The Uncanny of Mind in a Machine: Humanoid Robots as Tools, Agents, and Experiencers

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Abstract

The uncanny valley hypothesis suggests that a high (but not perfect) human likeness of robots is associated with feelings of eeriness. We distinguished between experience and agency as psychological representations of human likeness. In four online experiments, vignettes about a new generation of robots were presented. The results indicate that a robot's capacity to feel (experience) elicits stronger feelings of eeriness than a robot's capacity to plan ahead and to exert self-control (agency, Experiment 1A), which elicits more eeriness than a robot without mind (robot as tool, Experiments 1A and 1B). This effect was attenuated when the robot was introduced to operate in a nursing environment (Experiment 2). A robot's ascribed gender did not influence the difference between the eeriness of robots introduced as experiencers, agents, or tools (Experiment 3). Additional analyses yielded some evidence for a non-linear (quadratic) effect of participants' age on the robot mind effects.

Keywords— uncanny valley; mind perception; experience; agency; service robots

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Humanlike robots can be a source of bewilderment and eeriness (Freud, 1919/2003; Jentsch, 1906/1997; Mori, 1970 / Mori, MacDorman, & Kageki, 2012). Recent work suggests that the eeriness of humanlike robots does not only depend on their visual appearance, but can also stem from the perception of feelings and experience in a machine (Gray & Wegner, 2012; Wegner & Gray, 2016). We follow the distinction between the ability to feel (experience) and the ability for thought and cognition (agency) of mind perception (Gray, Gray, & Wegner, 2007) and investigate the effects of both components of mind perception on participants' feelings of eeriness in response to a service robot. Importantly, we examine the role of a robot's experience and agency under varying boundary conditions, that is, in a nursing context (as compared to an unspecified field of application), for female or male gendered robots, and for the spectrum of users' age.

1.1 Humanoid Robots and the Uncanny Valley

The number of robots built each year is on the rise (International Federation of Robotics, 2018). Most of the robots are meant to work in automotive manufacturing or chemical industries, like they have done since the 1950s. In recent years, however, the use of robots in non-industrial fields has increased rapidly (Graetz & Michaels, 2018; Grewal, Motyka, & Levy, 2018). Not only are robots built to clean the carpet or mow the garden lawn, robots are envisaged to play a key role in future sex work, military, tourism, education, and retail. The sector that has arguably attracted most attention by the industry as well as related research is nursing and healthcare for older people (cf. Locsin & Ito, 2018). Initial evidence points out that social robots might bring benefits to older people, such as a reduction in loneliness or increasing social interactions (Kachouie, Sedighadeli, Khosla, & Chu, 2014; Shibata & Wada, 2011).

A recent multi-wave analysis of EU survey data suggests that, along with the proliferation of robots, attitudes towards robots are getting more negative (Gnambs & Appel, 2019). Much of the literature on the acceptance of robots, humanoid robots in particular, has been guided by the uncanny valley hypothesis (Mori, 1970; for reviews see Kätsyri, Förger, Mäkäräinen, & Takala, 2015; Wang, Lilienfeld, & Rochat, 2015; Złotowski, Proudfoot, Yogeeswaran, & Bartneck, 2015). According to Mori's conception, increasing the human likeness of robots (and other anthropomorphic technologies) elicits increasing acceptance and likeability at low to moderate levels of human likeness. However, with a further increase, as soon as a very high level of nearly realistic human likeness is obtained, this relationship is reversed. At this point, valence drops substantially, and the almost perfectly humanlike robot elicits a negative and irritating feeling of eeriness among its human observers. When a robot's design approaches perfect human likeness even further, user responses turn positive again (cf. Kätsyri et al., 2015; Wang et al., 2015). Whereas human likeness is often conceptualized as a feature of the visual appearance of the robot alone, research suggests that perceptions of human-likeness are subject to all visual and functional features of the robot, user variables, and variables of the situation in which the human-robot-interaction takes place (e.g., Broadbent, 2017; Lischetzke, Izydorczyk, Hüller, & Appel, 2017; MacDorman, & Entezari, 2015; Mara & Appel, 2015; Piwek, McKay, & Pollick, 2014; Rosenthal-von der Pütten & Krämer, 2015; Rosenthal-von der Pütten, & Weiss, 2015).

More broadly, these features determine users' perceived capabilities of the robot which translate to cognitive, affective, and behavioral responses (e.g., Hoffmann, Bock, & Rosenthal-von der Pütten, 2018; Rosenthal-von der Pütten & Krämer, 2014; 2015). One aspect of ascribed robot attributes that was considered to be particularly influential from early on is the mind ascribed to a robot (e.g., Hegel, Krach, Kircher, Wrede, Sagerer, 2008).

1.2 Mind Perception

Several lines of theory suggest that the uncanny valley is based on users' perceptions of human mind in a machine (Hegel et al., 2008; Gray & Wegner, 2012; Stein & Ohler, 2017; Wegner & Gray, 2016). More specifically, two dimensions of mind perception have been distinguished: experience and agency (Gray et al., 2007; Waytz, Gray, Epley, & Wegner, 2010). The general idea that human likeness and its influence on eeriness might involve more than one dimension can be found in other work (e.g., realism and prototypicality; Burleigh, Schoenherr, & Lacroix, 2013). From a mind perception perspective, however, identifying characteristics that are attributed to humans only (and not to machines or animals) is key to explain the uncanny valley. Gray and colleagues presented descriptions of characters (mainly humans of different ages and mental states, animals) and participants evaluated these characters along a list of 24 attributes. They identified the two factors on the basis of principal components factor analyses of these attributes. Agency involves characteristics of self-control, morality, memory, emotion recognition, planning, communication, and thought, whereas experience is characterized by hunger, fear, pain, pleasure, rage, desire, personality, consciousness, pride, embarrassment, and joy (order of the terms listed represents factor loadings in Gray et al., 2007).

Connecting both mind perception dimensions to the uncanny valley phenomenon and resulting experiences of eeriness, Gray and Wegner (2012) presented participants with either a video of a humanoid robot that focused on its electrical components and wirings or a video of the same robot with a focus on its humanoid face. In the latter condition, participants ascribed more experience to the robot and reported more eeriness, whereas ascribed agency did not differ between conditions. Experience (but not agency) predicted eeriness and mediated the effect of the video conditions on eeriness. In a second study, participants received descriptions of a "supercomputer" which was simply more powerful (control condition), was able to "independently execute actions" with "self-control and the capacity to plan ahead" (agency condition), or was able to feel some form of "hunger, fear and other emotions" (experience condition). Eeriness was elevated in the experience condition as compared to both the control condition and the agency condition (eeriness in the latter two conditions was about at par). These results suggest that experience is the dimension of human likeness that is responsible for the eeriness elicited by humanoid robots. Agency, on the other hand, appears to be unrelated to the negative responses to this new technology.

In a study set in a retirement village, the differential influence of experience and agency was tested in an applied setting (Stafford, MacDonald, Jayawardena, Wegner, & Broadbent, 2014). A healthcare robot was introduced to the retirees, and the retirees' behavior and perceptions in response to the robot were documented. Participants ascribed higher capacity for agency than capacity for experience to the robot, corroborating the distinction between both mind perception dimensions in an applied context with a key target user group. In contrast to what could be expected from the earlier results (Gray & Wegner, 2012), however, ascribed agency was negatively related to the actual use of the robot, whereas ascribed experience was unrelated to using the robot. Thus, in this particular setting, negative responses to the robot were associated with perceived agency, not with perceived experience (Stafford et al., 2014). However, the evidence regarding robot mind and eeriness gained from this study is indirect, given that users' eeriness was not examined. Research in a related field further supports the notion that perceived experience might not be a driving force underlying the feeling of eeriness: embodied conversational agents that expressed emotions were preferred over a non-experiencing, neutral counterpart (Creed, Beale, & Cowan, 2014).

A recent study on autonomous agents in a VR environment, however, supports the notion that mind perception elicits eeriness (Stein & Ohler, 2017). The question regarding which aspect of mind is linked to eeriness was not answered in this study, however, as the results could be driven by perceptions of experience, of agency, or perceptions of both. To complicate things further, others did not identify a relationship between both mind dimensions ascribed to a robot and the evaluation of the robot in terms of damage to humans and their identity (Ferrari, Paladino, & Jetten, 2016).

The differences between the available empirical results highlight the need for further empirical investigations. Thus, our first aim was to investigate the influence of experience and agency ascribed to a robot on users' eeriness. We predicted that a robot with experience as well as a robot with agency would elicit eeriness among (potential) users, with experience leading to most eeriness. Importantly, we further assumed that the influence of a robot's mind on user responses is crucially affected by moderating variables that determine whether a robot's experience, agency, or both elicits eeriness. The variables we focused on are introduced in the following.

1.3 The Role of Context, Robot Gender, and Users' Age

1.3.1 Nursing as a relevant context. A robot's field of application could moderate the influence of the mind dimensions on eeriness. Currently, elderly care and nursing are fields in which service robots are increasingly deployed (Archibald & Barnard, 2018; Locsin & Ito, 2018). In hospitals and retirement homes, however, emotional sensitivity and emotional intelligence are key affordances of successful work (e.g., Cadman & Brewer, 2001). Thus, in this important field of application, the experience of affect by robots could be perceived as rather appropriate for dealing with the tasks at hand (Stafford et al., 2014). We therefore assumed that the differences between the perceived eeriness of a robot with experience, a robot with agency, and a robot without mind would decrease in a nursing context.

1.3.2 Robot gender. Gender is one of the most salient attributes of humans and the development of humanoid robots has put questions about the impact of a robot's gender representation on the agenda (e.g., Carpenter et al., 2009; Eyssel & Hegel, 2012; Reich-Stiebert & Eyssel, 2015; Tay, Jung, & Park, 2014). Agency and experience are closely associated with expectations regarding both genders in person perception, with women expected to show experience, and men expected to show agency (cf. agency vs. communion, Bakan, 1966; competence vs. warmth, Fiske, Cuddy, & Glick, 2007; dominance vs. nurturance, Wiggins & Broughton, 1991; see Abele & Wojciszke, 2014, for an overview). People tend to respond to computers and robots as if they responded to other humans (computers as social actors; Nass, Steuer, & Tauber, 1994). In a seminal study on gender and robots, Eyssel and Hegel (2012) manipulated the perceived gender of a robot and demonstrated that a masculine robot was perceived as having more agency and less communion than a feminine robot. Prior research has shown that a match between a robot's gender and its task (and a match between its personality and task) yielded more positive attitudes and favorable perceptions than a mismatch (Tay et al., 2014). Many explanations of the uncanny valley involve a conflict between existing schemas and expectations (cf. Kätsyri et al., 2015). Given that the male or female gender of a robot elicits contrasting expectations regarding agency and communion or experience (Eyssel & Hegel, 2012), the influence of agency and experience ascribed to the robot on eeriness should vary with the robot's gender. If the robot's mind fit its gender (experience and female, agency and male), we would expect lower eeriness than when the robot's mind did not fit its gender.

1.3.3 Age. With respect to the user, age could be a variable to moderate the impact of robot minds. Most findings of the uncanny valley literature are based on samples of adolescents and young adults (e.g., Bartneck, Kanda, Ishiguro, & Hagita, 2009; Burleigh et al., 2013; Cheetham, Suter, & Jäncke, 2011; Gray & Wegner, 2012; Lischetzke et al., 2017). Some studies suggest that the reaction towards as well as the experience with robots might change with age—yet, the available evidence is somewhat inconclusive. For example, Liang and Lee (2017) found that age was a positive predictor of the fear of autonomous robots and artificial intelligence. However, other studies found contradicting evidence. Older age groups expressed less general anxiety towards humanoid robots in some studies (e.g., Nomura, Syrdal, & Dautenhahn, 2015), while in another study, age was unrelated to the quality of experience with a healthcare robot (Broadbent et al., 2010). In addition, besides the well documented age-related decline of, for example, processing speed or working memory, findings from the research group around Carstensen suggest that the experience of complex emotions increases with age (Carstensen et al., 2011) and that older adults show superior cognitive performance for emotional relative to non-emotional information (Charles, Mather, & Carstensen, 2003). In sum, age has played a substantial role in theory and research on the uncanny valley from early on (e.g., Ishiguro, 2007), but its impact on responses to robots with experience or agency is far from clear. Based on the growing importance of emotional stimuli over the course of a lifetime and higher wariness regarding new technologies (Gilly & Zeithaml, 1985; Mostaghel, 2016), older adults could show a particularly pronounced negative reaction (high eeriness) towards a robot with experience (as compared to a robot with agency or a control condition). In contrast, findings around the positivity effect suggest that as people get older, they experience fewer negative emotions and have more difficulty identifying others' negative emotions than younger adults (Carstensen & Mikels, 2005; Mather et al., 2004; Mather & Carstensen, 2005; Nomura & Nakao, 2010; Wong, Cronin-Golomb, & Neargarder, 2005). Following the latter reasoning, one might expect a different shape of the moderator effect of age, namely that older people experience less eeriness in the experiencer condition than in the other conditions. A similar pattern of results could emerge for participants in their late teens and early twenties, due to a particularly strong openness for new technologies (Gnambs & Appel, 2019).

1.4 Study Overview

Humanlike but not perfectly human robots are considered to fall into the uncanny valley (Mori, 1970), eliciting eeriness among human observers. The aim of our series of experiments was to examine the influence of experience and agency as theory-guided representations of human likeness (Gray et al., 2007; Gray & Wegner, 2012). Complementing prior work in which appearance or behavior of robots were manipulated (e.g., Hegel et al., 2008; Rosenthal-von der Pütten & Krämer, 2015), our aim was to maximize the internal validity of our agency and experience manipulation. To this end, we built our work on the attributes that defined agency and experience in previous work (Gray et al., 2007).

Using vignettes of future humanoid robots, we first tested the prediction that a robot with experience is eerier than a robot with agency, and we compared both robot mind conditions to a control condition in which the robot was merely a tool (Experiments 1A and 1B). In addition to eeriness, we examined the perceived femininity and masculinity of the robot (cf. Eyssel & Hegel, 2012), as well as behavioral intentions to interact with the robot. In describing the robots, we tried to follow closely the initial operational definitions of the mind perception dimensions (Gray et al., 2007). Importantly, the influence of agency and experience was examined under varying boundary conditions, regarding the field of application, the robot's gender, and users' age. In Experiment 2, we examined the role of the robot's field of application on the effect of robot minds. We contrasted a nursing context to an unspecified context. Experiment 3 focused on a robot's gender. We ascribed a male or a female name to the robot and investigated whether the influence of the robot's mind on eeriness differed between female and male robots. In a final set of analyses, the moderating influence of users' age was examined. Given the possibility of nonlinear effects of age, we examined linear as well as non-linear (quadratic) effects of users' age on the mind perception–eeriness link.

2. Experiments 1A and 1B

Experiments 1A and 1B were meant to investigate the effect of a robot's mind on users. The studies were conducted independently in two countries, the USA and Germany. We had no a priori assumptions regarding differences between US and German samples. By conducting the studies in two different countries (and two different languages), we sought to increase generalizability. Both studies adhered to a similar design; hence, the method and the results sections are presented together. Three descriptions of robots were constructed that represented a robot with experience, a robot with agency, and a robot without mind (robot-as-tool). Respondents' eeriness in response to the robot served as our main dependent variable, reflecting the assumed robot mind effects. In addition, manipulation check variables on the robot's experience and agency, and items on the robot's gender and behavioral intentions in response to the robot were included.

2.1 Method

2.1.1 Participants. The intended sample size for each study was a priori determined to be at least 84, required to detect a medium to large effect (f = .35) for the three-group omnibus ANOVA test (with alpha-error probability = .05, and beta-error probability = 0.20, cf. Faul, Erdfelder, Buchner, & Lang, 2009). In Experiment 1A, members of the MTurk participant pool from the US were invited and 101 participants completed the study. We inspected the data for careless responding using the time spent on the survey and a control question (Meade & Craig, 2012). Based on the descriptive data distribution of the total response times for the survey, four participants who needed less than 50 seconds to complete the questionnaire were excluded. An additional four participants did not recognize the name of the robot at the end of the survey, indicating low data quality.[1] These eight participants were excluded from all further analyses.

[1] The results remained virtually unchanged when the participants who failed to remember the name of the robot were included.

The remaining sample consisted of *n* = 93 US residents (48 female) with an average age of *M* = 34.55 years (*SD* = 10.75, age range 19 to 64 years). In Experiment 1B, 117 members of the German Clickworker participant pool completed the study online. The descriptive data distribution indicated that 70 seconds appeared to be a sensitive threshold in this sample, with less time spent signaling careless responding. Four participants needed less time to answer the questionnaire. One participant did not recognize the name of the robot at the end of the survey. The remaining sample consisted of 112 participants (50 female) with an average age of *M* = 37.41 years (*SD* = 10.63, age range 18 to 62 years).

2.1.2 Stimuli. The study was introduced to be about a new generation of robots. After asking for gender and age of the participant, a short description of a humanoid robot named ‘Ellix’ was presented. We showed one out of three descriptions by random assignment (similar to the descriptions of a “supercomputer” by Gray & Wegner, 2012, Study 2). One description introduced Ellix as a tool without mind (tool condition serving as a control condition), one introduced Ellix as a robot with agency (agency condition), and the third introduced Ellix as a robot with experience (experience condition). The descriptions included the attributes most characteristic of the agency and experience mind perception dimensions, as outlined by the principle component analysis conducted by Gray and colleagues (2007). In experiment 1B, the study material was translated into German using the committee scale translation method. The committee approach is a procedure derived from cross-cultural research to obtain a linguistically equivalent instrument, using a committee of bilinguals and experienced scholars fluent in both languages (Van de Vijver & Leung, 1997). The robots were introduced as follows (tool vs. agent vs. experiencer):

Tool condition: "Ellix is a robot with arms and hands to carry and to grasp things. Ellix assists people in their everyday chores. Ellix was developed with the ability to act on orders of an individual. The user can command the robot to execute actions."

Agency condition: "Ellix is a robot with arms and hands to carry and to grasp things. Ellix assists people in their everyday chores. Ellix was developed with the ability of self-control, morality, memory, and emotion recognition. Ellix has the capacity to plan ahead and to independently execute actions."

Experience condition: "Ellix is a robot with arms and hands to carry and to grasp things. Ellix assists people in their everyday chores. Ellix was developed with the ability to feel some form of hunger, fear, pain, pleasure, and other emotions. Ellix is characterized by consciousness and personality."

2.1.3 Measures

Perceived agency and perceived experience (manipulation check). Two items assessed the robot's agency as perceived by the participants ("This robot has the capacity to plan actions"; "This robot has the capacity to exercise self-control"; Experiment 1A: $\alpha = .80$; Experiment 1B: $\alpha = .84$). Both items were averaged. Two items assessed the robot's perceived experience ("This robot has the capacity to feel pain"; "This robot has the capacity to feel fear"; Experiment 1A: $\alpha = .96$; Experiment 1B: $\alpha = .90$). An average score of the two items was built. All four items originated from Gray and Wegner (2012) and went with a five-point scale ranging from *not at all* (1) to *extremely* (5).

Eeriness. We again followed Gray and Wegner (2012) and measured feelings of eeriness in response to the robot with the help of three items ("uneasy", "unnerved", "creeped out"). The items went with a five-point scale ranging from *not at all* (1) to *extremely* (5). The scores of the three items were averaged. The reliability of this eeriness scale was good (Experiment 1A: α = .96; Experiment 1B: α = .88).[2]

Additional measures. Experiment 1A included two questions about the robot's perceived masculinity and femininity ("How would you describe the robot? Ellix is...": "masculine" and "feminine"), both to be rated independently on a five-point scale from *not at all* (1) to *extremely* (5). Experiment 1B included three items on the behavioral intentions to interact with the robot ("I would avoid any contact with the robot" [reverse scored]; "I can imagine that I would buy such a robot"; "I would sign a petition to ban such robots"). Excluding the third item heightened the scale's reliability; thus, only the first two items were used to make up a scale (α = .71). All items were rated on a five-point scale from *not at all* (1) to *extremely* (5).

2.1.4 Procedure. The experiment started with sociodemographic questions. Next, the description of the robot was presented along with the eeriness scale. The additional measure followed. The experiment closed with the perceived agency/experience (manipulation check) items and a multiple choice-question on the name of the robot.

2.2 Results

2.2.1 Manipulation check. The results of the manipulation check indicated that the introductions elicited the intended representations of the robot among our participants. One-way analyses of variance revealed significant differences between the three conditions for both agency, Experiment 1A: $F(2, 90) = 25.53$, $p < .001$, $\eta_p^2 = .36$, Experiment 1B: $F(2, 109) = 30.86$, $p < .001$, $\eta_p^2 = .36$, and experience, Experiment 1A: $F(2, 90) = 33.46$, $p < .001$, $\eta_p^2 = .43$, Experiment 1B: $F(2, 109) = 46.07$, $p < .001$, $\eta_p^2 = .46$. Least Significant Difference (LSD) tests

[2] We acknowledge that there are other scales available to assess eeriness. We chose the present scale due to its briefness, its face validity, unidimensionality, and translatability to German. The semantic differential scale by Ho and MacDorman (2010; 2017), which is used by many scholars, is challenging from a psychometric perspective, as the anchors of the scale are semantically non-opposite adjectives.

revealed that the robot with agency (agent) was perceived to possess more agency (Experiment 1A: $n = 38$, $M = 3.82$, $SD = 0.99$; Experiment 1B: $n = 36$, $M = 4.24$, $SD = 0.79$) than the robot introduced as a tool (Experiment 1A: $n = 22$, $M = 1.86$, $SD = 0.89$; Experiment 1B: $n = 46$, $M = 2.34$, $SD = 1.27$), *p*s < .001, and more agency than the robot with experience (Experiment 1A: $n = 33$, $M = 3.03$, $SD = 1.13$; Experiment 1B: $n = 30$, $M = 2.90$, $SD = 1.12$), *ps* < .001. Robots with experience yielded higher experience ratings (Experiment 1A: $M = 3.21$, $SD = 1.31$; Experiment 1B: $M = 3.68$, $SD = 1.25$) than both the robot introduced as a tool (Experiment 1A: $M = 1.02$, $SD = 0.11$; Experiment 1B: $M = 1.38$, $SD = 0.76$), *p*s < .001), and the agentic robot (Experiment 1A: $M = 1.83$, $SD = 1.02$; Experiment 1B: $M = 1.99$, $SD = 1.14$), *p*s < .001.

2.2.2 Effect of mind on eeriness. Our main analysis focused on the eeriness ratings. As expected, eeriness differed between conditions in Experiment 1A, $F(2, 90) = 10.36$, $p < .001$, $\eta_p^2 = .18$[3], as well as in Experiment 1B, $F(2, 109) = 6.96$, $p = .001$, $\eta_p^2 = .11$. The robot with experience was perceived to be uncanniest (Experiment 1A: $M = 2.75$, $SD = 1.32$; Experiment 1B: $M = 2.46$, $SD = 1.04$), followed by the agent (Experiment 1A: $M = 2.14$, $SD = 1.09$; Experiment 1B: $M = 2.17$, $SD = 0.78$), while the robot introduced as a tool was perceived to be least uncanny (Experiment 1A: $M = 1.36$, $SD = 0.67$; Experiment 1B: $M = 1.70$, $SD = 0.89$). Follow-up comparisons (LSD tests) showed that in Experiment 1A all differences between the groups were significant, *p*s < .025. In Experiment 1B, eeriness was significantly lower in the tool condition than in the experiencer condition, $p < .001$, and in the agent condition, $p = .02$, but there was no significant difference between the experiencer and the agent conditions, $p = .19$.

[3] In addition to the ANOVAs reported in this manuscript, Brown-Forsythe tests were conducted which provide more conservative estimates in case the assumptions of homoscedasticity and normality of distributed residuals are violated (Brown & Forsythe, 1974). In all cases, the results of the Brown-Forsythe tests were equivalent to the ANOVA results.

2.2.3 Perceived femininity and masculinity (Experiment 1A) and behavioral intentions (Experiment 1B). Regarding the robot's perceived femininity and masculinity (Experiment 1A), all robot descriptions were rated equally masculine, $F(2, 90) = 1.04$, $p = .35$, $\eta_p^2 = .02$. Significant differences were revealed regarding the robot's supposed femininity, $F(2, 90) = 4.43$, $p = .01$, $\eta_p^2 = .09$. The experiencer robot was ascribed most feminine attributes (M = 3.12, SD = 0.89), followed by the agent (M = 2.89, SD = 1.18), and the tool (M = 2.27, SD = 1.03). Follow-up comparisons (LSD tests) showed that all differences between the groups were significant, ps < .03, except the difference between experiencer and agent, $p = .36$. The results regarding behavioral intentions (Tool: M = 3.80, SD = 0.94; Experiencer: M = 3.53, SD = 0.93; Agent: M = 3.35, SD = 1.05) revealed no significant difference between the three experimental conditions in Experiment 1B, $F(2, 109) = 2.29$, $p = .10$, $\eta_p^2 = .04$.

2.3 Discussion

The findings of both experiments provide support for the assumption that robots with mind elicit higher eeriness than robots without mind (cf. Stein & Ohler, 2017). Our results, obtained from two independent samples that worked on a survey in two different languages, further support the importance of distinguishing between agency and experience as dimensions of human and robotic minds (Gray et al., 2007). Most eeriness was elicited when robots incorporated the ability to feel (the experience dimension of mind perception), which is in line with prior research on computers (Gray & Wegner, 2012) and related expectations regarding robotic technologies (Wegner & Gray, 2016). A robot that incorporated agency, however, consistently yielded increased ratings of eeriness versus baseline as well, suggesting that agency contributes to humanoid robots' eeriness. This finding contradicts the results by Gray and Wegner (2012; Study 2), who examined responses to a "supercomputer" and found that a computer's agentic mind did not increase eeriness scores as compared to a computer without mind. Complementing prior research on robot gender, we showed that ascribing experience or agency determines the perceived femininity of the robot (cf. Eyssel & Hegel, 2012). Masculinity, however was unaffected (Experiment 1A). Moreover, the effect on eeriness did not translate to differences in behavioral intentions regarding the robots (Experiment 1B). After elucidating the general effect of robot minds on eeriness, our goal was to examine whether the effect of both mind dimensions would be attenuated in the applied setting of nursing and elderly care.

3. Experiment 2

In many relevant fields of application for service robots, emotions play a considerable role (e.g., sex work, nursing, education). The aim of our second experiment was to replicate and extend the findings of Experiments 1A and 1B by examining eeriness as a function of a robot's mind as well as of work context. We predicted that in the context of nursing, uncanny feelings regarding the experiencer robot would be reduced, as compared to an unspecified context, yielding a less pronounced difference between robots as tools, agents, and experiencers.

3.1 Method

3.1.1 Participants. In Experiment 2, members of the MTurk participant pool (restricted to US residents) were recruited. Based on the more complex design and in order to be able to identify small to medium moderation effects of the context in which the robot is presented, a larger number of participants than in Experiments 1A and 1B was aspired. The study was completed by 406 participants. To reduce the influence of careless responding, we excluded 15 participants who worked for less than 50 seconds on the survey, as well as five participants who did not recognize the name of the robot at the end of the survey. The final sample consisted of 386 participants (155 female) with an average age of 33.37 years (SD = 10.42, range 19 to 74 years). Two participants did not indicate their gender or age.

3.1.2 Stimuli. Using the same procedure as in Experiment 1, we presented descriptions of a robot named Ellix, which was introduced as a tool, an agent, or an experiencer. For half of the participants, we specified that the robot would fulfill tasks in the field of elderly health care, whereas the context was unspecified (as in Experiment 1) for the other half (see Appendix for the descriptions). In the nursing condition, the particular tasks of the robot were specified in one of two ways, either as to carry, grasp, and to feed the elderly or as to clean the elderly and everything around them. This variation was meant to improve the generalizability of our findings to the actual field of nursing, and it did not affect the findings. The experiment followed a 3 (robot mind: none/tool vs. agent vs. experiencer) x 2 (context: unspecified vs. nursing) between-subjects design.

3.1.3 Measures. The same scales as in Experiment 1A were employed. The eeriness scale showed good reliability ($\alpha = .93$). Again, we asked for the robot's femininity and masculinity. The items measuring agency and experience (used for the manipulation check) showed high internal consistency ($\alpha = .78$ and .94, respectively). All items went with a five-point scale ranging from *not at all* (1) to *extremely* (5).

3.2 Results

3.2.1 Manipulation check. The results of the manipulation check indicated that the descriptions of the robots elicited the intended representations among our participants (descriptive statistics are reported in Table 1). Two-way analyses of variance revealed a significant main effect of robot mind for both agency, $F(2, 380) = 89.10$, $p < .001$, $\eta_p^2 = .32$, and experience, $F(2, 380) = 130.08$, $p < .001$, $\eta_p^2 = .41$. The agent was perceived to possess more agency than both the tool and the experiencer. Robots with experience yielded higher experience ratings than both the robot introduced as a tool and the agentic robot (all ps $< .001$). Work context exerted a significant main effect on experience ratings, $F(1, 380) = 12.94$, $p < .001$, $\eta_p^2 = .03$, but no significant main effect on agency ratings, $F(1, 380) = 0.89$, $p = .34$. The interaction between the two factors was significant regarding the agency ratings, $F(2, 380) = 3.73$, $p = .025$, $\eta_p^2 = .02$. As Tukey post-hoc tests showed, agency ratings were larger in the agent condition than in the experiencer condition when the context was unspecified, t (380) = 4.77, $p < .001$, but agency ratings did not differ between the agent and the experiencer condition in the nursing context, t (380) = 0.93, $p = .939$. No significant interaction between the two factors was found for the experience ratings, $F(2, 380) = 2.73$, $p = .066$, $\eta_p^2 = .01$.

Table 1

Effects of robot mind and robot context on perceived eeriness, agency, experience, masculinity, and femininity ratings: Descriptive statistics (Experiment 2)

		n	Eeriness *M (SD)*	Agency *M (SD)*	Experience *M (SD)*	Masculinity *M (SD)*	Femininity *M (SD)*
Context: Unspeci-fied	Tool	71	1.76 (0.87)	2.04 (1.10)	1.24 (0.81)	2.77 (1.02)	2.66 (1.07)
	Agent	70	2.29 (1.08)	3.82 (1.04)	1.83 (0.96)	2.67 (1.13)	2.78 (1.14)
	Experiencer	52	2.86 (1.23)	2.92 (1.10)	3.29 (1.29)	2.60 (1.18)	2.54 (1.16)
Context: Nursing	Tool	72	1.94 (0.90)	2.10 (1.05)	1.20 (0.58)	2.51 (0.95)	2.99 (1.06)
	Agent	61	2.17 (1.09)	3.57 (0.92)	1.39 (0.66)	2.18 (0.83)	3.31 (1.12)
	Experiencer	60	2.36 (1.26)	3.40 (0.94)	2.76 (1.13)	2.15 (0.68)	3.43 (0.98)

3.2.2 Effect of mind and context on eeriness. Like in Experiment 1, our main focus was on eeriness (see Figure 1). A two-way analysis of variance revealed a significant main effect of the robot mind on eeriness, $F(2, 380) = 15.96$, $p < .001$, $\eta_p^2 = .08$, whereas the work context yielded no main effect, $F(1, 380) = 1.68$, $p = .20$, $\eta_p^2 = .004$. Importantly, the two-way interaction between the two factors was significant, $F\ (2, 380) = 3.24$, $p = .040$, $\eta_p^2 = .02$. In the unspecified context, the experiencer was perceived to be most uncanny, followed by the agent, while the robot introduced as a tool was perceived to be least uncanny, with $F(2, 380) = 16.12$, $p < .001$, $\eta_p^2 = .08$ for the simple main effect. In the unspecified context condition, all differences between the robot mind conditions (LSD) were significant, *p*s < .01. Yet, if put in a health care context, the simple main effect was not significant, $F(2, 380) = 2.53$, $p = .081$, $\eta_p^2 = .01$, and comparisons between single conditions indicated that the difference between experiencer and tool was significantly different from zero ($p = .026$), whereas the others were not (ps > .21). Looking at the simple main effects from the other experimental factor's perspective, in the tool condition the eeriness scores did not significantly differ between the unspecified and the nursing contexts $F(1, 380) = 1.12$, $p = .291$, $\eta_p^2 = .003$. Likewise context did not affect eeriness when the robot with agency was portrayed, $F(1, 380) = 0.38$, $p = .537$, $\eta_p^2 = .001$. For the robot with experience, however, eeriness was lower in the health care/nursing context than in the unspecified context, $F(1, 380) = 6.06$, $p = .014$, $\eta_p^2 = .016$.

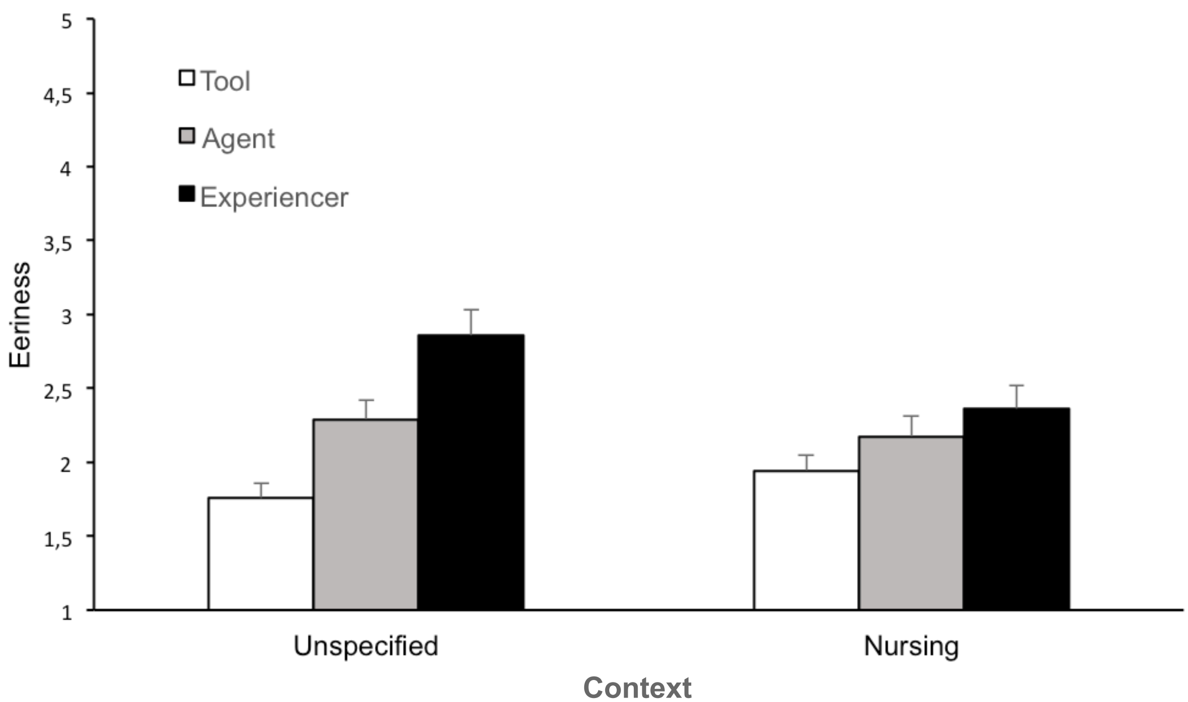

Figure 1. Eeriness in response to robots as tools, agents, and experiencers in an unspecified and in a nursing context (Experiment 2, means and standard errors of the mean)

3.2.3 Perceived femininity and masculinity. Regarding the robot's supposed masculinity, the robot mind yielded no significant main effect, $F(2, 379) = 2.87$, $p = .06$, $\eta_p^2 = .01$, whereas the work context of the robot did, $F(1, 379) = 15.69$, $p < .001$, $\eta_p^2 = .04$. Robots were ascribed less masculinity in the nursing context ($M = 2.30$, $SD = 0.85$) than in the unspecified context ($M = 2.69$, $SD = 1.10$). There was no indication for an interaction between the two factors, $F(2, 379) = 0.52$, $p = .60$, $\eta_p^2 = .003$. Parallel results were found for femininity: robot mind had no main effect, $F(2, 379) = 1.54$, $p = .22$, $\eta_p^2 = .008$, whereas the work context of the robot yielded a significant main effect, $F(1, 379) = 27.32$, $p < .001$, $\eta_p^2 = .07$. Robots were ascribed more femininity in the nursing context ($M = 3.23$, $SD = 1.07$) than in the unspecified context ($M = 2.67$, $SD = 1.12$). There was no indication for an interaction between the two factors, $F(2, 379) = 2.18$, $p = .11$, $\eta_p^2 = .011$.

3.3 Discussion

As expected, context mattered with respect to the eeriness of humanoid robots. In the unspecified context, the pattern of results found in our first set of experiments was replicated. Robots were uncanniest when their mind comprised experience, least uncanny when they had no mind at all, with agency falling in-between, eliciting more eeriness than robots in the control condition, but less eeriness than robots with experience. When the robot's work context was specified to be nursing, the effect of the robot mind manipulation was reduced. In particular, eeriness in the nursing context was reduced for robots who can feel. These findings corroborate the notion that robots with the same attributes can elicit more or less eeriness in different contexts (Tay et al., 2014). A substantial amount of the research on the uncanny valley is based on robotic stimuli that are placed in an unspecified environment (cf. Wang et al., 2015). The lack of context appears to be a remarkable caveat to this line of work.

In addition to our results on eeriness, we found that robots in a nursing context were ascribed more femininity and less masculinity than robots in an unspecified context. This result is in line with work on user's application of stereotypes regarding humans to robots (e.g., Bartneck et al., 2018; Eyssel & Hegel, 2012). Given the link between experience and female gender (and agency and male gender), we examined how a match/mismatch may affect users' eeriness in Experiment 3.

4. Experiment 3

Experience is the aspect of mind that is associated with the female gender role (e.g., *communion*, Bakan, 1966; *femininity*, Spence, Helmreich & Stapp, 1975; cf. Abele & Wojciszke, 2014), whereas agency is the aspect of mind that is associated with the male gender role (e.g., *agency*, Bakan, 1966; *masculinity*, Spence et al., 1975; cf. Abele & Wojciszke, 2014). In Experiment 1A, a robot with experience was rated to be most feminine. Given that the uncanny valley is often explained as a conflict between existing schemas and expectations, we tested the assumption that a robot with experience and female gender would be perceived to be less eerie than a robot with experience and male gender, whereas the effect of ascribed gender on eeriness should be reversed for robots with agency.

4.1 Method

4.1.1 Participants. Experiment 3 was again conducted online and US members of the MTurk participant pool were recruited. Of the 561 participants who finished the study, ten participants needed less than 50 seconds to complete the questionnaire, which indicated that these participants did not work on the survey thoroughly. An additional two participants did not answer the questions on several scales and were also excluded. Moreover, 45 participants did not remember the gender of the robot at the end of the survey, indicating low data quality (cf. Meade

& Craig, 2012). The remaining sample consisted of 504 US residents (237 female) with an average age of 34.33 years (*SD* = 10.51, range between 18 and 73 years).

4.1.2 Stimuli. Participants received a description of a new generation of robots like in the previous studies. In addition to the three different human likeness conditions, we manipulated the robot's supposed gender by changing its name. The participants were assigned to one out of three robot gender conditions (neutral vs. female vs. male). In the neutral condition, the robot's name was 'Ellix', while for the female condition one of five female names ('Emily', 'Madison', 'Emma', 'Olivia', 'Hannah') and for the male condition one of five male names ('Jacob', 'Michael', 'Joshua', 'Matthew', 'Daniel') was provided. The specific names were chosen because they were the five most popular female or male given names for newborns in the 2000s, based on US social security card application data (Social Security Administration, 2017). Thus, robot descriptions were identical to the descriptions of Experiment 1A except for the fact that for one third of the participants the robot's name was Ellix, for one third the robot had a female name, and for one third the robot had a male name.

4.1.3 Measures. The same scales and measures as in Experiment 1A and 2 were employed. The eeriness scale showed good reliability ($\alpha = .95$). The scales on perceived agency ($\alpha = .80$) and experience ($\alpha = .93$), which served as a manipulation check, were also internally consistent. Furthermore, we asked for the robot's femininity and masculinity with the same two items as before. Again, all items went with a five-point scale ranging from *not at all* (1) to *extremely* (5).

4.2 Results

4.2.1 Manipulation check. The results of the manipulation check indicated that the introductions were successful and elicited the intended representations of the robot's agency and experience in our participants. Significant differences between the tool, agent, and experiencer conditions were found for agency, $F(2,501) = 157.09$, $p < .001$, $\eta_p^2 = .38$, as well as for experience, $F(2,501) = 171.54$, $p < .001$, $\eta_p^2 = .41$. Robots in the agent condition ($M = 3.83$, $SD = 0.90$) were perceived to possess more agency than the robots in the experiencer condition ($n = 169$, $M = 2.95$, $SD = 1.02$), and those in the tool condition ($M = 1.94$, $SD = 1.00$), all *p*s < .001. Robots in the experiencer condition had higher experience ratings ($M = 3.16$, $SD = 1.24$) compared to robots in the agent ($M = 2.00$, $SD = 1.10$) and in the tool condition ($M = 1.15$, $SD = 0.45$), all *p*s < .001. The robot's gender (neutral vs. female vs. male name) neither affected agency, $F(2,501) = 1.58$, $p = .21$, $\eta_p^2 = .006$, nor experience, $F(2,501) = 2.41$, $p = .09$, $\eta_p^2 = .009$.

Robot gender had the intended effect on perceived femininity and masculinity, as the results showed significant differences for femininity, $F(2,501) = 79.31$, $p < .001$, $\eta_p^2 = .24$, and masculinity, $F(2,501) = 69.36$, $p < .001$, $\eta_p^2 = .21$, between the neutral, male, and female conditions. Robots with a female name were rated higher in femininity ($M = 3.46$, $SD = 1.21$) than robots with a male name ($M = 2.01$, $SD = .88$) or with a neutral name ($M = 2.49$ $SD = 1.10$), all *ps* < .001. Moreover, robots with a male name ($M = 3.22$, $SD = 1.17$) were perceived as more masculine than robots with a female name ($M = 1.88$, $SD = .87$) or a neutral name ($M = 2.71$ $SD = 1.13$), all *ps* < .001. No differences were found between the mind perception conditions for femininity, $F(2,501) = 0.27$, $p = 0.77$, $\eta_p^2 = .001$, and for masculinity, $F(2,501) = 0.12$, $p = 0.88$, $\eta_p^2 < .001$. Descriptive statistics for all conditions are displayed in Table 2.

Table 2

Effects of robot mind and robot gender on perceived eeriness, agency, experience, masculinity, and femininity ratings: Descriptive statistics (Experiment 3)

		n	Eeriness *M (SD)*	Agency *M (SD)*	Experience *M (SD)*	Masculinity *M (SD)*	Femininity *M (SD)*
Neutral Robot	Tool	56	1.50 (0.63)	1.93 (0.99)	1.11 (0.37)	3.09 (1.07)	2.41 (0.95)
	Agent	53	2.22 (0.86)	3.70 (0.97)	1.71 (0.96)	2.41 (1.10)	2.60 (1.23)
	Experiencer	62	2.25 (1.02)	2.96 (0.94)	3.20 (1.27)	2.61 (1.14)	2.45 (1.13)
Female Robot	Tool	61	1.73 (0.73)	1.98 (1.08)	1.17 (0.52)	1.82 (0.90)	3.36 (1.20)
	Agent	50	1.99 (0.91)	3.77 (0.89)	1.85 (0.98)	1.88 (0.96)	3.48 (1.33)
	Experiencer	57	2.33 (0.95)	2.94 (0.98)	2.99 (1.20)	1.93 (0.75)	3.56 (1.12)
Male Robot	Tool	48	1.74 (0.77)	1.88 (0.92)	1.16 (0.44)	3.15 (1.27)	1.85 (0.77)
	Agent	67	2.24 (0.91)	3.97 (0.84)	2.34 (1.21)	3.25 (1.06)	2.13 (0.97)
	Experiencer	50	2.26 (1.03)	2.95 (1.17)	3.29 (1.26)	3.26 (1.21)	2.00 (0.86)

4.2.2 Effect of mind and ascribed gender on eeriness. Like in Experiments 1 and 2, our main focus was on eeriness. The mind of a robot yielded a significant effect, $F(2,495) = 24.12$, $p < .001$, $\eta_p^2 = .088$, whereas the gender of the robot did not, $F(2,495) = 0.51$, $p = .60$, $\eta_p^2 = .002$. The two-way interaction between both factors was not significant, $F(4,495) = 1.25$, $p = .33$, $\eta_p^2 = .009$. Robot mind influenced the eeriness of a female robot, $F(2,165) = 7.24$, $p < .001$, $\eta_p^2 = .081$, as well as the eeriness of a male robot, $F(2,162) = 5.37$, $p < .01$, $\eta_p^2 = .062$. Follow-up comparisons for the mind factor showed that the robot without mind (tool, $M = 1.65$, $SD = 0.72$) was perceived to be significantly less eerie than the robot with experience ($M = 2.28$, $SD = 0.99$)

and the robot with agency ($M = 2.16$, $SD = 0.89$), ps < .001. The difference between the experiencer and the agent conditions was not significant, $p = .13$.

4.3 Discussion

Gender is one of the defining characteristics in the perception of other humans. When the distinction of social content in two dimensions is applied (cf. Abele & Wojciszke, 2014), women are associated with communion or experience, whereas men are associated with agency (Bakan, 1966; Spence et al., 1975). Given that social categories for humans tend to be applied to computers and robots as well (Nass et al., 1994) – including category of gender (e.g., Eyssel & Hegel, 2012) – the eeriness of a robot's mind was assumed to vary with the robot's gender. In contrast to our expectations, however, a feeling robot named Emily (or Hannah or Olivia) was not less eerie than a feeling robot named Jacob (or Michael or Daniel). Likewise, the male agentic robot provoked neither lower nor higher eeriness than the female agentic robot. Thus, simply giving a robot a female name does not reduce its eeriness, even if experience is its prominent characteristic.

5. Agents, Experiencers, and Participants' Age

Several authors have suggested that the uncanny valley could be a function of the participants' age (e.g., Ishiguro, 2007; Kuo et al., 2009; Stein & Ohler, 2017), but the nature and direction of this effect is unclear. Therefore, we analyzed the data from Experiments 2 and 3 to test whether age moderates the effect of a robot's mind (tool vs. agent vs. experiencer) on eeriness. We refrained from building arbitrary age groups and examined both linear and nonlinear (quadratic) interaction effects (we did not test this moderator hypothesis on data from Experiments 1A and 1B, because the sample size was limited and much smaller than in Experiments 2 and 3).

5.1 Method of Data Analysis

The data from Experiments 2 and 3 was analyzed separately to be able to investigate whether a potential moderator effect of age replicates across studies. The data of two participants from Experiment 2 were excluded from the analyses because they did not indicate their age. Thus, the analyses were based on a sample of 384 participants in Experiment 2 who were between 19 and 74 years old (*M* = 33.37; *SD* = 10.42), and on 504 participants in Experiment 3 whose age ranged between 18 and 73 years (*M* = 34.33; *SD* = 10.51).

To test whether age moderates the effect of robot mind on eeriness in a linear or quadratic fashion, we conducted moderated regression analyses. We used two dummy-coded indicator variables for the robot mind factor (reference category: experiencer) and we centered the continuous variable age before calculating quadratic terms for age and interaction terms with the dummy variables. We specified a linear model (i.e., a model including a linear effect of age on eeriness as well as interactions between the linear age term and the dummy variables):

$$Eerie_i = \beta_0 + \beta_1 * Tool_i + \beta_2 * Agent_i + \beta_3 * Age_i + \beta_4 * (Tool_i * Age_i) + \beta_5 * (Agent_i * Age_i) + \varepsilon_i \quad (1)$$

and a quadratic model (i.e., a model including both a linear and a quadratic term for age as well as interactions between the linear and quadratic age terms and the dummy variables):

$$Eerie_i = \beta_0 + \beta_1 * Tool_i + \beta_2 * Agent_i + \beta_3 * Age_i + \beta_4 * Age^2{}_i + \beta_5 * (Tool_i * Age_i) + \beta_6 * (Agent_i * Age_i) + \beta_7 * (Tool_i * Age^2{}_i) + \beta_8 * (Agent_i * Age^2{}_i) + \varepsilon_i$$

(2)

For both datasets, we tested whether there was a moderating effect of age and whether the quadratic model (2) fitted the data better than the linear model (1).

5.2 Results and Discussion

The results of the moderator analyses are presented in Table 3.[4] In Experiment 2, there was no significant difference between the linear and the quadratic model, $F(3, 375) = .72$, $p = .54$. In the linear model, we found no age effects on eeriness in the experiencer condition (main effect of age) and no interaction effects between age and robot mind.[5] In Experiment 3, the quadratic model showed a significantly better fit to the data than the linear model, $F(3, 495) = 2.89$, $p = .034$. In Experiment 3, there was a significant quadratic relationship between age and eeriness in the experiencer condition (main effect of the quadratic term of age), $b = .001$, $t(495) = 2.34$, $p = .020$. Moreover, the interaction between the quadratic term of age and the tool dummy variable (representing the difference between the tool and the experiencer condition) was significant, $b = -.002$, $t(495) = -2.94$, $p = .003$. To gain more insight into the form this interaction effect took, we plotted the predicted curves for each experimental condition. As shown in Figure 2, the difference in eeriness between robots without minds (robots-as-tools) and robots with experience were more pronounced for young as well as old participants than for middle-aged participants.

[4] For Experiment 2, we also tested a model which additionally included the experimental nursing context factor. There was no interaction between the linear or quadratic terms of age and nursing context, and no three-way interactions between age, nursing context, and robot mind. Therefore, we did not include this model in the results section.

[5] There was a significant interaction effect between age and the tool indicator variable in the quadratic model. However, given that the quadratic model did not fit the data better than the linear model and given that the interaction between age and the tool indicator variable was not significant in the linear model, we refrained from interpreting this age*tool interaction effect that turned significant in the quadratic model (possibly due to suppressor effects).

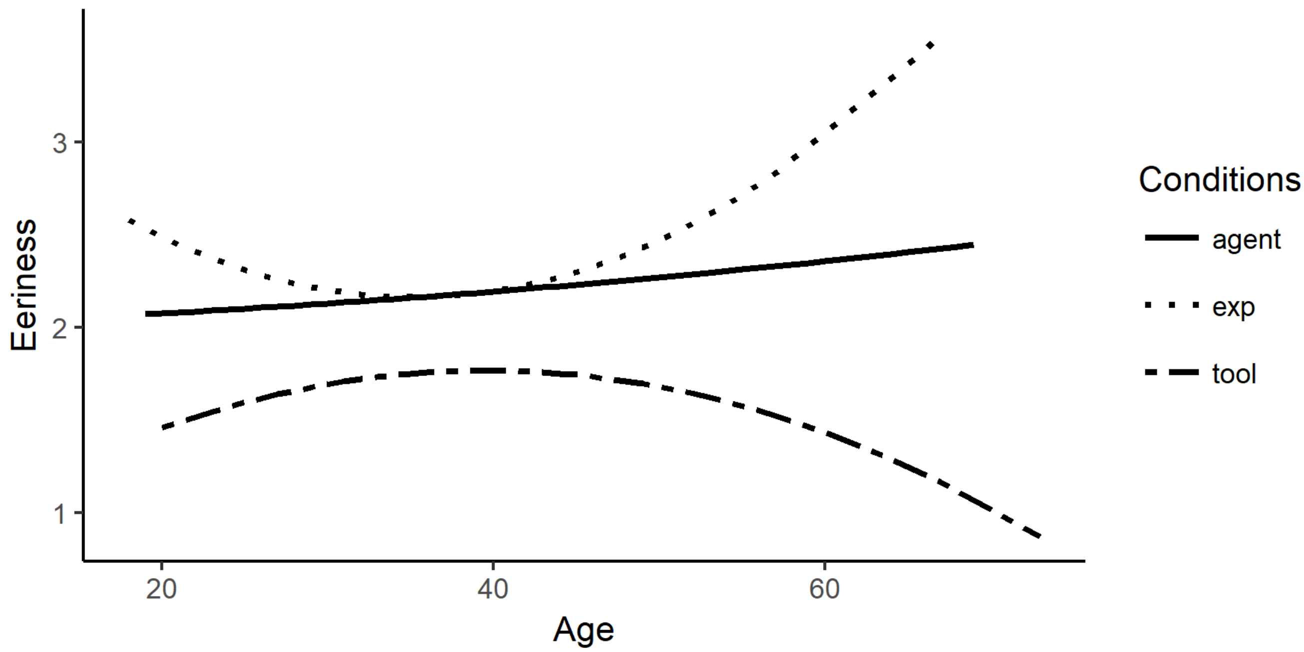

Figure 2. Eeriness in response to robots in the tool, agent, and experiencer condition. Quadratic interaction with age (Experiment 3)

The latter findings need to be interpreted with caution, as the moderator effect of age was only found in one of the two datasets we analyzed. We consistently found no support for a linear effect of age on eeriness. These findings are in contrast to the assumption that the relatively higher eeriness of experiencer robots decreases with participants' age. As a caveat of our findings, it needs to be noted that our sample was recruited via MTurk, and therefore, did not comprise the complete age range. It mainly included individuals in the young old-age segment (65-74 years of age), but few fell into the old segment (75-84 years) and no one belonged to the oldest-old age segment (85 years and above). Thus, these results hold only for a younger segment of the older adult population. Moreover, further research is needed to draw a distinction between age and cohort effects in an ever-changing technological environment.

Table 3a

Results of the age effect analysis in Experiment 2 for the linear and quadratic model

Predictors	*b*	*SE b*	*b* 95 % CI [LL,UL]	β	β 95 % CI [LL,UL]	*R*	R^2
Linear Model						0.282	.0793**
Intercept	2.584**	0.102	[2.384 , 2.784]				
Tool	-0.737**	0.136	[-1.004, -0.470]	-0.321	[-0.437, -0.204]		
Agent	-0.354**	0.139	[-0.627, -0.081]	-0.151	[-0.267, -0.034]		
Age	0.014	0.009	[-0.005, 0.033]	0.131	[-0.043, 0.305]		
Tool x Age	-0.018	0.013	[-0.044, 0.007]	-0.101	[-0.243, 0.041]		
Agent x Age	-0.013	0.013	[-0.039, 0.013]	-0.072	[-0.212, 0.069]		
Quadratic Model							
Intercept	2.669**	0.121	[2.431 , 2.908]			0.291	.0845**
Tool	-0.877**	0.171	[-1.213, -0.540]	-0.381	[-0.528, -0.235]		
Agent	-0.449**	0.171	[-0.785, -0.113]	-0.191	[-0.334, -0.048]		
Age	0.028	0.014	[0.000 , 0.056]	0.262	[-0.003, 0.526]		
Age^2	-0.001	0.001	[-0.002, 0.000]	-0.146	[-0.367, 0.076]		
Tool x Age	-0.038*	0.019	[-0.075, -0.001]	-0.210	[-0.415, -0.004]		
Tool x Age^2	0.001	0.001	[-0.001, 0.003]	0.138	[-0.060, 0.336]		
Agent x Age	-0.028	0.019	[-0.065, 0.009]	-0.153	[-0.353, 0.047]		
Agent x Age^2	0.001	0.001	[-0.001, 0.003]	0.093	[-0.098, 0.283]		

Note. Experiment 2: N = 384. Experiencer was used as reference category. b = unstandardized regression weight; β = standardized regression weight.. 95% CI = 95% confidence interval.

* $p < .05$; ** $p < .01$

Table 3b

Results of the age effect analysis in Experiment 3 for the linear and quadratic model

Predictors	*b*	*SE b*	*b* 95 % CI [LL,UL]	β	β 95 % CI [LL,UL]	*R*	R^2
Linear Model						.307	.0943
Intercept	2.295**	0.068	[2.162 , 2.429]				
Tool	-0.636**	0.097	[-0.826, -0.446]	-0.326	[-0.424, -0.228]		
Agent	-0.133	0.096	[-0.321, 0.056]	-0.068	[-0.166, 0.029]		
Age	0.010	0.008	[-0.005, 0.025]	0.112	[-0.058, 0.282]		
Tool x Age	-0.014	0.010	[-0.033, 0.005]	-0.100	[-0.235, 0.036]		
Agent x Age	-0.003	0.010	[-0.022, 0.017]	-0.018	[-0.151, 0.114]		
Quadratic Model							
Intercept	2.165**	0.087	[1.994, 2.336]			.330	.109
Tool	-0.420**	0.121	[-0.658, -0.181]	-0.215	[-0.337, -0.093]		
Agent	-0.009	0.124	[-0.253, 0.235]	-0.005	[-0.130, 0.121]		
Age	-0.003	0.009	[-0.020, 0.015]	-0.029	[-0.234, 0.176]		
Age^2	0.001*	0.001	[0.000, 0.003]	0.298	[0.052, 0.543]		
Tool x Age	0.011	0.013	[-0.015, 0.037]	0.078	[-0.106, 0.262]		
Tool x Age^2	-0.002**	0.001	[-0.004, -0.001]	-0.351	[-0.586, -0.117]		
Agent x Age	0.009	0.013	[-0.016, 0.034]	0.062	[-0.110, 0.233]		
Agent x Age^2	-0.001	0.001	[-0.003, 0.000]	-0.189	[-0.399, 0.020]		

*Note. Experiment 3: N = 504. Experiencer was used as reference category, b represents unstandardized regression weights; β indicates the standardized regression weights; LL and UL indicate the lower and upper limits of a confidence interval, respectively. * $p < .05$; ** $p < .01$*

6. General Discussion

In many societies around the world, intelligent personal assistants (such as Siri and Alexa), autonomous vehicles, and smart homes have become part of people's everyday lives or are projected to be mass phenomena in the very near future. Humans have a tendency to ascribe mind to non-human entities (Gray et al., 2007) and they sometimes respond to computer technologies in ways similar as to real social beings (Nass et al., 1994). With the proliferation of these smart systems and increasing computational power, it is relevant to understand users' responses to these humanlike but non-human systems. Responses to these technologies may provide insight to basic human experience and behavior and they are relevant for creators and marketers.

The technological innovation in the field that is arguably most challenging for theory and research in the social sciences (as well as for legislators, e.g., EU Directorate-General for Internal Policies, 2016) are humanoid service robots, meant to provide sexual pleasure, to accomplish tasks in military operations, or to assist in hospitals or nursing homes. A dominant framework to predict user responses to humanoid robots is the uncanny valley hypothesis, positing that humanlike but not perfectly human robots elicit feelings of eeriness among (future) users (Mori, 1970; Wang et al., 2015). According to a recent perspective at understanding the eeriness of humanoid robots, this negative response is a function of perceiving mind in a machine (Gray & Wegner, 2012; Stein & Ohler, 2017; Wegner & Gray, 2016). Based on a two-dimensional approach to mind perception (Gray et al., 2007; Tanibe et al., 2017), it has been assumed more specifically that humanoid robots with experience elicit eeriness because experience or emotions are exclusively associated with the concept of humans. Agency, the second mind perception dimension, however, was considered to be unrelated to eeriness (Gray & Wegner, 2012; Wegner & Gray, 2016). User responses to a future supercomputer provided initial evidence for this assumption (Gray & Wegner, 2012), but findings in an applied context were somewhat contradictory (Stafford et al., 2014). If experience but not agency would be responsible for the uncanny valley phenomenon, this would not only inform theory, but it could also have important implications for the design and the marketing of future robots.

A series of four experiments was conducted, to test the impact of a robot's agency and experience on eeriness, including moderation effects of the context in which the robot is set, its gender, and users' age. In all of our experiments, we found that a robot with experience elicited stronger feelings of eeriness than a robot without mind. In our initial two experiments (Experiments 1A and 1B), we further found that a robot with agency elicited stronger feelings of eeriness than a robot without mind. Whereas the results on robots who can feel corroborate previous research (Gray & Wegner, 2012), the latter result is novel in demonstrating that both dimensions of mind perception can elicit eeriness and both may be responsible for the eeriness of humanoid robots examined in uncanny valley research. The subsequent experiment (Experiment 2) showed that the impact of a robot's mind on eeriness is reduced when the robot is set in a nursing context, particularly, a robot with experience is perceived to be less eerie when its task is to feed or to clean in a nursing context than to operate without the given context. Recognizing the role of context could be important for other research questions on the uncanny valley hypothesis as well. For roboticists and HRI developers, our results suggest that it might not be feasible to work towards general design implications in the field of social robotics; instead, we consider it more reasonable to identify different „sets“ of robot characteristics that work more or less in different contexts.

Despite the strong link between experience and agency attributions and gender (e.g., Bakan, 1966; Fiske et al., 2007; Spence et al., 1975), ascribing female or male gender to a robot had no attenuating effect on the eeriness of robotic minds (Experiment 3). Today, the distinction between male and female is still one of the most influential categories in human-human perception (Ellemers, 2018). Prior research shows that a robot's gender affects human responses to the robot as well (e.g., Eyssel & Hegel, 2012). Our findings indicate, however, that stereotypical expectations about a robot's gender cannot override the general influence of the robot mind dimensions. In our final analyses, the moderating influence of participants' age was examined. Findings were mixed, as the influence of robot mind on eeriness was unrelated to respondents' age in Experiment 2. The same analysis conducted for the data of Experiment 3, however, yielded a significant quadratic interaction, suggesting that the difference between robots with experience and with no mind at all is smallest between the ages of 30 and 50 with larger differences at an earlier or older age. This finding is in contrast to hopes that robots that elicit eeriness for many elicit rather low eeriness among individuals of young old age and older.

The design of our series of experiments was focused on testing the influence of experience and agency on users' eeriness in a most internally valid manner. To this end, we used the attributes that defined both dimensions (Gray et al., 2007) in our description of a future generation of robots. Our research was not aimed at identifying factors that lead users to ascribe experience and agency in the first place. Wang and Krumhuber (2018), for example, showed that the proposed function of a robot (social vs. sales) affects the ascribed experience of the robot. The embodiment of an artificial character is another factor that likely influences ascriptions of mind. Hoffmann and colleagues (2018) proposed that embodiment predicts the perceived attributes of nonverbal expressiveness, (shared) perceptions, mobility, tactile interaction, and corporeality (physical existence) which in turn determine user responses. Research is encouraged to enrich our understanding as to how embodiment factors change ascribed agency and experience.

Our series of studies provided novel insights, but limitations need to be noted. First, our studies were based on vignettes, that is, descriptions of a new generation of robots, which were varied to manipulate the mind of the robot (along with its occupational role, and its gender in Experiments 2 and 3). This methodological approach had been used in closely related work before (Gray & Wegner, 2012, Study 2) and we believed that a textual description of a robot's mind provides the most exact operationalization of both dimension of mind that drove our research questions (Gray et al., 2007). Much of the research on the uncanny valley is based on images of robots and or morphs between humans and robots (Wang et al., 2015). Such visual stimuli are arguably able to elicit perceptions of mind, but a differentiation between agency and experience that adheres to theoretical distinctions is difficult to fathom. We need to acknowledge that the description of the robot in the tool condition was shorter than the description of the robot in both other conditions. We have no indication that the differences between the conditions were a function of the mere amount of attributes of the robot. That said, future research should strive for constant length or complexity. Moreover, our experimental design did not include a condition in which robots are ascribed both agency and experience. Stein and Ohler (2017) compared agents with both, agency and experience, to agents who were programmed by humans (similar to the tool condition) showing that the former elicited more eeriness. Users' responses to robots with agency and experience – as compared to robots with only one component – are still to be examined.

Second, our approach to mind perception closely followed earlier theory. Our description of the robot with agency included the characteristics of self-control, morality, memory, emotion recognition, and planning, whereas the robot with experience was characterized by hunger, fear, pain, pleasure, consciousness, personality, and other emotions. These descriptors were almost identical to the attributes that founded each of the mind perception factors in the principal component analysis presented by Gray and colleagues (2007). We believe that our distinction between the agency and experience dimensions of mind perception and the operationalization of robots that are closely aligned to the descriptions of the mind perception dimensions makes our work readily accessible to the research community. Our findings, however, do not rule out the feasibility of alternative conceptions of mind (e.g., potential one-, three-, or more-dimensional solutions which would be based on different markers of mind). On a related note, our findings do not rule out the possibility that some characteristics within a mind dimension (e.g., morality) could elicit more eeriness than others (e.g., memory; morality and memory are both constituents of agency).

Last, all experiments were conducted online, using participant pools such as MTurk and Clickworker. People who are actively involved in an online participant pool might show higher levels of openness towards innovation or technology. Further, all participants were recruited in Western cultures (i.e., the US and Germany). In addition to the limited age distribution discussed above, these aspects limit the generalizability of our findings.

7. Conclusion

Connecting research on mind perception and research on the uncanny valley hypothesis, we showed that a humanoid robot who can feel (experience) as well as a humanoid robot who can think and plan ahead (agency) elicit more eeriness than a robot without mind (robot-as-tool), with experience yielding highest eeriness. This supports previous findings on the eeriness of robots with feelings, but theory and practice should acknowledge that robots with agency do elicit eeriness as well. The effects of a robot's mind are attenuated when a nursing context is introduced. A robot's gender had no influence on the eeriness of robots with minds. Non-linear effects of participants' age on the robot mind-eeriness link were found, but need corroboration.

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Appendix

Descriptions of Robots with Mind and Context manipulated (Experiment 2)

Note: Participants were randomly assigned to read one out of the following descriptions and to indicate how they feel when thinking about the robot. Note that the “Carry and Grasp” and the “Cleaning” variants were developed to increase the generalizability of the results. They did not show any different effects. Thus, the results for these conditions were collapsed.

Tool / Unspecified Context / Carry and Grasp

Ellix is a robot with arms and hands to carry and to grasp things. Ellix assists people in their everyday chores.

Ellix was developed with the ability to act on orders of an individual. The user can command the robot to execute actions.

Tool / Unspecified Context / Cleaning

Ellix is a robot with arms and hands to clean things. Ellix assists people to keep their surroundings tidy.

Ellix was developed with the ability to act on orders of an individual. The user can command the robot to execute actions.

Tool / Nursing / Carry and Grasp

Ellix is a nursing robot with arms and hands to carry and to grasp things. Ellix assists elderly people who are in need of support. One of its main tasks is to feed people.

Ellix was developed with the ability to act on orders of an individual. The user can command the robot to execute actions.

Tool / Nursing / Clean

Ellix is a nursing robot with arms and hands to clean things. Ellix assists elderly people who are in need of support. One of its main tasks is to keep the elderly and everything around them tidy.

Ellix was developed with the ability to act on orders of an individual. The user can command the robot to execute actions.

Agent / Unspecified Context / Carry and Grasp

Ellix is a robot with arms and hands to carry and to grasp things. Ellix assists people in their everyday chores.

Ellix was developed with the ability of self-control, morality, memory, and emotion recognition. Ellix has the capacity to plan ahead and to independently execute actions.

Agent / Unspecified Context / Cleaning

Ellix is a robot with arms and hands to clean things. Ellix assists people to keep their surroundings tidy.

Ellix was developed with the ability of self-control, morality, memory, and emotion recognition. Ellix has the capacity to plan ahead and to independently execute actions.

Agent / Nursing / Carry and Grasp

Ellix is a nursing robot with arms and hands to carry and to grasp things. Ellix assists elderly people who are in need of support. One of its main tasks is to feed people.

Ellix was developed with the ability of self-control, morality, memory, and emotion recognition. Ellix has the capacity to plan ahead and to independently execute actions.

Agent / Nursing / Cleaning

Ellix is a nursing robot with arms and hands to clean things. Ellix assists elderly people who are in need of support. One of its main tasks is to keep the elderly and everything around them tidy.

Ellix was developed with the ability of self-control, morality, memory, and emotion recognition. Ellix has the capacity to plan ahead and to independently execute actions.

Experiencer / Unspecified Context / Carry and Grasp

Ellix is a robot with arms and hands to carry and to grasp things. Ellix assists people in their everyday chores.

Ellix was developed with the ability to feel some form of hunger, fear, pain, pleasure, and other emotions. Ellix is characterized by consciousness and personality.

Experiencer / Unspecified Context / Cleaning

Ellix is a robot with arms and hands to clean things. Ellix assists people to keep their surroundings tidy.

Ellix was developed with the ability to feel some form of hunger, fear, pain, pleasure, and other emotions. Ellix is characterized by consciousness and personality.

Experiencer / Nursing / Carry and Grasp

Ellix is a nursing robot with arms and hands to carry and to grasp things. Ellix assists elderly people who are in need of support. One of its main tasks is to feed people.

Ellix was developed with the ability to feel some form of hunger, fear, pain, pleasure, and other emotions. Ellix is characterized by consciousness and personality.

Experiencer / Nursing / Cleaning

Ellix is a nursing robot with arms and hands to clean things. Ellix assists elderly people who are in need of support. One of its main tasks is to keep the elderly and everything around them tidy.

Ellix was developed with the ability to feel some form of hunger, fear, pain, pleasure, and other emotions. Ellix is characterized by consciousness and personality.