001$).

To compare the observed patterns of association across all outcome variables of interest, the latter model was also computed for ratings of safety, likeability, and believability (see Table 2). For safety, a similar pattern of associations as for eeriness was observed. For likeability, however, all four within-person predictors explained variance in the outcome variable. In other words, robots were considered more likeable, the more animated, human-like, intelligent, and the more emotionally capable they seemed. Finally, robots were considered more believable, the more animate and intelligent, but the less emotionally capable they seemed. All three within-person predictor models reduced the variance to be explained across individuals (Wald *Z* for safety: 8.45; likeability: 7.99; believability: 8.34; all *p*s < .001) and within individuals (Wald *Z* for safety: 54.78; likeability:

54.77; believability: 54.78; all *p*s < .001), showing enhanced data fit compared to their corresponding no predictor models (safety: BIC0 = 20794.51, BIC2 = 20476.93; likeability: BIC0 = 20605.31, BIC2 = 19034.19; believability: BIC0 = 22208.76, BIC2 = 22128.98).

Finally, we conducted a set of regression analyses with eeriness as the outcome variable and additional between-person predictors. First, we included a person's age (X1), requiring the model to estimate six random effects (the interaction intercept, the individual intercept, and the slopes of W1, W2, W3, and W4 varying across individuals) as well as ten fixed effects, including the cross-level interactions of interest (the overall intercept, W1, W2, W3, W4, X1, X1*W1, X1*W2, X1*W3, X1*W4). Neither a main effect of age, nor any interaction effects with this variable emerged. Similarly, no significant main or interaction effects emerged for participants' level of education. However, a significant gender by animacy interaction was observed, signaling that the association between ratings of animacy and feelings of eeriness was significantly stronger in females than in males. Moreover, entering participants' grand-mean centered familiarity with robots as an additional between-person predictor (X2) revealed a significant main effect (but no interaction effects), revealing that enhanced familiarity with robots was accompanied by reduced feelings of eeriness towards them. Similarly, entering participants' grand-mean centered self-reported proficiency in English (X3) revealed a significant main effect (but no interaction effects), suggesting that enhanced proficiency was accompanied by higher ratings of eeriness. The parameter estimates of our final model, including the nine fixed effects of relevance (the overall intercept, W1, W2, W3, W4, X1, X2, X3, X1*W3) are displayed in Table 3. Inclusion of the relevant between-person predictors enhanced model fit further (BIC3 = 20031.18), again reducing the variance in eeriness across (Wald Z = 7.83, p <. 001) as well as within individuals (Wald Z = 52.53, p < .001).

Discussion

In our first study participants were asked to rate the same type of robot in various social scenarios regarding its mind capacities, non-mind qualities, and overall appeal. Associations between the obtained ratings were analyzed based on theoretically derived questions of interest. It was found that feelings of eeriness were linked to mind attributions in a nuanced manner (Q1). Specifically, robots appeared eerier, the less emotionally capable and the less intelligent they seemed. Thus, nuanced associations emerged for both types of mind attributions (Q2). When mind attributions were considered in concert with traditional non-mind judgments, however, attributions of emotional capability failed to make a unique contribution to predicting eeriness. Additionally, ratings of animacy performed equally well as ratings of intelligence at predicting feelings of eeriness (Q3). The same pattern of associations as for feelings of eeriness emerged for evaluations of (a robot's lack of) safety. Evaluations of (dis)likeability, in contrast, behaved slightly differently, signaling that the feelings of eeriness did not simply capture broad negative affect (Q4). For instance, emotional capability remained a significant predictor of likeability, but not of safety or eeriness, beyond ratings of intelligence, animacy, and human likeness.

The data further revealed systematic associations between mind attributions, non-mind judgments and perceivers' expectations (Q5). A robot's behavior was considered more believable, the more animate and intelligent, but the less emotion-related it seemed. Phrased differently, increases in perceived emotional capability simultaneously enhanced a robot's likeability, but reduced its believability. Finally, examining the impact of inter-individual differences across perceivers (Q6) revealed that people reported more eeriness, the less familiar they were with robots. In addition, women's compared to men's feelings of eeriness were more affected by a robot's apparent lack of animacy.

But are the obtained findings specific to robotic targets after all? Although feelings of eeriness are usually studied in the context of robots, initial evidence suggests that the experience can also be triggered by conspecifics (Krämer, von der Pütten, & Eimer, 2012; Kuhlmeier, Bloom, & Wynn, 2004). In particular, people who seem to have an atypical human mind have been found to elicit eeriness (Gray & Wegner, 2012). It has therefore been recommended to also explore eeriness in response to humans (Zlotowski, Proudfoot, et al., 2015). To address this concern, we repeated our study including human-human interactions (HHI).

Study 2

Study 2 investigated to which extent the observed associations between mind capacities, non-mind qualities, and target evaluations as observed for HRI would generalize to HHI. Additionally, in order to address common concerns with online data (cf. Evans & Mathur, 2005), study 2 was conducted in a laboratory setting. Adopting a lab-based approach also allowed us to manipulate participants' psychological state during task completion. Doing so seemed warranted considering that people's inclination to attribute human minds towards non-human entities is known to differ considerably across situations (Epley, Waytz, & Cacioppo, 2007; Hallgren, 2012). In particular, following an experience of powerlessness and/or uncertainty, people seem to engage more strongly in mind attributions towards non-human entities, including animals, objects, and gods (Barrett & Johnson, 2003; Epley, Waytz, Akalis, & Cacioppo, 2008b; Kay, Moscovitch, & Laurin, 2010; Norenzayan & Hansen, 2006). In other words, mind attributions towards non-human entities often serve as a cognitive tool that allows perceivers to establish a sense of control (Waytz, Gray et al., 2010). What remains uncertain is whether people's momentary sense of powerlessness can also shape their reliance on mind attributions towards humanoid robots. In consequence, study 2 examined how the associations between mind attributions, non-mind judgments, and target evaluations would be affected A) by target type (i.e., robot vs. person) and B) by perceivers' temporary mental state (i.e., powerful vs. powerless).

Participants

109 students and teaching/research assistants (68 females, 18 – 37 years of age) from NYUAD participated in the study for course credit or cash (AED 150.00). Due to the university's admissions standards, all participants were proficient English speakers. They were assigned in a pseudo-random manner to the two experimental conditions of interest [powerful (PF) vs. powerless (PL)]. Participants who provided the exact same judgment on at least one rating dimension across the entire set of interactions were again excluded (n = 3). Thus, the final sample consisted of 106 participants, distributed across two experimental conditions comparable in age [PF: M = 20.1, SD = 2.67; PL: M = 20.5, SD = 2.93; $t(104) = 0.82$, p = .42] and gender composition [PF: 36 females, 18 males; PL: 32 females, 20 males; $X^2(1) = 0.30$, p = .69]. All participants provided informed consent before study completion and followed a protocol approved by the IRB of NYUAD.

Procedure

Upon arrival at the laboratory, participants were asked to complete two unrelated tasks on the perception and evaluation of social interactions. The first task required participants to recall a memory of a social interaction, whereas the second task required them to judge a series of social interactions. The recall task was administered in paper-and-pencil form and required participants to write about a time in which they felt powerful and/or powerless (cf. Galinsky, Gruenfeld, & Magee, 2003). Subsequently, participants completed a manipulation check, rating the extent to which the situation they had just described made them feel like A) they were in control, B) they were in charge of others (1 = *not at all* to 7 = *very much*). Afterwards, participants were asked to complete a rating task similar to that used in Study 1 but on a 15 inch MacBook Pro laptop.

The rating task was again administered as an online survey. Participants were first prompted to indicate their current mood (*1* = very unpleasant to *9* = very pleasant; three participants skipped this question), before receiving on-screen instructions to look at a series of social interactions that involved either a robot and a human or two humans (see Figure 1B). Participants were told further that for each interaction one agent would be marked with an asterisk (*) and that their task was to respond to each designated target without being influenced by any of their preceding judgments. To ensure that the laboratory study could be completed within a reasonable amount of time (i.e., $\leq$ 60 min), we used a subset of twenty HRI from the original online survey and their matching HHI (for further details on stimulus creation see Wang & Quadflieg, 2015). Given our interest in the effects of nuanced mind attributions, we selected interactions that covered a wide range of mind attributions based on the ratings in the original online survey (i.e., images that elicited mind attributions ranging from low to high emotional capability and/or intelligence). The resulting forty interactions (i.e., 20 HRI, 20 HHI) were presented in randomized order.

On each trial, ratings were again requested for eight dimensions of relevance. This time, however, a shared understanding of eeriness across participants was ensured by presenting a sign above the computer screen which informed participants that eeriness was defined as a ‘strange and slightly frightening feeling’. The sign also listed the words ‘uncanny and weird’ as synonyms and gave an example of how the word could be used (i.e., ‘an eerie green glow in the sky’). Moreover, to enhance the clarity of our measures, the rating task in study 2 presented unipolar instead of bipolar rating scales, requiring participants to rate the presence of a single attribute at a time (e.g., *eeriness*) on a scale from 1 (*not at all*) to 7 (*very much*). As before, participants were asked to rate each target's overall appeal (i.e., eeriness, likeability, and believability). Only safety judgments were dropped from the original list of evaluations as they had closely resembled eeriness judgments in the original online survey. Additionally, participants rated again each target's mind capacities (i.e., its emotional capability and intelligence). Yet, in addition to study 1, participants were also asked to judge each target's apparent ability to be considerate. Acting considerately has received particular attention in the literature on robot etiquette (e.g., Koay et al., 2013; Walters et al., 2008) and has been declared an important marker of mind capacities that goes beyond the mere capability of having feelings (Gray et al., 2007). Hence, we included this important facet of an agent's alleged mind capacities. Finally, we replaced the two original non-mind judgments of animacy and human likeness with dynamism and usefulness. The latter two non-mind judgments have also traditionally featured in the field of social robotics (e.g., Lee et al., 2011; Waytz, Morewedge et al., 2010), but promised to be better suited for capturing impressions of both robots and humans. Upon study completion, participants were thanked, payed, and debriefed.

Results

All essays were analyzed for word length, demonstrating that participants in both experimental conditions elaborated on their memories to a similar extent [PF: M = 209 words, SD = 35; PL: M = 221 words, SD = 45; $t(104) = 1.55$, $p = .12$]. Analysis of the manipulation check questions additionally confirmed that participants in the PF condition felt more powerful in the situation they described (M = 4.89, SD = 1.49) than participants in the PL condition (M = 2.37, SD = 1.72; $t(104) = 8.05$, $p < .001$). Moreover, participants' overall mood when starting the interaction rating task was marginally more positive for PF participants (*M* = 6.72, *SD* = 1.41) than PL participants (*M* = 6.21, *SD* = 1.45; *t*(103) = 1.82, *p* = .07].

We then began our analysis of the interaction task by averaging the collected ratings based on rating dimension and target type (see Table 4, columns 2-5). In order to investigate whether variations in attributions of mind and non-mind judgments corresponded for HHI and HRI, we correlated the average ratings per interaction (i.e., by collapsing across individuals) for both types of targets (HHI, HRI), separately for each experimental condition (PF vs. PL, see Table 4, columns 6 and 7). It was found that increases in a robot's alleged emotional capability or intelligence in the context of a certain HRI, was associated with increases in a human target's emotional capability or intelligence in the context of the corresponding HHI, regardless of experimental condition. Such correspondence also occurred for judgments of consideration, as well as for non-mind judgments, and ratings of likeability. In other words, similar rankings for mind attributions and non-mind judgments were found across the selected interactions, regardless of target type. Yet, such a pattern was notably absent for ratings of eeriness and believability.

In a next step, we again computed no-predictor models for the outcome variables of relevant, that is, eeriness (BIC0 = 16576.68), likeability (BIC0 = 14679.51), and believability (BIC0 = 18270.12). For all three variables, significant variation across interactions (Wald *Z* eeriness: 2.90; likeability: 3.01; believability: 2.76; *p* < .01), across individuals (Wald *Z* eeriness: 6.42; likeability: 6.72; believability: 5.90; *p* < .001), and within individuals (Wald *Z* eriness/likeability/believability: 45.36, *p* < .001) was observed. We then proceeded by specifying a model with the outcome variable eeriness and the between-person predictor experimental condition (X1), as well as the within-person predictors target type (W1), emotional capability (W2), and intelligence (W3), and their relevant interactions. Including these predictors resulted in a model that estimated six random effects (the interaction intercept, the individual intercept, the slopes of W2 and W3, their slope x target type interactions X1 x W2 and X1 x W3) as well as twelve fixed effects of interest (the overall intercept, X1, W1, W2, W3, X1 x W1, X1 x W2, X1 x W3, W1 x W2, W1 x W3, X1 x W1 x W2, X1 x W1 x W3, see Table 7).

Compared to the no-predictor model, this model showed enhanced data fit (BIC1 = 14437.06), reducing variance in eeriness across (Wald $Z = 6.18$; $p < .001$) as well as within individuals (Wald $Z = 42.86$, $p < .001$). Specifically (see Table 5), it revealed a main effect of target type, signaling that robots were generally rated eerier than humans. In addition, effects of emotional capability and intelligence emerged for HHI, indicating that humans were eerier, the less emotionally capable or the less intelligent they appeared. For robots, in contrast, the effect of emotional capability was absent, whereas the effect of intelligence was slightly more pronounced. Finally, the effect of intelligence on eeriness was also found to be affected by condition, such that for both types of targets the association was stronger in the powerful than the powerless condition.

In a next step, we re-specified the model to include all predictor variables, that is, also judgments of consideration (W4), dynamism (W5), and usefulness (W6), as well as the relevant interaction terms (see Table 6 and Figure 2). Doing so further reduced the variance to be explained across (Wald Z: 6.02; $p < .001$) and within individuals (Wald Z: 40.92; $p < .001$), resulting in even better model fit (BIC2 = 14116.02). The effect of emotional capability was now modulated by target type and marginally so by condition. Thus, humans felt eerier, the less emotionally capable they appeared. This effect was absent for robots. In addition, the observed difference in slopes for human and robot targets was slightly smaller in the powerful than the powerless condition. In contrast, with regard to intelligence, humans were found to be less eerie, the more intelligent they seemed. Although the effect was reduced for robots, the difference in slopes was not significant. For attributions of consideration it was found that both humans and robots were found to be slightly eerier, the less considerate they appeared. Furthermore, for robots, but not for humans, increases in eeriness were linked to decreases in perceived usefulness. Finally, for judgments of dynamism no significant effects emerged.

We also computed the latter, full predictor model with the outcome variables likeability and believability (see Figure 2). For likeability (see Table 7), we observed enhanced model fit compared to the no-predictor model (BIC2 = 11265.05), reducing variance across individuals (Wald $Z = 5.04$; $p < .001$) as well as within individuals (Wald $Z = 41.42$, $p < .001$). A main effect of target type signaled that robots were rated slightly more likeable than humans overall. Additionally, it was found that both robots and humans were rated more likable, the more considerate, emotionally capable, intelligent, dynamic, and useful they appeared. Among these predictors, the effects of consideration and emotional capability were qualified by a significant interaction with target type such that the effects of these two variables on likeability were stronger for humans than for robots.

For the outcome variable believability (see Table 8), the full predictor model also reduced variance within (Wald $Z = 40.79$, $p < .001$) and across individuals (Wald $Z = 5.88$; $p < .001$) compared to the no-predictor model, resulting in better model fit (BIC2 = 14091.49). A main effect of target type signaled that humans were generally more believable than robots. Additionally, an effect of emotional capability was modulated by target type. Thus, humans but not robots were considered more believable, the more emotionally capable they seemed. Vice versa, for usefulness it was found that robots, but not humans, were considered more believable, the more useful they appeared. Both humans and robots were generally more believable, the more considerate they appeared. For intelligence and dynamism, no significant findings emerged.

Discussion

In study 2, perceivers rated a series of HRI and HHI after describing a memory of a situation in which they felt either powerful or powerless. Ratings and associations between perceived mind capacities, non-mind qualities, and target evaluations differed substantially based on target type and marginally so based on the memory retrieved. In short, perceivers experienced enhanced eeriness towards humans, the less considerate, emotionally capable, and intelligent they appeared (Q1, Q2). Yet, non-mind ratings failed to predict eeriness towards humans (Q3). In contrast, evaluations of likeability were predicted by both mind and non-mind ratings (Q4). Specifically, humans were considered more likeable, the more they were rated as capable of having emotions, intelligent, considerate, dynamic, and useful. Evaluations of believability, in turn, were linked solely to (some) mind attributions (Q5): Humans were rated more believable, the more capable of emotions and the more considerate they seemed. Finally, the full predictor model returned a marginally significant interaction between perceivers' temporary feelings of power and their ratings of eeriness (but not their ratings of likability or believability). This interaction signaled that the link between attributions of emotional capability and feelings of eeriness was slightly enhanced following a powerless compared to a powerful prime (Q6).

These findings differed notably from those observed for robotic targets. Perceivers experienced enhanced eeriness towards robots, the less intelligent and considerate they seemed, but such a link was absent for judgments of emotional capability (Q1, Q2). In addition, the strongest predictor of eeriness towards robots (but not humans) was a non-mind attribute (Q3): Eeriness enhanced most strongly, the less useful robots appeared. Interestingly, associations with likeability were generally similar for both types of targets (Q4). Thus, just like humans, robots were seen as more likeable, the more capable of emotions, intelligent, considerate, dynamic, and useful they seemed. Nevertheless, significant interaction effects signaled that the links between emotional capability and likeability as well as between consideration and likeability were somewhat stronger for humans than for robots. Furthermore, robots were rated more believable, the more considerate, but also the more useful they appeared (Q5). Finally, in response to robots, associations between mind attributions, non-mind judgments, and target evaluations were unaffected by feelings of powerlessness (Q6). In summary, these findings revealed that associations between mind capacities, non-mind qualities, and target evaluations differed substantially based on whether human or robotic targets were assessed.

General Discussion

According to prominent theories on mind perception, humans infer that other entities have an invisible mind similar to their own based on two major attributions (Gray et al., 2007): On the one hand, they evaluate the degree to which an entity has agency. On the other hand, they judge a target's capacity for experience. Based on these two assessments even non-human targets, such as robots, are occasionally perceived as possessing human-like minds (Fink, 2012; Vogeley & Bente, 2010). Recent data suggest, however, that attributing human-like minds to robots may come at the price of feeling eerie towards them (Gray & Wegner, 2012). A similar affective cost may accompany encounters with conspecifics that lack a normal human mind (Zlotowski, Proudfoot et al., 2015). Fascinated by these two closely related claims, we conducted one online survey (Study 1) and one laboratory study (Study 2) in order to revisit them. Therefore, two groups of participants were asked to rate robots (Study 1) and humans (Study 2) in various social situations regarding their mind capacities, non-mind qualities, and overall appeal in various social scenarios.

First and foremost, it was found that embedding robotic and human targets in otherwise identical scenarios succeeded at inviting similar mind attributions for both types of targets. Thus, scenarios that resulted in higher attributions of agency and/or experience for robots, also resulted in higher attributions of agency and/or experience for humans. But what were the consequences of these mind attributions (Q1, Q2)? For human targets, it was found that increases in mind attributions were associated with decreases in eeriness, regardless of whether aspects of experience (e.g., emotional capability, consideration) or agency (e.g., intelligence) were probed. For robots, similar effects emerged but less consistently so. For instance, in Study 1, both attributions of intelligence and emotional capability predicted feelings of eeriness towards robots, but only as long as these variables were considered separately from non-mind predictors. Upon inclusion of the latter, the association between emotional capability and eeriness disappeared. In Study 2, this association was never observed, regardless whether non-mind predictors were considered or not (for similar null findings see Broadbent et al., 2013).

Compared to Study 1, Study 2 used less stimuli per target type and required participants to report their judgments for both types of targets on the same scale. Thus, a drop in overall measurement sensitivity could account for the lack of replication. Yet, under the same conditions, the link between ratings of intelligence and feelings of eeriness towards robots was replicated. Thus, the data consistently support the conclusion that robots appear eerier, the less intelligent they seem. Most importantly, however, the data also consistently challenge the claim that attributions of experiential capacities (such as emotional capability) would increase, rather than decrease, feelings of eeriness towards robots (Gray & Wegner, 2012). The data further indicate that recently proposed mind attributions are not necessarily better predictors of eeriness towards robots than traditionally used non-mind judgments (Q3).

In study 1, ratings of intelligence and animacy were equally effective at predicting feelings of eeriness towards robots. In study 2, the main predictor of eeriness was a robot’s perceived usefulness. These findings emphasize the need for more careful theorizing concerning possible associations between mind attributions and non-mind judgments with feelings of eeriness towards robots. Future work should examine the degree of conceptual overlap between mind and non-mind predictors. The elimination of the association between emotional capability and feelings of eeriness upon including ratings of animacy and human likeness in study 1, for instance, signaled that these variables shared substantial variance. Similarly, the drop in associative strength between ratings of intelligence and feelings of eeriness upon including non-mind predictors in studies 1 and 2 signaled conceptual overlap between mind and non-mind predictors. It seems likely, for instance, that intelligent robots are also frequently considered useful. Given this relation, attributions of intelligence may appear more strongly related to feelings of eeriness towards robots than they actually are – an effect that can only become apparent upon considering both types of predictors in parallel (or experimentally controlling for one of them). Thus, the relative contribution of mind and non-mind judgments on attitudes towards robots deserves further theoretical and empirical consideration.

Furthermore, looking at the effects of mind and non-mind predictor variables in concert suggests that it is the general assessment of a robot’s (in)ability to assist or serve a human interaction partner that most strongly predicts perceivers’ feelings of eeriness (cf. Dautenhahn, 2014; Dautenhahn et al., 2005). As revealed in study 2, eeriness towards robots decreased most strongly, the more useful a robot was perceived to be. However, a robot’s ability to assist may not only depend on its mind capacities and non-mind qualities per se, but also on the task for which assistance is sought (Goetz, Kiesler, & Powers, 2003; Walters et al, 2013). Phrased differently, the effect of mind attributions and non-mind judgments on eeriness towards robots may also depend on their purpose. Recent evidence suggests, for instance, that a robot allegedly capable of emotions is considered less eerie when expected to work as a social worker rather than a data analyst (Waytz & Norton, 2014). Taken together, these data indicate that eeriness towards robots may primarily arise when people perceive inconsistencies between the robots' mind capacities, non-mind qualities, and its assigned role (Lee et al., 2011; Li, Rau, & Li, 2010; Joosse, Lohse, Perez, & Evers, 2013).

Moreover, the data demonstrated that the two pivotal measures of discomfort towards robots (i.e., evaluations of likeability and eeriness) can return markedly different results (Q4). Across both studies, the patterns of associations between mind/non-mind ratings and feelings of eeriness did not align with the patterns of associations between mind/ non-mind ratings and likeability. This observation provides empirical support for Mori's original distinction between shinwakan (i.e., likeability) and bukimi (i.e., eeriness). The differential patterns of associations further emphasize the need to use both measures in parallel in order to capture discomfort towards robots in a more comprehensive manner (MacDorman & Entezari, 2015; Zlotowski, Sumioka et al., 2015). Most importantly, by delineating different aspects of discomfort scientists may ultimately be able to predict which aspect(s) compromise(s) people's willingness to engage with or accept robots (Ho & MacDorman, 2010; Patel & MacDorman, 2015).

It must also be noted that the associative patterns observed for feelings of eeriness and evaluations of safety were highly similar in the current work (cf. Study 1). This observation suggests that both types of evaluations may be linked by a common affective core, supporting definitions of eeriness which emphasize feelings of fear and anxiety (Cheetham, Suter, & Jäncke, 2011). The exact relation between feelings of eeriness and safety concerns, however, deserves further investigation. For instance, it seems feasible that mind attributions and non-mind judgments may trigger concerns about a robot's potential to harm others (Gray & Wegner, 2009), which could in turn elicit feelings of eeriness. Alternatively, mind attributions and non-mind judgments may trigger feelings of eeriness, which in turn could elicit safety concerns. What seems certain to date is that safety concerns are of central importance when it comes to establishing satisfying HRI and deserve particular empirical attention considering that robots can "provide a level of potential danger seldom experienced with other domestic technologies in the past" (Young et al., 2009, p. 105).

Interestingly, it has been argued that differences in eeriness (and safety concerns) towards robots and humans may ultimately arise from the different expectations that perceivers' hold about these two types of targets (Gray & Wegner, 2012). Based on common media portrayals, for instance, both robots and humans are generally expected to act intelligently, but emotional experiences are primarily expected in humans (Bartneck, 2013; Gray et al., 2007). Eeriness based on mind attributions may only arise if these mind attributions violate perceivers' expectations. To address this assumption, we also asked participants to judge how believable they found each of the portrayed targets across the different social scenarios. Yet, the obtained data were inconclusive. For instance, people were rated systematically more eerie and also less believable, the less emotionally capable they seemed. They were also rated less eerie, the less intelligent they seemed, but this time ratings of intelligence and ratings of believability were unrelated. Similarly, for robots it was found (across both studies) that decreases in perceived intelligence were accompanied by increases in eeriness, as well as decreases in believability. But then again, such corresponding associative pattern were absent for attributions of emotional capability. Even more so, the link between ratings of emotional capability and ratings of believability was inconsistent across both studies. While Study 1 signaled that robots were seen as less believable, the more they seemed emotionally capable, Study 2 was unable to replicate this link. While differences in samples, measurement sensitivity, and considered non-mind predictors are likely to account for the observed differences, future research is necessary to better understand the relation between perceivers' preconceived notions about robots and their attitudes towards them.

Finally, the current work explored the role of a range of perceiver variables in predicting mind-attribution based feelings of eeriness towards robots (e.g., age, sex, education, and familiarity with robots in study 1; temporary feelings of power in study 2). Study 1 revealed that increases in familiarity with robots were associated with decreases in eeriness towards them. Familiarity failed, however, to modulate the strength of association between mind attributions and eeriness for robotic targets. Study 2 suggested that the strength of associations between attributions of emotional capability and eeriness may be modulated by feelings of powerlessness, but only when other humans rather than robots were concerned. Thus, additional research is needed to understand the effect of perceiver variables on eeriness towards robots. For instance, though study 1 did not find an effect of perceivers' age, it must be noted that neither the opinions of children and adolescents, nor of the elderly (> 55 years of age) were probed. Considering that these age groups may be particularly likely to interact with companion robots in the future (cf. Flandorfer, 2012; Tanaka, Cicourel, & Movellan, 2007), their responses towards different types of companion robots deserves particular scientific scrutiny.

Before concluding, a final short-coming of the current work must be discussed. In line with previous HRI research (e.g., Beck et al., 2012; Chammat et al., 2010; Erden, 2013; Lee et al., 2011; Prakash & Rogers, 2015; Rosenthal-van der Pütten & Krämer, 2014), participants in both studies based their judgments on static images of robots and humans. This methodology enabled us to present a wide variety of carefully controlled social interactions to a large group of perceivers, unrestricted by the question of whether such interactions could currently unfold in the real world. However, the same approach limits our ability to speculate on how well the obtained findings generalize to observations of real-world interactions. The lack of motion cues, for instance, may have systematically underestimated the impact of motion-sensitive judgments (e.g., ratings of animacy and/or dynamism) on feelings of eeriness. In a related manner, the lack of direct exposure to real-world interactions may have resulted in subdued emotional responding in our participants. Future work should therefore examine perceiver responses to real-world social interactions which either strictly control for relevant motion cues (e.g., both human and robotic targets display the exact same movements) or systematically manipulate them (e.g., both types of targets display human and 'robotic' movements; cf. Cross et al., 2012).

In summary, the current work adopted a novel methodological approach (i.e., the portrayal of social interactions) to investigate the link between mind attributions, non-mind judgments, and target evaluations for both robots and humans. It was found that feelings of eeriness towards conspecifics intensified, the less they were seen as possessing either experience or agency. For robots, similar associations, but of weaker strength emerged. In addition, for robots (but not for people!), feelings of eeriness increased, the less useful they appeared. Finally, feelings of eeriness towards both robots and humans were not simply reducible to experiences of dislike, but formed a distinct emotional response that was largely unaffected by characteristics of the perceiver.

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Figures

Figure 1. Examples of interactions as presented in studies 1 and 2. (A): Human-Robot Interactions (HRI); (B): Human-Human Interactions (HHI). Images of humans were downloaded from www.shutterstock.com and are reproduced in this manuscript in adherence with the company's standard license terms of service (http://www.shutterstock.com/licensing.mhtml).

Figure 2. Regression slopes for evaluations of eeriness, likeability, and believability based on the between-person predictor experimental condition (powerful vs. powerless) and the within-person predictors target type (HHI vs. HRI), emotional capability, intelligence, consideration, dynamism, and usefulness.

Tables

Table 1. *Study 1: Mean ratings and standard deviations (in brackets) collapsed across individuals and interactions for each dimension of judgment, including minimum ratings (Min) and maximum ratings (Max) for the entire set of human-robot interactions collapsed across individuals only.*

Dimensions of Judgment	Mean	Min	Max
Animacy	2.87 (0.26)	2.30	3.46
Believability	3.37 (0.68)	2.35	4.79
Emotional Capability	3.61 (0.60)	2.48	4.52
Human Likeness	3.05 (0.34)	2.34	3.68
Intelligence	3.04 (0.37)	2.41	3.71
Likeability	2.94 (0.38)	2.36	4.43
Reassuringness (vs. Eeriness)	3.39 (0.58)	2.57	4.65
Safety	3.04 (0.51)	2.43	4.39

Table 2. *Study 1: Multi-level regression analyses for the different outcome variables as measured in response to forty human-robot interactions.*

	Parameter Estimates	SE	df	*t*-value	*p*-value
Reassuringness (vs. Eeriness)					
Intercept	3.39	.12	95.39	27.22	<.001
Animacy	0.12	.02	6134.86	7.55	<.001
Emotional Capability	0.00	.02	6183.12	0.15	.878
Human Likeness	0.08	.02	6123.08	4.81	<.001
Intelligence	0.13	.02	6128.43	8.34	<.001
Safety					
Intercept	3.04	.12	110.30	26.02	<.001
Animacy	0.11	.02	6128.88	6.89	<.001
Emotional Capability	0.02	.01	6178.29	1.64	.102
Human Likeness	0.07	.02	6116.55	4.67	<.001
Intelligence	0.10	.01	6124.27	6.68	<.001
Likeability					
Intercept	2.94	.08	79.18	36.20	<.001
Animacy	0.19	.01	6165.72	13.36	<.001
Emotional Capability	0.10	.01	6153.73	7.56	<.001
Human Likeness	0.15	.01	6163.27	11.25	<.001
Intelligence	0.18	.01	6186.11	13.41	<.001
Believability					
Intercept	3.37	.13	87.67	25.01	<.001
Animacy	0.11	.02	6143.35	6.14	<.001
Emotional Capability	-0.05	.02	6188.86	-2.87	.004
Human Likeness	0.00	.02	6131.91	-0.09	.927
Intelligence	0.09	.02	6136.73	5.41	<.001

Table 3. *Study 1: Multi-level regression analysis for judgments of reassuringness (vs. eeriness) targeting human-robot interactions, including mind capacity attributions and non-mind quality judgments as within-person predictors as well as perceivers' proficiency in English, familiarity with robots, and gender as between-persons predictors.*

	Parameter Estimates	SE	df	*t*-value	*p*-value
Intercept	3.50	.14	151.36	25.77	<.001
Animacy	0.08	.03	150.96	2.62	.010
Emotional Capability	0.00	.02	156.39	0.04	.972
Human Likeness	0.08	.03	140.93	3.31	.001
Intelligence	0.10	.02	178.34	4.44	<.001
English Proficiency	-0.49	.16	147.08	-2.97	.003
Familiarity With Robots	-0.10	.05	146.71	-1.99	.048
Gender*	-0.13	.16	145.92	-0.77	.444
Gender x Animacy*	0.16	.04	148.68	3.72	<.001

*The reference group is male participants. Estimates are shown for female participants.

Table 4. *Study 2: Mean ratings and standard deviations (in brackets) for human-human interactions (HHI) and human-robot interactions (HRI) collapsed across individuals and interactions according to experimental conditions, powerful (PF) or powerless (PL). The final two columns show correlations for interaction-based average ratings (i.e., collapsed across all participants) between both types of targets based on experimental condition.*

	HHI		HRI		HHI-HRI *r*(38)	
	PF	PL	PF	PL	PF	PL
Believability	6.34 (0.82)	6.29 (0.59)	3.45 (1.22)	3.30 (1.30)	.10	.08
Consideration	5.35 (0.73)	5.47 (0.69)	4.45 (1.21)	4.37 (1.26)	.88*	.87*
Dynamism	4.87 (0.88)	4.96 (0.92)	4.23 (1.14)	4.41 (1.21)	.54*	.70*
Eeriness	1.46 (0.43)	1.43 (0.43)	3.24 (1.38)	3.28 (1.39)	.44	.28
Emotional Capability	5.83 (0.71)	5.77 (0.66)	3.76 (1.42)	3.72 (1.29)	.69*	.61*
Likeability	5.20 (0.74)	5.27 (0.79)	4.52 (1.13)	4.67 (1.08)	.78*	.86*
Intelligence	4.78 (0.78)	4.73 (0.86)	4.38 (1.11)	4.34 (1.27)	.53*	.74*
Usefulness	5.26 (0.69)	5.34 (0.72)	5.04 (0.76)	5.18 (0.91)	.95*	.97*

*Correlation is significant at $p < .05$.

Table 5. *Study 2: Multi-level regression analysis for judgments of eeriness including the between-persons predictor experimental condition (powerful vs. powerless) and the within-person predictors target type (human-human interactions vs. human-robot interactions), emotional capability, and intelligence.*

	Parameter Estimates	SE	df	*t*-value	*p*-value
Intercept	1.75	0.15	72.95	11.69	<.001
Conditionº	-0.03	0.16	133.96	0.21	.837
Target Type*	1.48	0.08	3490.30	18.81	<.001
Condition x Target Typeº*	-0.01	0.11	3423.84	0.09	.931
Emotional Capability (EC)	-0.29	0.05	154.54	5.96	<.001
Intelligence (IN)	-0.07	0.04	124.27	1.83	.069
Condition x ECº	0.08	0.07	179.73	1.13	.261
Condition x INº	-0.11	0.05	135.71	2.08	.039
Target Type x EC*	0.29	0.06	132.94	4.45	<.001
Target Type x IN*	-0.15	0.06	113.93	2.30	.023
Condition x Target Type x ECº*	-0.14	0.09	150.85	1.48	.141
Condition x Target Type x INº*	0.09	0.09	126.21	1.03	.306

ºThe reference group is powerful. Estimates are shown for powerless.
*The reference group is HHI. Estimates are shown for HRI.

Table 6. *Study 2: Multi-level regression analysis for judgments of eeriness including the between-persons predictor experimental condition (powerful vs. powerless) and the within-person predictors target type (human-human interactions vs. human-robot interactions), emotional capability, intelligence, consideration, dynamism, and usefulness.*

	Parameter Estimates	SE	df	*t*-value	*p*-value
Intercept	1.74	0.12	104.73	14.17	<.001
Conditionº	-0.06	0.15	129.91	0.43	.666
Target Type*	1.54	0.08	3160.54	19.71	<.001
Condition x Target Typeº*	-0.08	0.11	3259.80	0.70	.487
Emotional Capability (EC)	-0.22	0.05	194.47	4.82	<.001
Intelligence (IN)	-0.08	0.04	173.53	1.99	.048
Consideration (CO)	-0.10	0.04	238.49	2.44	.015
Dynamism (DY)	0.00	0.04	105.99	0.04	.965
Useful (US)	0.01	0.04	151.96	0.38	.704
Condition x ECº	0.11	0.07	223.28	1.65	.101
Condition x INº	-0.10	0.06	193.90	1.81	.072
Condition x COº	-0.02	0.05	190.45	0.44	.660
Condition x DYº	-0.03	0.05	122.54	0.64	.521
Condition x USº	0.03	0.05	161.64	0.49	.625
Target Type x EC*	0.24	0.06	176.17	3.75	<.001
Target Type x IN*	0.03	0.06	156.81	0.57	.569
Target Type x CO*	0.01	0.06	193.24	0.13	.899
Target Type x DY*	0.00	0.07	141.72	0.03	.979
Target Type x US*	-0.34	0.05	172.17	6.51	<.001
Condition x Target Type x ECº*	-0.18	0.09	193.87	1.97	.051
Condition x Target Type x INº*	0.07	0.09	177.42	0.79	.430
Condition x Target Type x COº*	0.04	0.09	188.45	0.50	.615
Condition x Target Type x DYº*	-0.00	0.09	153.19	0.05	.964
Condition x Target Type x USº*	-0.02	0.07	187.98	0.32	.748

ºThe reference group is powerful. Estimates are shown for powerless.
*The reference group is HHI. Estimates are shown for HRI.

Table 7. *Study 2: Multi-level regression analysis for judgments of likeability including the between-persons predictor experimental condition (powerful vs. powerless) and the within-person predictors target type (human-human interactions vs. human-robot interactions), emotional capability, intelligence, consideration, dynamism, and usefulness.*

	Parameter Estimates	SE	df	*t*-value	*p*-value
Intercept	4.73	0.08	56.54	59.61	<.001
Conditionº	-0.05	0.08	184.77	0.66	.506
Target Type*	0.28	0.05	2469.65	5.14	<.001
Condition x Target Typeº*	-0.01	0.08	2526.91	0.16	.875
Emotional Capability (EC)	0.24	0.03	352.61	7.67	<.001
Intelligence (IN)	0.08	0.03	210.93	2.71	.007
Consideration (CO)	0.40	0.03	350.37	13.50	<.001
Dynamism (DY)	0.15	0.03	207.18	5.28	<.001
Useful (US)	0.13	0.03	240.27	4.56	<.001
Condition x ECº	0.01	0.05	396.19	0.16	.871
Condition x INº	0.04	0.04	238.15	1.04	.302
Condition x COº	-0.02	0.04	282.59	0.40	.691
Condition x DYº	0.04	0.04	232.08	1.06	.292
Condition x USº	-0.01	0.04	249.25	0.18	.855
Target Type x EC*	-0.10	0.04	286.83	2.68	.008
Target Type x IN*	0.03	0.04	226.35	0.79	.431
Target Type x CO*	-0.12	0.04	239.00	3.22	.001
Target Type x DY*	-0.02	0.04	227.15	0.50	.621
Target Type x US*	0.07	0.04	234.26	1.97	.051
Condition x Target Type x ECº*	0.07	0.06	322.17	1.22	.224
Condition x Target Type x INº*	-0.05	0.06	265.08	0.88	.380
Condition x Target Type x COº*	0.07	0.05	228.04	1.32	.189
Condition x Target Type x DYº*	-0.05	0.06	250.74	0.90	.370
Condition x Target Type x USº*	-0.06	0.05	257.42	1.15	.251

ºThe reference group is powerful. Estimates are shown for powerless.
*The reference group is HHI. Estimates are shown for HRI.

Table 8. *Study 2: Multi-level regression analysis for judgments of believability including the between-persons predictor experimental condition (powerful vs. powerless) and the within-person predictors target type (human-human interactions vs. human-robot interactions), emotional capability, intelligence, consideration, dynamism, and usefulness.*

	Parameter Estimates	SE	df	*t*-value	*p*-value
Intercept	6.00	0.11	96.63	53.03	<.001
Condition°	.09	0.13	146.82	0.72	.472
Target Type*	-2.74	0.08	3300.76	34.91	<.001
Condition x Target Type°*	0.21	0.11	3399.46	1.90	.057
Emotional Capability (EC)	0.21	0.04	202.70	4.74	<.001
Intelligence (IN)	0.05	0.04	147.73	1.27	.206
Consideration (CO)	0.08	0.04	3808.62	2.26	.024
Dynamism (DY)	-0.02	0.04	159.37	0.42	.673
Useful (US)	0.01	0.04	211.73	0.15	.878
Condition x EC°	-0.02	0.06	231.72	0.24	.815
Condition x IN°	0.03	0.05	168.41	0.59	.553
Condition x CO°	-0.08	0.05	3784.34	1.65	.100
Condition x DY°	0.05	0.06	182.35	0.90	.367
Condition x US°	0.06	0.05	218.90	1.08	.281
Target Type x EC*	-0.26	0.07	167.33	4.02	<.001
Target Type x IN*	0.00	0.06	172.99	0.05	.962
Target Type x CO*	0.02	0.06	257.71	0.33	.740
Target Type x DY*	0.13	0.07	120.96	1.85	.067
Target Type x US*	0.33	0.06	169.60	6.02	<.001
Condition x Target Type x EC°*	0.10	0.09	183.08	1.11	.271
Condition x Target Type x IN°*	-0.15	0.09	193.04	1.63	.105
Condition x Target Type x CO°*	0.04	0.08	251.72	0.48	.634
Condition x Target Type x DY°*	-0.14	0.10	130.69	1.45	.148
Condition x Target Type x US°*	0.00	0.08	183.33	0.03	.976

°The reference group is powerful. Estimates are shown for powerless.
*The reference group is HHI. Estimates are shown for HRI.