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Reducing the uncanny valley by dehumanizing humanoid robots

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ABSTRACT

Humanoid robots are often experienced as unnerving, a psychological phenomenon called the "uncanny valley." Past work reveals that humanlike robots are unnerving in part because they are ascribed humanlike feelings. We leverage this past work to provide a potential solution to the uncanny valley. Three studies reveal that "dehumanizing" humanoid robots—stripping robots of their apparent capacity for feelings—can significantly reduce the uncanny valley. Participants high on trait dehumanization (Study 1) or experimentally instructed to dehumanize (Study 2) reported lower feelings of uncanniness when viewing a humanoid robot, an effect mediated by reduced perceptions of feelings. We replicate these effects in an experimental field study where hotel guests interacted with real humanoid robots in Japan, and reveal that dehumanization reduces the uncanny valley without decreasing customers' satisfaction (Study 3).

Humans have long sought to create robots that look human. In 1495, Leonardo Da Vinci created a mechanical knight (Moran, 2006) and more recently Hollywood movies have imagined robots that can speak, walk, and act as if they were humans. Recent technological advances are turning our imagination into reality, with robots now guiding tourists in airports (Joosse & Evers, 2017), helping doctors perform surgeries (Berlyand et al., 2018), and assisting guests in stores (Corkery, 2020). Humanoid robots provide an important advantage over non-humanoid robots as "they provide a sense of familiarity and helps humans empathize with the machines" (Wagner, 2017).

However, there is a pitfall to humanoid robots: the more machines look human, the more they seem to find them creepy and revolting, a phenomenon referred to as the "uncanny valley" (Mori, 1970). The uncanny valley appears across various robots, perceivers, and cultures, and—as with any complex psychological phenomenon—there are many contributors to these feelings of unease, including low-level feature abnormalities in humanoid robots such as unnatural skin coloring and abnormal eyes (Seyama & Nagayama, 2007), general ambiguity about the category humanoid robots belong to (Weis & Wiese, 2017), the resemblance of humanoid robots to dead people (Mori, MacDorman, & Kageki, 2012) and the violation of expectations about how facial features should be arranged (MacDorman, Green, Ho, & Koch, 2009).

One explanation for the uncanny valley is that humanoid robots are unnerving because they seem to possess a humanlike mind. Although robots may not truly have a humanlike mind, ample work suggests that minds are often *perceived* (Epley & Waytz, 2010; Wegner & Gray, 2016). Whether someone—or something—has a mind is often in the eye of the beholder. A popular theory of mind perception suggests that people perceive minds along the two dimensions of *agency* and *experience* (Gray, Gray, & Wegner, 2007). Agency refers to the ability to think, plan, and act, whereas experience is the ability to feel emotions and bodily sensations, such as hunger, pleasure, and pain (Gray et al., 2007; Gray & Wegner, 2012).

Studies reveal that perceptions of experience are seen as both more essentially present in humans (Haslam, Bain, Douge, Lee, & Bastian, 2005) and as essentially lacking in machines (Gray & Wegner, 2012). For this reason, a robot perceived to have experience—the capacity for feelings and emotions—should be evoke the uncanny valley. This hypothesis has been confirmed by a variety of studies (Gray & Wegner, 2012; Shank, Graves, Gott, Gamez, & Rodriguez, 2019). Robots are unnerving when they are perceived to have the capacity for humanlike emotions, whether because of their appearance, their actions, or simply how they are described.

The mind perception explanation of the uncanny valley suggests that the humanlike features of humanoid robots—which can be unsettling by themselves—also prompt people to see humanlike minds, which most essentially involve the ability to feel and have conscious experience (Schein & Gray, 2015). Although humans can spontaneously perceive

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some levels of agency in robots (Gray et al., 2007), perceiving experience in robots conflicts with people's explicit knowledge that robots—as mere machines—lack these humanlike mental capacities, and this mismatch creates an affective aversion (Gray & Wegner, 2012; Shank et al., 2019). We note that this explanation is consistent with both the perceptual features (MacDorman et al., 2009) and category ambiguity (Weis & Wiese, 2017) explanations of the uncanny valley, which both emphasize a violation of expectations.

If the increased perception of experience in machines can increase feelings of uncanniness, then perhaps *decreasing* perceptions of experience can *decrease* feelings of uncanniness. In other words, by stripping away from humanlike robots their misplaced ability feel and sense, we may help to eliminate the uncanny valley (Wang, Lilienfeld, & Rochat, 2015; Złotowski, Proudfoot, & Bartneck, 2013). Here we explore this "reduced mind perception" strategy of uncanny valley mitigation.

Much past work has examined how people fail to perceive minds in other people. Although human beings clearly have rich mental lives, it is quite easy for people to strip away these minds, at least in their perceptions. This process of reduced mind perception in other people is called "dehumanization" (Haslam et al., 2005)—a term that highlights the essential role of mind in making us human. Importantly, like mind perception, dehumanization progresses along two dimensions (Haslam, 2006). These are termed "animalistic dehumanization" and "mechanistic dehumanization," each of which are roughly tied to different dimensions of mind perception.

Animalistic dehumanization is defined as a process in which "[entities] are denied qualities that are considered to distinguish them from animals—qualities such as refinement, self-control, intelligence, and rationality" (Christoff, 2014, p. 748). These uniquely human capacities are similar to "agency" in mind perception terms. Denying someone these mental abilities licenses people to treat others as livestock or other animals.

In contrast, mechanistic dehumanization is a process by which "[entities] are likened to objects or automata and are denied qualities such as warmth, emotion, and individuality"—qualities which are seen as essential to human nature (Christoff, 2014, p. 748). In other words, mechanistic dehumanization denies the ability to have experience, and leads targets to be seen as emotionally unresponsive and socially unconnected. Denying someone these mental abilities licenses people to treat others as unfeeling threats, as people did with prisoners of war (Haslam, 2006). Given that past work has established experience perceptions to be key in the uncanny valley process (Gray & Wegner, 2012), we focus on mechanistic dehumanization (hereafter as dehumanization), which primarily reduces an entity's experience.

Dehumanization can lead to negative outcomes among interpersonal and intergroup contexts such as dislike, distrust, and systematic harm—include genocide (Haslam, 2006). However, here we explore whether the process of dehumanization can have *positive* consequences for the uncanny valley. Dehumanization is seen as bad in people because people *do* have minds and so we should not strip those minds away. Conversely, humanlike robots — at least today's humanlike robots — do *not* have minds, and so we may be better off stripping away any misplaced perceptions of mental capacity. Specifically, we examine whether engaging in mechanistic dehumanization, which involves seeing others as mere machines, can reduce the experience of the uncanny valley with humanlike robots. In other words, we investigate whether stripping away the capacity for experience in humanlike robots can decrease feelings of uncanniness.

We report three studies that test whether dehumanization—specifically regarding ascriptions of experience—can reduce feelings of uncanniness in humanoid robots. Study 1 examines whether individual differences in dehumanization predict feelings of uncanniness, as mediated by reduced perceptions of experience. Studies 2 and 3 explore whether manipulations of dehumanization can decrease feelings of uncanniness, both among Americans watching videos of humanoid robots (Study 2) and Japanese tourists interacting with real humanoid robots at the Henn na Hotel, the world's first robot-staffed hotel in Sasebo, Japan (Study 3).

All data and syntax could be anonymously assessed online.[1] We reported all measures and manipulations. We included attention check items in Studies 1 and 2 and only a handful of participants failed them (*Ns* = 12 and 26, respectively). Removing them did not affect the analyses and hence we chose not to exclude any participants in all studies.

1. Study 1: correlational evidence

This study examined whether individual differences in the tendency to dehumanize predicted feelings of uncanniness after watching a video of a humanoid robot that has previously been used to induce the uncanny valley (Gray & Wegner, 2012). We also assessed perceptions of experience and agency, predicting that experience (but not agency) would mediate the relation between dehumanization and uncanniness. We also measured anthropomorphism, which some have argued is the opposite tendency to dehumanization (e.g., Schroeder & Epley, 2016; Waytz, Epley, & Cacioppo, 2010); whereas dehumanization is the stripping away of mind from entities who have it, anthropomorphism is the conferral of mind to entities that lack it. According to our theory, those high on anthropomorphism should report stronger feelings of uncanniness, which would lend converging support for our hypotheses regarding dehumanization.

1.1. Method

Participants (N = 299; M_{age} = 31.69, SD = 11.90; 47.5% female; 63.2% White, all Americans recruited from Prolific) first completed trait dehumanization and anthropomorphism scales (counterbalanced order). Participants then watched a 12-s video of Kaspar, a humanoid robot specifically designed to engage others in social interactions (see Fig. 1 for a video still) and has been used in prior psychological research on uncanny valley and human-robot interaction (e.g., Gray & Wegner, 2012). In the video, Kaspar displayed movement but did not engage in specific tasks or speak. Finally, participants rated Kaspar's agency, experience, and uncanniness.

1.2. Measures

See Appendix A for full measures and materials.

1.2.1. Dehumanization

We assessed participants' trait dehumanization with four items from the dehumanization sub-scale of moral disengagement (Detert, Treviño, & Sweitzer, 2008; 1 = strongly disagree to 7 = strongly agree). This scale was first developed by Bandura, Barbaranelli, Caprara, and Pastorelli (1996) and required adaption because the original dehumanization items were developed for children. This scale has been widely used in organizational behavior (e.g., Reynolds, Dang, Yam, & Leavitt, 2014). A sample item is "Some people deserve to be treated like animals."

1.2.2. Anthropomorphism

We measured trait anthropomorphism with Waytz, Cacioppo, and Epley's (2010) 15-item scale (1 = strongly disagree to 7 = strongly agree). This scale is the most well-established individual difference measure of anthropomorphism and was validated with thousands of subjects across eight studies in Waytz, Cacioppo, and Epley (2010). A sample item is "The average mountain has free will."

[1] https://osf.io/u8m9x/?view_only=1b5d7d621d3344ac840fc70527c030c9.

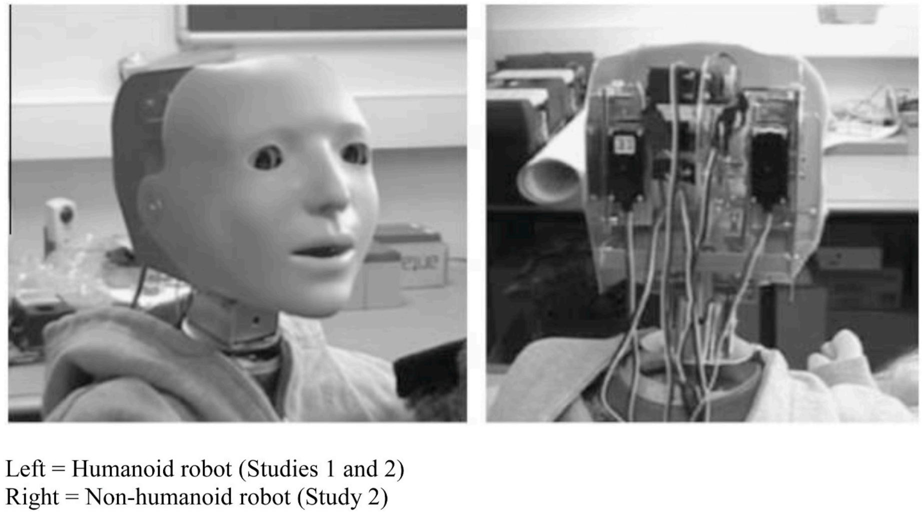


Fig. 1. Video stills in Studies 1 and 2. Left = Humanoid robot (Studies 1 and 2). Right = Non-humanoid robot (Study 2).

1.2.3. Agency

We measured perceived agency with four items based on Bigman and Gray (2018); 1 = strongly disagree to 7 = strongly agree).[2] The scales for agency and experience have been used in multiple research areas and yielded meaningful results, including organizational behavior (Tang & Gray, 2018; Yam et al., 2020; Yam, Fehr, Burch, Zhang, & Gray, 2019), moral judgments (Gray et al., 2007; Gray, Jenkins, Heberlein, & Wegner, 2011), child development (Brink, Gray, & Wellman, 2019), and psychopathology (Gray et al., 2011). Agency and experience are multifaceted constructs, and items from these two scales tap into the wide scope of each dimension, as demonstrated in prior research. A sample item is “the robot can think.”

1.2.4. Experience

We measured perceived experience with four items based on Bigman and Gray (2018); 1 = strongly disagree to 7 = strongly agree). A sample item is “the robot can feel pain.”

1.2.5. Uncanniness

We measured perceived uncanniness with three items from Gray and Wegner (2012); 1 = not at all to 7 = extremely). Uncanniness is often described as an unsettling emotional state. We did not use the word “uncanny,” and instead used the words “uneasy,” “unnerved,” and “creeped out” because they should be more familiar and less ambiguous to lay people.

1.3. Results

Table 1 shows the descriptive statistics and the correlations among the study variables.

We first tested whether dehumanization is directly and indirectly associated with uncanniness via perceptions of experience with regression analyses and bootstrapping indirect effect tests. As predicted, dehumanization had a significant and negative direct effect on uncanniness ($\beta = -0.20$, $t = -3.43$, $p = .001$). Using Hayes’ (2015) PROCESS model (5000 bootstrap samples), we find that dehumanization also had an indirect effect on uncanniness via perceptions of experience (coefficient = −.05, $SE = 0.02$, 95% CI = −0.10 to −0.01; Fig. 2a), such that the higher people were on trait dehumanization the less experience they attributed to the robot and the less uncanniness they experienced.

Revealing convergent evidence, anthropomorphism also impacted uncanniness both directly and indirectly via perceptions of experience. A regression revealed that trait anthropomorphism had a significant and positive effect on uncanniness ($\beta = 0.13$, $t = 2.33$, $p = .020$); using Hayes’ (2015) PROCESS model we also find that anthropomorphism exerted a positive indirect effect on uncanniness via increased perceptions of experience (coefficient = 0.15, $SE = 0.04$, 95% CI = 0.08 to 0.26; Fig. 2b). In other words, the higher people were on trait anthropomorphism, the more experience they attributed to the robot and the more uncanniness they experienced.

2. Discussion

Study 1 reveals that participants high in trait dehumanization reported lower levels of uncanniness when evaluating a humanoid robot, and this decrease in uncanniness is partially mediated by a decrease in perceived experience. Likewise, trait anthropomorphism is associated with higher levels of uncanniness when evaluating a humanoid robot, and this increase in uncanniness is fully mediated by an increase in perceived experience. In our next study we manipulate dehumanization to test for its causal effects in reducing uncanniness.

3. Study 2: experimentally inducing dehumanization

Participants first went through either a dehumanization manipulation or not. We then showed them a clip of either a humanoid or non-humanoid robot. We predict that manipulated dehumanization would reduce uncanniness when viewing a humanoid robot, as a result of reduced experience perceptions.[3]

3.1. Method

3.1.1. Power analysis and pre-registration

A power analysis (conducted with G*Power 3.1.9.2) revealed that a sample size of 779 participants is needed for achieving power of 0.8 to detect an effect size of $\eta_p^2 = 0.01$. The study was pre-registered.[4]

[2] All statistically significant results remain significant with or without controlling for agency. As such, we presented all results without this control.

[3] Due to an oversight, in the pre-registration we did not specify clearly that we were hypothesizing a first-stage moderated mediation model. Instead, the pre-registration depicted a simple mediation model without taking robot type into account.

[4] https://osf.io/y628h?view_only=b0347502c4ae4d37a8497be5b532eb9f.

Table 1
Descriptive statistics and correlations for study variables (study 1).

Variable	Mean	SD	1	2	3	4	5
1. Dehumanization	2.00	1.14	(0.85)				
2. Anthropomorphism	2.95	0.92	0.07	(0.88)			
3. Agency perceptions	3.31	1.55	0.06	0.37**	(0.86)		
4. Experience perceptions	2.04	1.30	-0.13*	0.31**	0.33**	(0.96)	
5. Uncanniness	2.59	1.42	-0.20**	0.13*	0.01	0.32**	(0.96)

Alpha coefficients for each scale are presented in the parentheses * $p < .05$ ** $p < .01$.

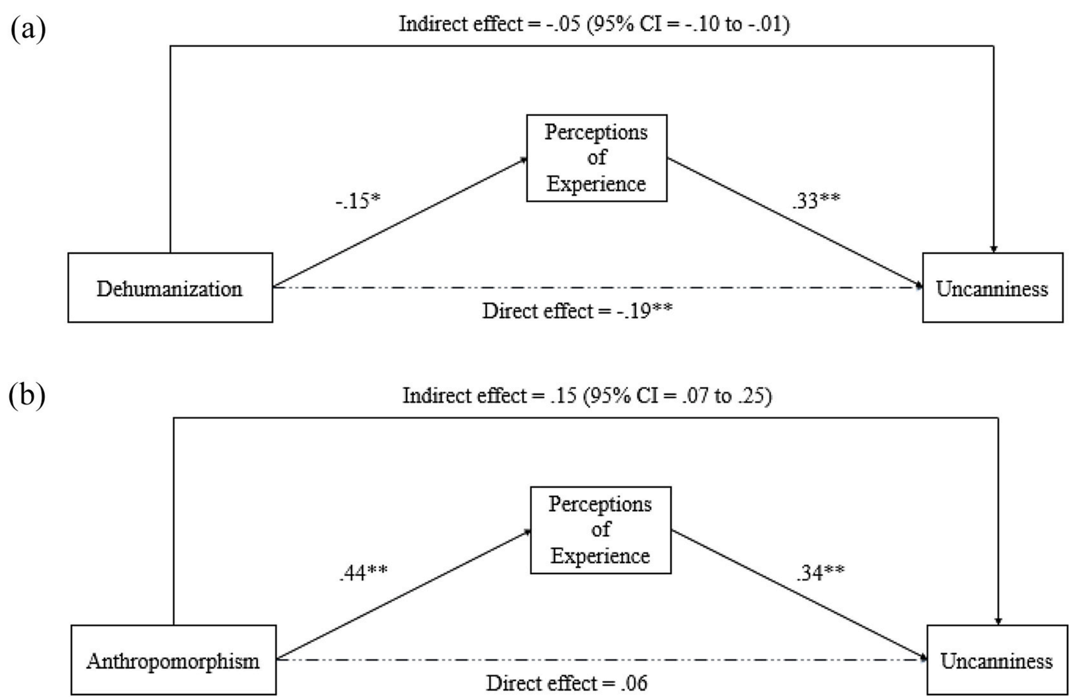


Fig. 2. (a) Mediation effect of dehumanization in Study 1. (b) Mediation effect of anthropomorphism in Study 1. *p < .05; **p < .01.

3.2. Participants and procedure

Participants ($N = 782$; $M_{age} = 32.13$, $SD = 16.14$; 49.6% female, 67% White, all Americans recruited from Prolific) were randomly assigned to one of four conditions in a 2 (type of robot: non-humanoid vs. humanoid) x 2 (dehumanization: control vs. present) between-subjects design. Although we manipulated dehumanization in a binary fashion in our experiment, we acknowledge that in the real-world it often is a continuous rather than binary progress. All participants were told they would evaluate a robot. Before viewing the robot, participants in the dehumanization condition read the following statement (participants in the control condition immediately viewed the video clip)[5]:

Although advanced robots can look similar to humans, they lack the most essential of human qualities-the ability to feel. Robots cannot experience love, desire, or any other emotions. They completely lack the ability to feel pain or pleasure. Unlike people, robots are not conscious; there is nothing that it is like to be them. Robots are merely a collection of cold silicon circuits.

In the humanoid robot condition, participants were shown the same 12-s clip of the humanoid robot Kaspar as in Study 1. In the non-humanoid condition, participants were shown a 12-s clip of Kaspar with a mechanical appearance (see Fig. 1). After watching the short clip, participants rated Kaspar's agency, experience, and uncanniness with the same scales used in Study 1.

3.3. Results

Table 2 shows the descriptive statistics and the correlations among the study variables.

3.3.1. Agency and experience

We first tested whether the dehumanization and robot type manipulations affected perceptions of agency and experience. A two-way ANOVA predicting perceptions of experience from dehumanization and robot type reveals that robot type affected perceptions of experience, $F(1,778) = 14.52$, $p < .001$, $\eta_p^2 = 0.02$, such that participants attributed more experience to the humanoid robot ($M = 1.98$, $SD = 1.37$) than the non-humanoid robot ($M = 1.66$, $SD = 1.05$). We also find a significant effect for dehumanization, $F(1,778) = 51.84$, $p < .001$, $\eta_p^2 = 0.06$, such that participants perceive the robots as having more

[5] We ran a pre-test to examine whether our dehumanization manipulation worked. Participants (N = 100, 9 did not complete the all DVs, final $N = 91$, 51.6% male, 47.3% female, 1.1% other/preferred not to disclose; Age: $M = 36.27$, $SD = 12.99$) first saw the image of the humanoid robot from Study 2. They then rated on a 0 to 100 scale the statement: "robots should have human rights" as a manipulation check. After that, participants read the dehumanization manipulation. Finally, participants rated again their agreement with the manipulation check statement – "robots should have human rights". A paired-sample t-test revealed that indeed, post the dehumanization manipulation, participants rated robots as less deserving human rights ($M = 12.71$, $SD = 22.96$) than pre-manipulation ($M = 18.38$, $SD = 28.89$), $t(90) = 3.03$, $p = .003$, Cohen's $d = 0.32$. These results provide evidence that indeed our dehumanization manipulation worked.

Table 2
Descriptive statistics and correlations for study variables (study 2).

Variable	Mean	SD	1	2	3	4	5
1. Type of robot	0.50	0.50	(–)				
2. Dehumanization	0.50	0.50	0.00	(–)			
3. Agency perceptions	3.16	1.43	0.05	0.02	(0.86)		
4. Experience perceptions	1.82	1.23	0.13**	-0.25**	0.26**	(0.97)	
5. Uncanniness	2.19	1.21	0.32**	-0.15**	-0.01	0.31**	(0.95)

Type of robot: 0 = control; 1 = humanoid.
Dehumanization: 0 = control; 1 = Dehumanization.
Alpha coefficients for each scale are presented in the parentheses.
**$p < .001$.

experience in the control condition ($M = 2.13$, $SD = 1.41$) than in the dehumanization condition. ($M = 1.52$, $SD = 0.92$). Finally, we find a significant robot type x dehumanization manipulation interaction, $F(1,778) = 6.07$, $p = .014$, $\eta_p^2 = 0.01$, such that the effect of dehumanization on perceived experience was larger for the humanoid robot (control: $M = 2.39$, $SD = 1.63$; dehumanization: $M = 1.58$, $SD = 0.90$, $p < .001$, $\eta_p^2 = 0.06$) than the non-humanoid robot (control: $M = 1.86$, $SD = 1.12$; dehumanization: $M = 1.46$, $SD = 0.93$, $p = .001$, $\eta_p^2 = 0.01$; Fig. 3).

A two-way ANOVA predicting perceptions of agency from dehumanization and robot type does not find a significant effect for robot type ($p = .178$), dehumanization ($p = .359$) or their interaction ($p = .647$). These results suggest that our manipulations were successful in changing the robots perceived experience (but not agency).

3.3.2. *Uncanniness*

A two-way ANOVA predicting uncanniness from dehumanization and robot type reveals that robot type affected uncanniness, $F(1,778) = 94.39$, $p < .001$, $\eta_p^2 = 0.11$, such that participants reported more uncanniness from the humanoid robot ($M = 2.59$, $SD = 1.31$) than the non-humanoid robot ($M = 1.80$, $SD = 0.96$), supporting the basic premise of the uncanny valley. We also find a significant effect for dehumanization, $F(1,778) = 20.39$, $p < .001$, $\eta_p^2 = 0.03$, such that participants reported less uncanniness in the dehumanization condition ($M = 2.01$, $SD = 1.13$) than in the control condition. ($M = 2.37$, $SD = 1.26$). Finally, we find a significant robot type x dehumanization manipulation interaction, $F(1,778) = 10.60$, $p = .001$, $\eta_p^2 = 0.01$, such that the effect of dehumanization on uncanniness was significant for the humanoid robot (control: $M = 2.90$, $SD = 1.28$; dehumanization: $M = 2.27$, $SD = 1.27$, $p < .001$, $\eta_p^2 = 0.04$), but not for the non-humanoid robot ($p = .371$; see Fig. 4).

3.3.3. *Mediation by perceived experience*

Finally, we tested whether perceptions of experience mediate the interaction's effect on uncanniness. Using Hayes' (2018) first-stage moderated mediation PROCESS model (Model 7), we entered robot type as the independent variable, perceptions of experience as the mediator, dehumanization as the first-stage moderator, and uncanniness

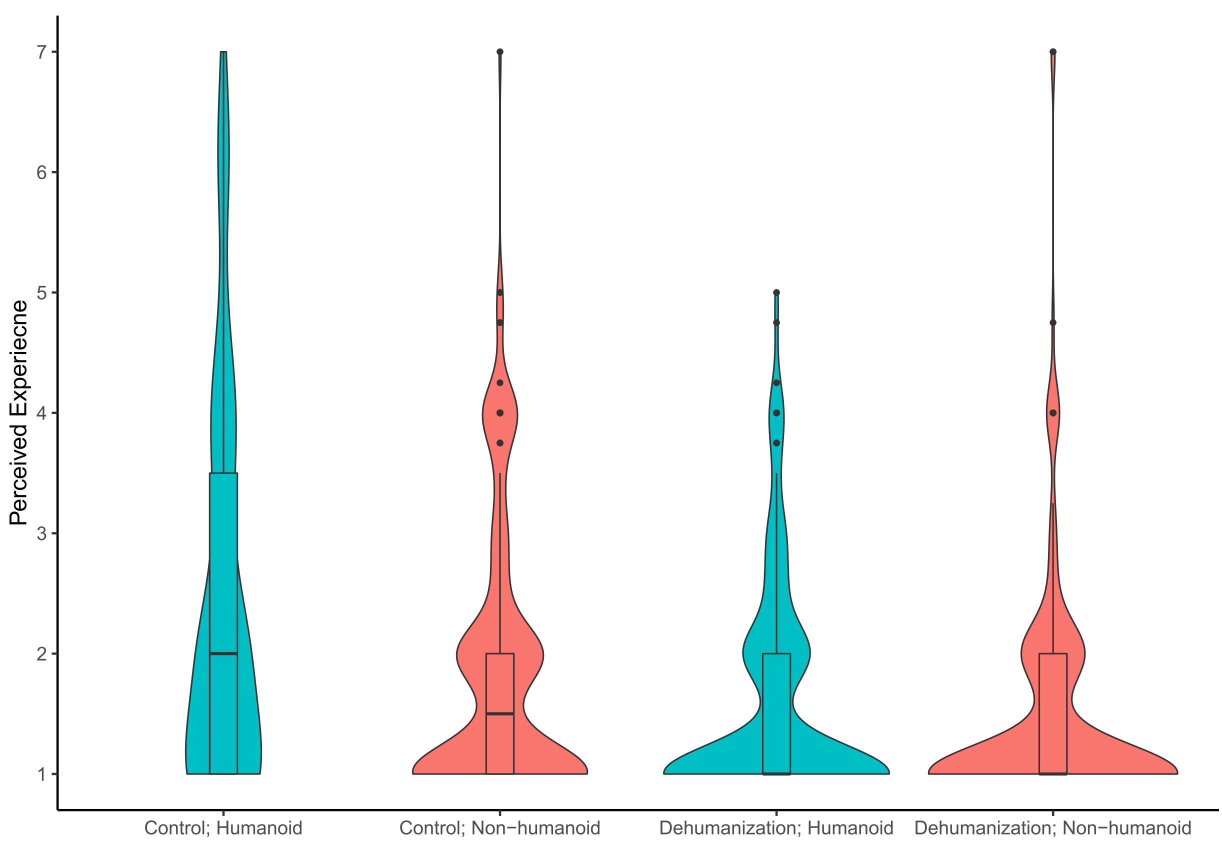


Fig. 3. Effect of dehumanization manipulation and robot type perceived experience (Study 2). Violin plots depict the density of the distribution, and box plots the interquartile range and average.

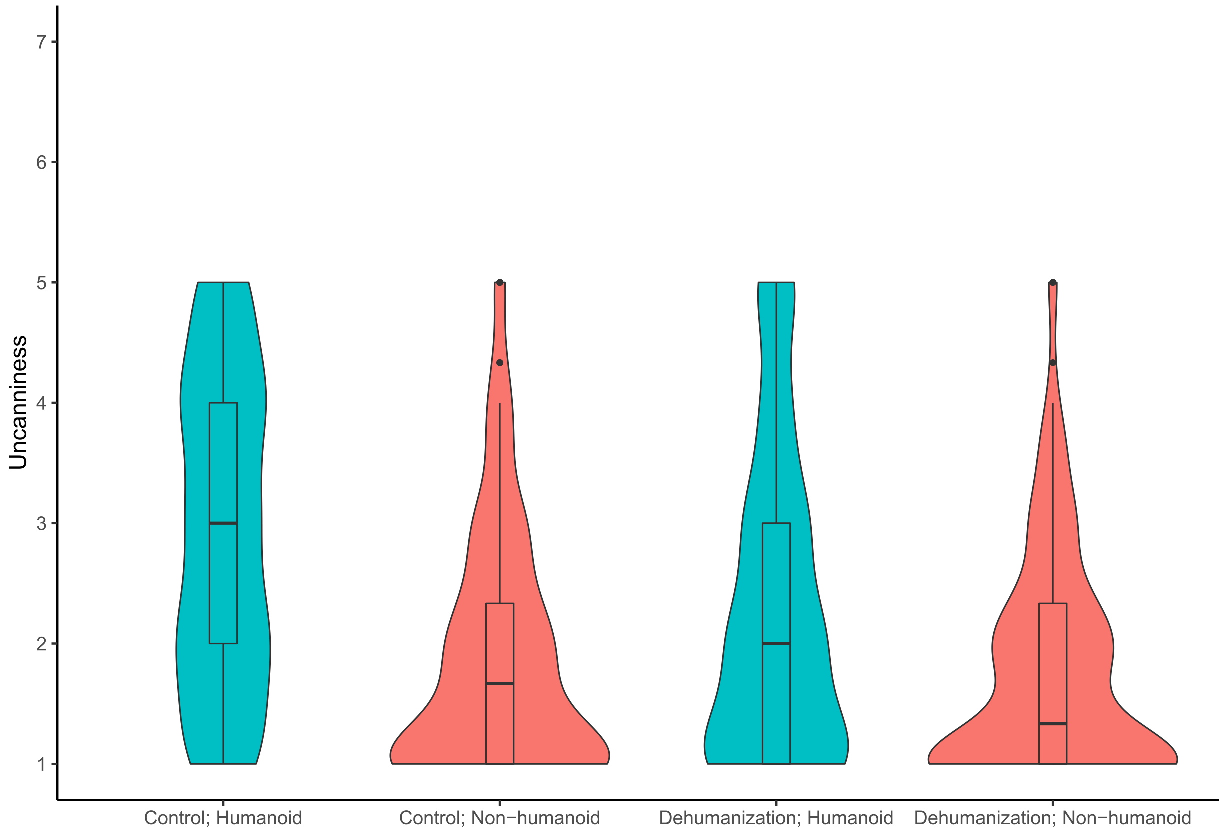


Fig. 4. Effect of dehumanization manipulation and robot type on uncanniness (Study 2). Violin plots depict the density of the distribution, and box plots the interquartile range and average.

as the dependent variable. We found that in the control condition, the indirect effect of robot type on uncanniness via perceived experience was significant (coefficient = 0.14, *SE* = 0.05, 95% CI = 0.06 to 0.24). However, in the dehumanization condition, the indirect effect was not significant (coefficient = 0.03, *SE* = 0.03, 95% CI = −0.02 to 0.06). The difference between the indirect effect in the control condition and the indirect effect in the dehumanization condition is likewise significant (index of moderated mediation = −0.11, *SE* = 0.05, 95% CI = −0.22 to −0.02), suggesting that participants who dehumanized the humanoid robot experienced lower levels of uncanniness as a result of lower perceived experience (relative to those who did not receive the dehumanization manipulation). We note that all of the effects on uncanniness hold when controlling for perceived agency. Furthermore, when entering perceived agency rather than perceived experience in the mediation analysis, none of the mediations are significant. This suggests that perceived experience, and not general mind perception, is related to uncanniness.

4. Discussion

Study 2 provides causal evidence supporting our hypotheses that dehumanizing humanoid robots can mitigate the uncanny valley by reducing perceived experience. However, these results have some limitations. Mainly, the use of videos and images of robots and the use of an online Western sample, which might have a more negative attitudes towards robots (Tett, 2019), and may not be generalizable to other cultures and populations (Henrich, Heine, & Norenzayan, 2010). To address these issues, in Study 3 we tested our theory with a field experiment.

5. Study 3: field experimental test

5.1. Participants and procedures

We collected data from Henn na Hotel (http://www.h-n-h.jp/en/), the world's first robot-staffed hotel (Guinness World Record, 2015). With over 200 rooms, this hotel only employs 11 full-time human employees (see Appendix B for additional information about the hotel). Instead, the vast majority of daily hotel operations, from customer check-in and luggage storage to room services, are all handled by robotic "employees." We recruited as many hotel guests as possible (N = 349, M_{age} = 34.36; *SD* = 13.30; 53.6% female) and compensated each participant with ¥1000 (~$9) over the span of four days (which determined our sample size).

As in Study 2, participants were randomly assigned to one of four conditions in a 2 (type of robot: non-humanoid vs. humanoid) x 2 (dehumanization: control vs. present) between-subjects design. When guests first walked in the hotel, we randomly assigned participants to either a dehumanization condition or a control condition. In the dehumanization condition, guests were greeted by a research assistant who provided them with the following statement:

Welcome to Henna Hotel! As you may know in our hotel you will be served by a variety of robots. We hope you enjoy your stay. Here, you will check in with one of our receptionist robots. Before you do, we wanted to tell you that although advanced robots can behave similarly to humans, they lack the most essential of human qualities – the ability to feel. Robots cannot experience love, desire, or any other emotions. Robots are merely a collection of cold silicon circuits; there are merely means to enhance our hotel's operation.

In the control condition, guests were greeted by the following statements:

Welcome to Henna Hotel! As you may know in our hotel you will be served by a variety of robots. We hope you enjoy your stay. Here, you will check in with one of our receptionist robots.

Immediately after this verbal manipulation, participants were randomly assigned to check in either with a humanoid or a non-humanoid robot (see Fig. 5 and a sample video for the check-in process). When guests approached near the robot, motion sense would trigger the robot to speak and a holographic interface would appear. The robot then proceeded to greet the guests in four different languages and provide check-in instructions. The guests then had to select options using the holographic interface to complete the check-in process. Once they are done, our research assistants approached them again to complete the survey. All survey measures were translated by a native Japanese speaker, and then back translated by a native English speaker who is also a professional Japanese language instructor (Brislin, 1980).[6]

We measured perceived agency, experience, and uncanniness with the same scales used in Studies 1–2. As a manipulation check of our dehumanization manipulation, at the end of the study we asked participants to report whether robots should have human rights (1 = definitively no to 5 = definitively yes). Participants in the dehumanization condition reported significantly lower ratings for robots' human rights ($M = 2.03$, $SD = 1.49$) compared to the control condition ($M = 3.11$, $SD = 1.72$), $t(347) = 6.23$, $p < .001$, $d = 0.67$. Furthermore, to account for differences of the two types of robot other than human-likeness, we asked participants to rate how novel the check in robot was with three items (i.e., the check-in robot was novel/original/new to me, Cronbach's $\alpha = 0.78$). Perceived novelty did not differ between the non-humanoid robot ($M = 4.21$, $SD = 1.40$) and the humanoid robot ($M = 4.35$, $SD = 1.28$, $t = -0.95$, $p = .341$). We also asked participants how satisfied they were to the check-in robot with three items (see Appendix A). Finally, we asked each participant to indicate whether he/she was the primary person interacting with the robotic receptionist during the check-in process (0 = no; 1 = yes). Whether participants were the primary person interacting with the robotic receptionist did not affect perceptions of the robot's agency, experience, novelty, satisfaction, or uncanniness ($ps > .126$).[7]

5.2. Results

Table 3 shows the descriptive statistics and the correlations among the study variables.

5.2.1. Agency and experience

We first tested whether the dehumanization and robot type manipulations affected perceptions of agency and experience. A two-way ANOVA predicting perceptions of experience from dehumanization and robot type reveals that robot type affected perceptions of experience, $F(1,345) = 25.83$, $p < .001$, $\eta_p^2 = 0.07$, such that participants attributed more experience to the humanoid robot ($M = 2.48$, $SD = 1.64$) than the non-humanoid robot ($M = 1.74$, $SD = 1.10$). We also find a significant effect for dehumanization, $F(1,345) = 7.09$, $p = .008$, $\eta_p^2 = 0.02$, such that participants perceive the robots as having more experience in the control condition ($M = 2.30$, $SD = 1.58$) than in the dehumanization condition. ($M = 1.91$, $SD = 1.26$). Finally, we find a significant robot type x dehumanization manipulation interaction, $F(1,345) = 4.99$, $p = .026$, $\eta_p^2 = 0.01$, such that the effect of dehumanization on perceived experience was significant for the humanoid robot (control: $M = 2.84$, $SD = 1.79$; dehumanization: $M = 2.12$, $SD = 1.40$, $p < .001$, $\eta_p^2 = 0.03$) but not in the non-humanoid robot (control: $M = 1.77$, $SD = 1.12$; dehumanization: $M = 1.70$, $SD = 1.08$, $p = .762$; see Fig. 6).

A two-way ANOVA predicting perceptions of agency from dehumanization and robot type does not reveal a significant effect for robot type ($p = .094$), dehumanization ($p = .423$) or their interaction ($p = .779$). These results suggest that our manipulations were successful in changing the robots perceived experience (but not agency).

5.2.2. Uncanniness

A two-way ANOVA predicting uncanniness from dehumanization and robot type reveals that robot type affected uncanniness, $F(1,345) = 7.49$, $p = .007$, $\eta_p^2 = 0.02$, such that participants reported more uncanniness from the humanoid robot ($M = 3.53$, $SD = 1.61$) than the non-humanoid robot ($M = 3.07$, $SD = 1.60$), supporting the basic premise of the uncanny valley. We also find a significant effect for dehumanization, $F(1,345) = 4.71$, $p = .031$, $\eta_p^2 = 0.01$, such that participants reported less uncanniness in the dehumanization condition ($M = 3.12$, $SD = 1.59$) than in the control condition ($M = 3.48$, $SD = 1.63$). Finally, we find a significant robot type x dehumanization manipulation interaction, $F(1,345) = 6.08$, $p = .014$, $\eta_p^2 = 0.02$, such that the effect of dehumanization on uncanniness was significant for the humanoid robot (control: $M = 3.93$, $SD = 1.49$; dehumanization: $M = 3.14$, $SD = 1.63$, $p < .001$, $\eta_p^2 = 0.03$), but not for the non-humanoid robot ($p = .834$; see Fig. 7).

5.2.3. Mediation by perceived experience

Finally, we tested whether perceptions of experience mediate the interaction's effect on uncanniness. Using Hayes' (2018) first-stage moderated mediation PROCESS model (Model 7), we entered robot type as the independent variable, perceptions of experience as the mediator, dehumanization as the first-stage moderator, and uncanniness as the dependent variable. We found that the indirect effect of robot type on uncanniness via perceived experience was significant for both the control condition (coefficient = 0.40, $SE = 0.12$, 95% CI = 0.20 to 0.67) and the dehumanization condition (coefficient = 0.16, $SE = 0.08$, 95% CI = 0.02 to 0.34). However, the difference between the two indirect effects was significant (index of moderated mediation = - 0.24, $SE = 0.12$, 95% CI = - 0.52 to - 0.05), suggesting that the uncanniness from viewing a humanoid robot (vs. non-humanoid) was lower when participants dehumanized the robot. We note that all of the effects on uncanniness hold when controlling for perceived agency. Furthermore, when entering perceived agency rather than perceived experience in the mediation analysis, none of the mediations are significant. This suggests that perceived experience, and not general mind perception is related to uncanniness.

6. Discussion

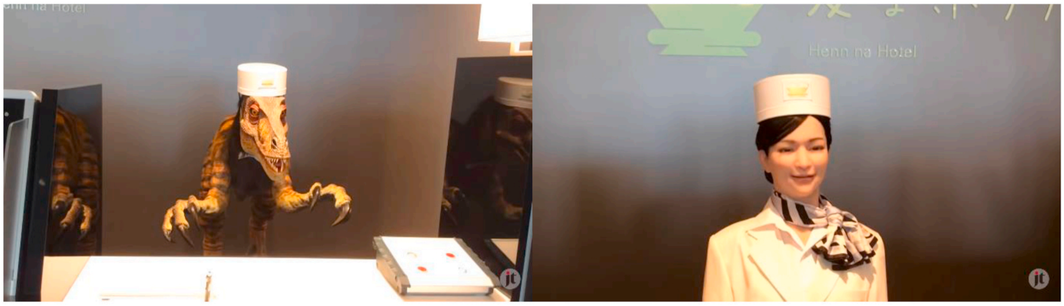
We replicated our previous results in an experiment examining real-life human-robot interaction in a robot-staffed hotel in Japan, providing strong generalizability of our findings beyond the lab and across both Western and Eastern cultures. As in Study 2, we found that dehumanizing humanoid robots (but not non-humanoid robots) can reduce uncanniness. Furthermore, we found this effect to be mediated by participants who perceived the humanoid robots as having less experience in the dehumanization condition. Finally, we did not find evidence that dehumanizing humanoid robots affected satisfaction in a two-way ANOVA ($p = .598$), suggesting that this manipulation can effectively offset the uncanny valley without compromising customers' satisfaction.

7. General discussion

People have long strived to build humanoid robots, and technological advances have made this goal more possible. Despite these advances, there is a key psychological issue that stands in the way: the uncanny valley. Consistent with much past research, our studies reveal that participants found humanoid robots to be unsettling (Gray &

[6] We only recruited Japanese participants.

[7] We controlled for agency, perceived novelty of the robot, and whether the participant was the primary handler of the check in process. Adding these controls do not affect the results and as such we presented results without any controls.



Left = non-humanoid robot; right = humanoid robot

Fig. 5. The robot receptionists in Study 3. Left = non-humanoid robot; right = humanoid robot. A sample link for the check-in robot: https://osf.io/u8m9x/?view_only=1b5d7d621d3344ac840fc70527c030c9.

Table 3
Descriptive statistics and correlations for study variables (study 3).

Variable	Mean	SD	1	2	3	4	5	6
1. Type of robot	0.50	0.50	(–)					
2. Dehumanization	0.50	0.50	0.00	(–)				
3. Agency perceptions	4.66	1.14	-0.09	0.04	(0.72)			
4. Experience perceptions	2.11	1.44	0.26**	-0.14*	0.15**	(0.95)		
5. Uncanniness	3.30	1.61	0.14**	-0.11*	-0.14*	0.35**	(0.94)	
6. Robot satisfaction	4.50	1.57	-0.02	-0.03	0.38**	0.06	-0.29**	(0.92)

Type of robot: 0 = control; 1 = humanoid.
Dehumanization: 0 = control; 1 = Dehumanization.
Alpha coefficients for each scale are presented in the parentheses.
*p < .05 ***p* < .01.

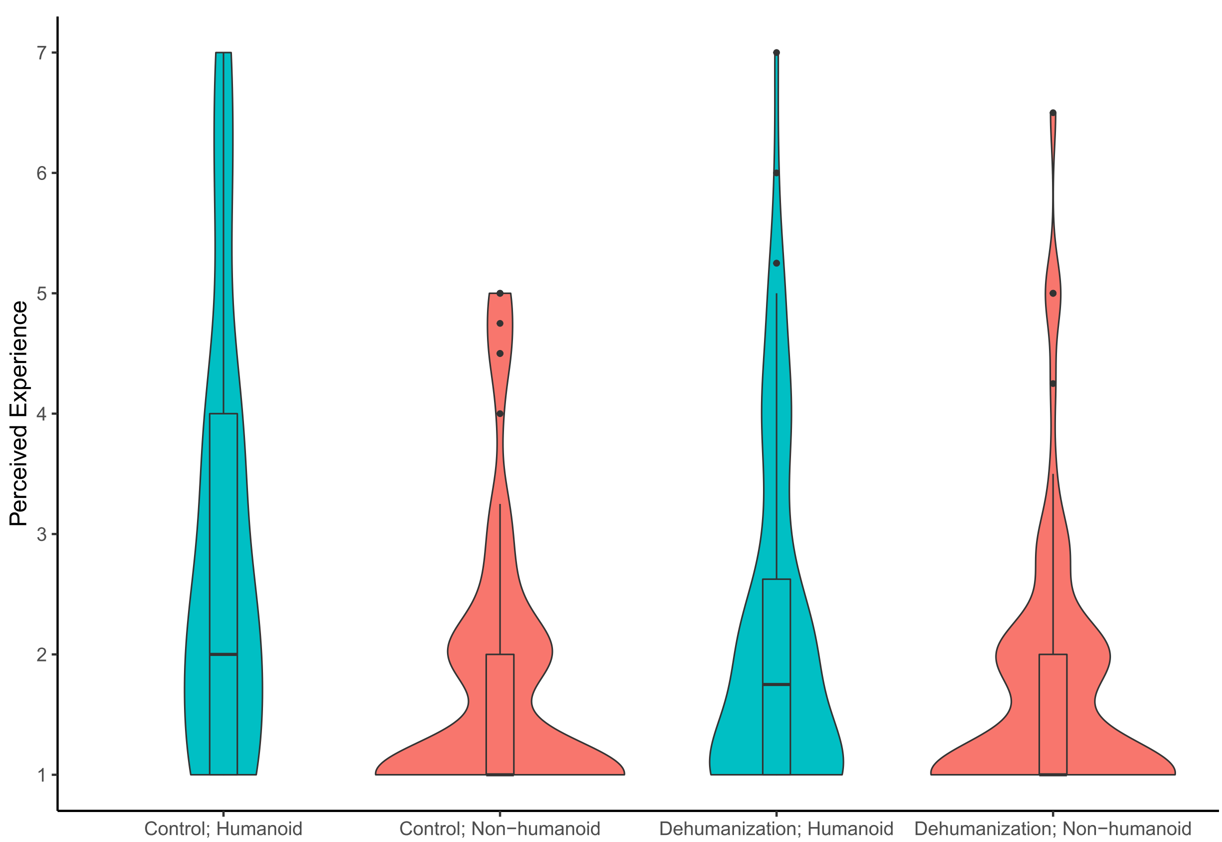


Fig. 6. Effect of dehumanization manipulation and robot type perceived experience (Study 3). Violin plots depict the density of the distribution, and box plots the interquartile range and average.

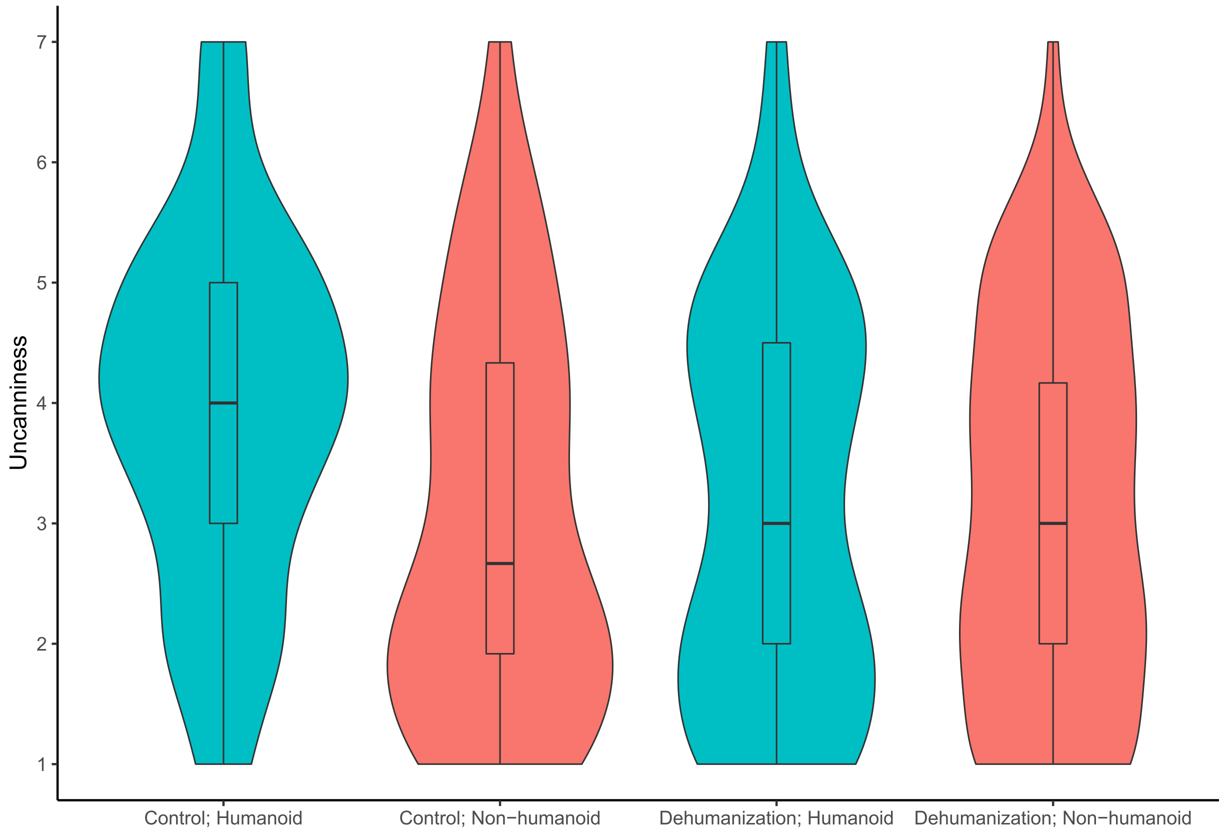


Fig. 7. Effect of dehumanization manipulation and robot type on uncanniness (Study 3). Violin plots depict the density of the distribution, and box plots the interquartile range and average.

Wegner, 2012; MacDorman et al., 2009; Mori, 1970; Shank et al., 2019; Weis & Wiese, 2017), in part because humanoid robots seem to possess the capacity for experience whereas objectively we know they should not (Gray & Wegner, 2012). Importantly, our studies reveal one easy way to mitigate the uncanny valley—decreasing perceptions of mind via dehumanization. Study 1 found that individual differences in dehumanization (and the inverse anthropomorphism) predicted lower perceptions of experience and reduced uncanny valley. Studies 2 and 3 revealed that experimentally manipulated dehumanization through a written prompt successfully decreased the uncanny valley, an effect mediated by reduced perceived experience. All together, these results suggest that stripping away mind from humanoid robots is not only relatively easy, but yields less unnerving robots, whether participants are watching videos (Study 2) or interacting with real robots (Study 3).

The current studies have both theoretical and practical contributions to the psychological study of human-robot interactions. In terms of theory, our results further highlight the importance of mind perception in understanding how people interact with mechanical agents. Past work has highlighted some drivers of the uncanny valley, especially the specific perceptual features of humanoid robots (Seyama & Nagayama, 2007; Weis & Wiese, 2017). Revealing the importance of mind perception is useful, because mind perception is amenable to change through relatively simple interventions, such as the text manipulation used in our studies. In terms of practical contributions, the studies reveal how the uncanny valley can be mitigated online, but most importantly also in a real-world setting—namely the world's first robot hotel. Many organizations are designing robots to be more human-like (including Study 3's hotel). Yet, from the uncanny valley literature and our own studies we also know that humans generally do not respond well to robots that are too humanlike. Given these considerations, our text- or verbal-based intervention to reduce the uncanny valley is virtually costless and has the potential to be used widely.

By using both correlational and experimental methods, and sampling both American participants from an online platform and Japanese tourists in an in-person setting, the current research demonstrates the generalizability of these effects. Although both the US and Japan are industrialized, wealthy, and democratic countries, we note that only relatively wealthy and industrialized nations are likely to be facing pressing concerns about human interactions with humanoid robots. These two different samples also had different levels of inclinations towards robots (Tett, 2019), with Japanese likely displaying a more positive attitude towards robots. Finally, the average American on Prolific is unlikely to have tried to set up face-to-face interactions with humanoid robots in everyday life, whereas the Japanese sample was doing exactly that—and both samples demonstrated similar effects.

8. Limitations and future research

There are limitations to the current studies. We note that the humanoid versus non-humanoid robots used between Studies 2 and 3 had very different appearances but we relied upon these robots because they were the ones used by the hotel in Study 3. That we found clear effects for our manipulation, even after accounting for perceived novelty, with real-world robots selected for reasons other than research is a testament to their generalizability. We also recognize that it may seem odd to discuss "dehumanization" of non-human agents. While this term might be relatively intuitive when dealing with humanoid robots, we acknowledge that the key effect is driven by reduced perceptions of mind, which is a key element for many definitions of dehumanization (e.g., Haslam, 2006; Schroeder & Epley, 2016; Waytz, Heafner, & Epley, 2014).

Likewise, demand effects might be a potential confound in Studies 2 and 3. We used a relatively heavy-handed manipulation of dehumanization, and participants might feel pressured to respond in certain ways.

One way to mitigate this is to increase temporal separation between the manipulation and the survey responses (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). For example, future research could design a multi-wave study where participants received the dehumanization manipulation first and respond to survey items at a later time point (see Yam, Christian, Wu, Liao, & Nai, 2018 for an example). In addition, Study 2 did not have a manipulation check, whereas in Study 3 some participants in the dehumanization condition continued to believe that robots should have human rights. This suggests although our text-based dehumanization might appear strong, some participants still refused to dehumanize. All in all, we recommend future research to replicate and extend our findings with more subtle manipulations of dehumanization.

Finally, our effect sizes across the three studies are in the 0.20s–0.30s range, representing small-to-medium effects. This might appear small, but because our intervention to reduce robots' uncanniness is costless and quick it has the potential to be scaled and used widely across many organizations and contexts. As Prentice and Miller (1992) noted, small effects can be practically useful provided that they can be widely adopted. Given the rapid development of humanoid robots and their adoptions in organizations, we suggest that our work can and do have practical implications.

Beyond methodological limitations, we also acknowledge that manipulating mind perception is not the only way to mitigate the uncanny valley, even when keeping the appearance of a robot constant. It may be possible to give participants other mindsets that decreases the effect. For example, focusing on a humanoid robot as "instrumental" in achieving your goals may make it less unnerving, although some research suggests that this kind of mindset is tied to reduced perceptions of experience (Schroeder & Fishbach, 2015). Likewise, we acknowledge that our manipulation—despite our mediation (Study 1) and moderated mediation (Studies 2–3) analyses—might operate through other mechanisms as well, such as decreasing categorical ambiguity (Weis & Wiese, 2017).

Finally, throughout this work we have only explored mechanistic and not animalistic dehumanization. Future research should examine whether an animalistic-based dehumanization can achieve the same results in reducing the uncanny valley. We believe this is unlikely because past work has established experience perceptions as the driving force of uncanniness (Gray & Wegner, 2012). Still, this remains to be an empirical question and prior research has discussed such a possibility (Swiderska & Küster, 2020; Küster & Swiderska, 2021). On a more conceptual level we encourage research to explore the distinction between dehumanization and experience perceptions. We discussed two types of dehumanization: mechanistic and animalistic, and used the former throughout this paper. However, we only observed small-to-moderate correlations between mechanistic dehumanization and experience perceptions ($rs = -0.25$ and -0.14 in Studies 2 and 3 respectively). This suggests that while on the surface mechanistic dehumanization and the denial of experience might appear synonymous, they are empirically distinguishable. Future research should explore what are the other consequences of mechanistic dehumanization beyond merely stripping entities of their experience perceptions.

9. Conclusion

It seems inevitable that someday all of us will be interacting with robots as we go about our daily lives. What is less inevitable is whether people will feel at ease with all these robots. Our research reveals one way to help make the experience of interacting with humanoid robots more familiar: remind people that—despite looking human—these human-looking robots are not *human-feeling* robots and lack the essence of a human mind.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2021.106945.

Author contributions

Kai Chi Yam Conceptualization, Methodology, Investigation, Formal Analysis, Data Curation, Writing – Original Draft, Funding Acquisition. Yochanan Bigman Methodology, Formal Analysis, Data Curation, Writing – Review & Editing. Kurt Gray Writing – Review & Editing, Supervision.

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