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Cross-Cultural Differences in Comfort with Humanlike Robots

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Abstract
The uncanny valley hypothesis describes how people are often less comfortable with highly humanlike robots. However, this discomfort may vary cross-culturally. This research tests how increasing robots' physical and mental human likeness affects people's comfort with robots in the United States and Japan, countries whose cultural and religious contexts differ in ways that are relevant to the evaluation of humanlike robots. We find that increasing physical and mental human likeness decreases comfort among Americans but not among Japanese participants. One potential explanation for these differences it that Japanese participants perceived robots to be more animate, having more of a mind, a soul, and consciousness, relative to American participants.

Keywords Cross-cultural · Humanoid · Comfort

1 Introduction and Motivation

Robots have started spreading beyond the factories and warehouses where they have been used for decades, taking up new roles in stores, restaurants, and private homes [23]. In 2021, the market value of physical robots that interact with and provide service to consumers amounted to $4.4 billion worldwide and this market is growing quickly [14]. As robots become more widespread in society, one factor that may shape how humans respond is how humanlike the robots look and act [4]. For example, research has found that people are uncomfortable with robots that look very (but not perfectly) humanlike: such robots are said to fall into the "uncanny valley" [18]. A recent meta-analysis find that this effect is large and robust to different operationalizations of human likeness and affective reactions [5]. There are many potential explanations for this phenomenon, many of which rely on the belief that robots and humans belong in separate categories, such that highly humanlike robots blur categorical boundaries, threaten human uniqueness, and create discomfort [7, 31]. Although most of the research in this area has focused on physical human likeness, some has also explored mental human likeness and found that increasing robots' perceived ability to experience emotion and sensation also decreases comfort [9]. As robots' mental human likeness continues to improve—including the abilities to detect, classify, and express emotion [8]—perceived threats to human uniqueness seem likely to escalate as well, creating discomfort among people [32, 33]. Discomfort with robots can in turn have negative consequences for both people interacting with the robots and the firms that develop and employ the robots [30].

However, there are reasons to believe that the effects of robot human likeness on comfort will differ cross-culturally. Japanese culture in particular offers an interesting point of comparison to Western cultures such as the United States. Japan is often depicted as a country that loves robots and uses them in a wide variety of commercial contexts [22]. Japanese companies have developed robots for entertainment and companionship, and robots are commonly deployed in Japanese nursing homes, schools, and offices [21]. The Japanese government has even defined the preservation of human mental and physical well-being as essential requirements for service robots [17]. The most famous Japanese robot in popular culture is Astro Boy, a hero that feels emotion and fights crime [22]. In contrast, Hollywood movies typically depict robots as threats to humans (i.e., *Terminator*, *I*, *Robot*).

The roots of Japanese attitudes towards robots may be found in religious traditions: Shinto, the official religion

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of Japan, emphasizes animism, or the belief that inanimate objects can have spirits, souls, or consciousness like humans do [15, 19]. Indeed, a Japanese robotics pioneer was quoted as saying "If one considers humans as the children of nature, artificial humans created by the hand of man are thus nature's grandchildren" [13]. This contrasts sharply with traditional Judeo-Christian ideas such as mind–body dualism and the privileging of humans over other living and nonliving things [22]. Thus, whereas increasing robots' human likeness tends to make Westerners uncomfortable by making the robots seem more threatening to human uniqueness and blurring the category boundaries between man and machine [7], we hypothesize that increasing human likeness will be less likely to produce these same negative effects among Japanese people, since their cultural-religious background does not emphasize human uniqueness or exceptionalism to the same degree. We test this hypothesis in the three studies presented here.

2 Related Research

There is very little prior research available on cross-cultural perceptions of robots including Japanese people. A small survey found that Americans had the most positive attitudes towards robots out of the six countries surveyed, while Mexicans had the most negative attitudes and Japanese fell in between [3]. A larger survey found that, relative to Koreans and Americans, Japanese participants were more likely to assume that robots have human characteristics such as autonomy and emotional capacity [25]. A comparison of Australian and Japanese reactions to interacting with a highly humanlike android robot found that Australians saw the robot as more likeable and more humanlike [10]. A survey comparing Japanese and European people found that Europeans had more personal experience interacting with robots but that both groups had similarly positive attitudes towards robots in general [10, 11]. Japanese participants were, however, more likely than Europeans to say that a robot should look like a human. British participants report more negative feelings towards humanoid robots than do Japanese participants [26], while an experiment found that Americans were more comfortable than Japanese participants with robots being described as having humanlike traits such as curiosity and friendliness [16]. A survey of American, Japanese, and German participants found that Americans had the most experience with robots, had the most interest in purchasing a robot for use in the home, and reported the most favorable attitudes to robots that look like humans, but that Japanese participants felt the most comfortable with robots being part of daily life [24]. Finally, recent experiments suggest that Japanese participants are more ready to accept robots as the targets of moral judgment and are more willing to let robots intervene in moral dilemmas, relative to Americans [20].

Of these existing studies, only two used experimental methods [16, 20] and none manipulated robots' physical human likeness. The various survey results are mixed, suggesting that Japanese people are not necessarily more comfortable with robots compared to Western people, but that they may be more comfortable specifically with robots high in human likeness. Our research therefore tests whether increasing robots' human likeness (both physical and mental) differentially affects Japanese and American people's comfort. We hypothesize that increasing human likeness will decrease Americans' comfort more than Japanese comfort.

3 Overview of Experiments

We conducted three experiments to test this hypothesis. Study 1 focuses on robots' physical human likeness, manipulating this factor and measuring comfort among American and Japanese participants. Study 2 builds on this approach, looking at perceived animacy as well as other potential mechanisms through which human likeness might differentially affect comfort among Japanese and American participants. This study also introduces the idea of a "perfect robot" and measures participants' comfort with a robot that is indistinguishable from a human being. Finally, study 3 shifts from physical to mental human likeness, focusing on how and why increasing this dimension of human likeness affects American and Japanese reactions. Images of the robots that we used as stimuli are shown in Fig. 1. We collect data from Amazon's Mechanical Turk, recruiting only participants with > 98% approval rating so as increase data quality. All data for this project is available at https://osf.io/cfyx9/?view_only=8db0a0d098b644b58d5001113e7eab7c.

4 Study 1

Our first study focuses on robots' physical human likeness, or the degree to which robots look humanlike. Although empirical support for the precise U-shaped curve of the uncanny valley hypothesis has been mixed [18], a robust effect is that people are less comfortable with robots very high in human likeness (sometimes called androids, which have humanlike skin, hair, and so on), than robots with low or moderate levels of physical human likeness. This study therefore focuses on testing whether this effect differs between American and Japanese participants.

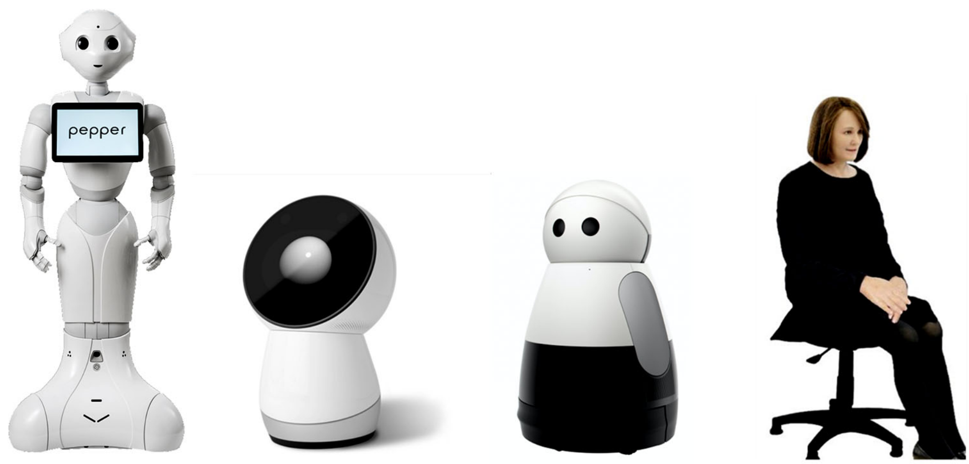

Fig. 1 Robots studied in our studies. From left to right: Pepper, Jibo, Kuri, Nadine

4.1 Method

We recruited 393 participants for this study: 250 Americans from Mechanical Turk (44% female, mean age = 34, SD = 10) and 143 Japanese from Lancers, a Japanese equivalent of Mechanical Turk (43% female, mean age = 37, SD = 11). Both of these websites are crowdsourcing websites that allow researchers to recruit participants over the Internet. Note that data collection from Japan took significantly longer than data collection from the United States, which is why the Japanese sample size is smaller. Our subsequent studies using alternative crowdsourcing websites achieve equal sample sizes. Participants from both countries were compensated equally. The surveys in both countries were administered in English, although subsequent studies also use Japanese surveys.

Participants saw a picture of one of three robots varying in physical human likeness: Jibo, Kuri, or Nadine. These robots have physical human likeness ratings of 1.44, 22.96, and 96.96 respectively according to the Anthropomorphic Robot Database, accessible at http://abotdatabase.info/ [29]. The robots were described as "home robots" meant to be used as a companion and assistant around the house.

Participants then completed a measure of uncanniness used in prior research [9], reporting how much they would feel creeped out, uneasy, and unnerved during an interaction with the robot in question, on 0–10 scales anchored at "not at all" and "very much." We reverse-scored this measure to create our primary dependent variable which we label "comfort" ($\alpha = 0.92$). We recognize that there is ambiguity and debate regarding the proper antonym for uncanny, such that alternative labels for our measure such as likeable or appealing may also be appropriate [5]. We also asked participants how much they would be interested in purchasing the robot, using the same scale.

4.2 Results and Discussion

A 2 × 3 ANOVA with robot condition and participants' country predicting comfort revealed a significant interaction, $F(1, 387) = 3.96$, $p = 0.019$, $\eta^2_p = 0.02$. Breaking down this interaction first by country, we observed that robot condition had a significant effect on comfort among Americans, $F(1, 247) = 17.02$, $p < 0.001$, $\eta^2_p = 0.12$, but not among Japanese participants, $F(1, 140) = 2.31$, $p = 0.103$, $\eta^2_p = 0.03$. American participants were most comfortable with Jibo ($M = 7.24$), equally comfortable with Kuri ($M = 7.20$, $t(387) = 0.09$, $p = 0.995$, and significantly less comfortable with Nadine ($M = 4.87$, $t(387) = 5.52$, $p < 0.001$ compared with Kuri). Japanese participants were most comfortable with Kuri ($M = 6.22$), equally comfortable with Jibo ($M = 6.15$, $t(387) = 0.13$, $p = 0.991$), and no less comfortable with Nadine ($M = 5.47$, $t(387) = 1.38$, $p = 0.352$ compared with Jibo). These and all other follow-up contrasts used the Tukey correction for multiple comparisons (a statistical adjustment that decreases the chances of false positives when conducting multiple tests for statistical significance).

Breaking down the interaction by robot, we observed that Americans were significantly more comfortable than Japanese participants with Jibo ($p = 0.021$) and with Kuri ($p = 0.049$), but nonsignificantly less comfortable with Nadine ($p = 0.203$). Figure 2 displays this effect visually using raincloud plots [1].

Turning to interest in purchasing the robot, we also observed a significant interaction, $F(1, 387) = 4.01$, $p = 0.019$, $\eta^2_p = 0.02$. The patterns were similar to the comfort measure. Americans were most interested in purchasing Kuri ($M = 5.76$) and Jibo ($M = 5.44$, *ns*) and significantly less interested in purchasing Nadine ($M = 3.06$, p's < 0.001). Japanese participants were most interested in purchasing Kuri ($M = 5.00$) and Jibo ($M = 4.67$, *ns*) but no less interested in purchasing Nadine ($M = 4.08$, p's > 0.257).

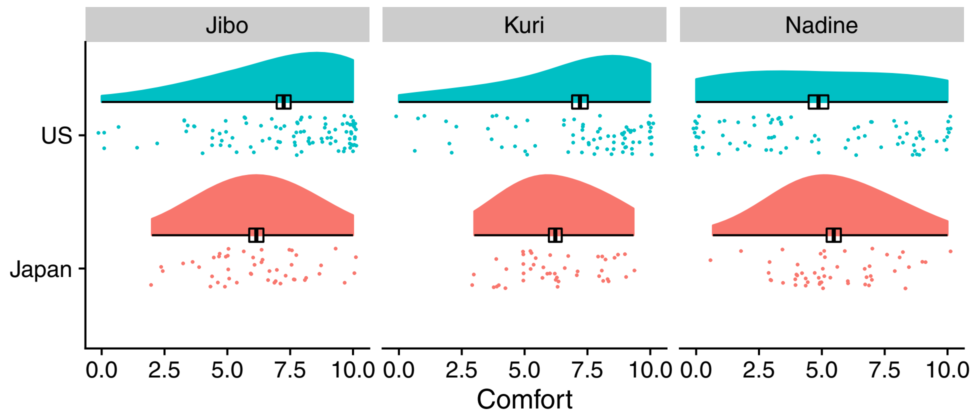

Fig. 2 Raincloud plots showing raw data (points), density (curves), means (thick vertical lines below each curve), standard errors (thin vertical lines below each curve), and range (horizontal lines below each curve). Comfort is depicted on the *X*-axis, with larger numbers indicating greater comfort. These details are the same for each raincloud plot

There was no significant difference between Japanese and American participants in their interest in purchasing Jibo ($p = 0.128$) or Kuri ($p = 0.154$). Japanese participants were, however, more interested in purchasing Nadine ($p = 0.048$).

These results do not support the common belief that Japanese people are overall more comfortable with robots than Americans. In fact, the opposite was true for the low human likeness robots. It therefore seems that cultural differences in comfort with robots depend on the physical human likeness of the robots in question.

The primary hypothesis of this research, however, was supported: increasing physical human likeness decreased Americans' comfort with robots but did not affect Japanese comfort.

5 Study 2

This study builds on Study 1 by adding two new conditions. First, in the human condition participants are asked to evaluate a human being, to provide a baseline with which to compare comfort with robots. Second, the perfect robot condition shows participants a picture of the same human used in the human condition (who is in fact the roboticist that designed the Nadine robot in her own likeness) but identifies the human as a highly humanlike robot. This condition therefore represents a hypothetical perfectly humanlike robot that is physically indistinguishable from a human. While such a robot does not yet exist, it is likely to exist soon given the pace of progress in humanoid robotics, and it is therefore worth studying how people across different cultures perceive such robots.

This study also measures several constructs that may be relevant to explaining cultural differences in comfort with humanlike robots. We measured familiarity with robots because it may contribute to comfort [22]. We measured perceived animacy of robots because Japanese culture may predispose Japanese people to see inanimate objects like robots as more lifelike [15], which may contribute to comfort. Finally, we measured loneliness because Japanese society is often portrayed as suffering from a loneliness epidemic [28], and loneliness has been shown to increase the tendency to anthropomorphize objects [6].

5.1 Method

We recruited 393 participants for this study: 200 Americans from Mechanical Turk (51% female, mean age = 34, SD = 9) and 193 Japanese from Lancers (39% female, mean age = 39, SD = 10). We control for age and gender in our analyses by including these factors as covariates in the ANCOVA given the significant demographic differences between the two samples. All materials used in this study were translated from English to Japanese by a native Japanese speaker fluent in English, and then back-translated from Japanese to English by a second native Japanese speaker also fluent in English. Japanese participants completed the survey in Japanese, and were required to have been born, raised, and to still live in Japan.

We assigned participants to one of four conditions: low human likeness robot (Kuri), high human likeness robot (Nadine), perfect robot, or human. The first two conditions displayed a picture of the robot in question; the second two displayed a picture of the human whom the Nadine robot was designed to resemble, merely altering whether the picture was labeled as a robot or as a human. The three robot conditions described the robot as a companion and assistant intended to be used at home.

We measured comfort as in Study 1. We measured perceived animacy of robots (1–5 point bipolar items: dead/alive, stagnant/lively, mechanical/organic, artificial / lifelike) using the animacy subscale of the Godspeed measure[1] [2], α =

[1] We thank an anonymous reviewer for alerting us to some of the Godspeed measure's limitations, such as a high correlation with likeability and a non-orthogonal relationship with the warmth dimension of interpersonal perception [12].

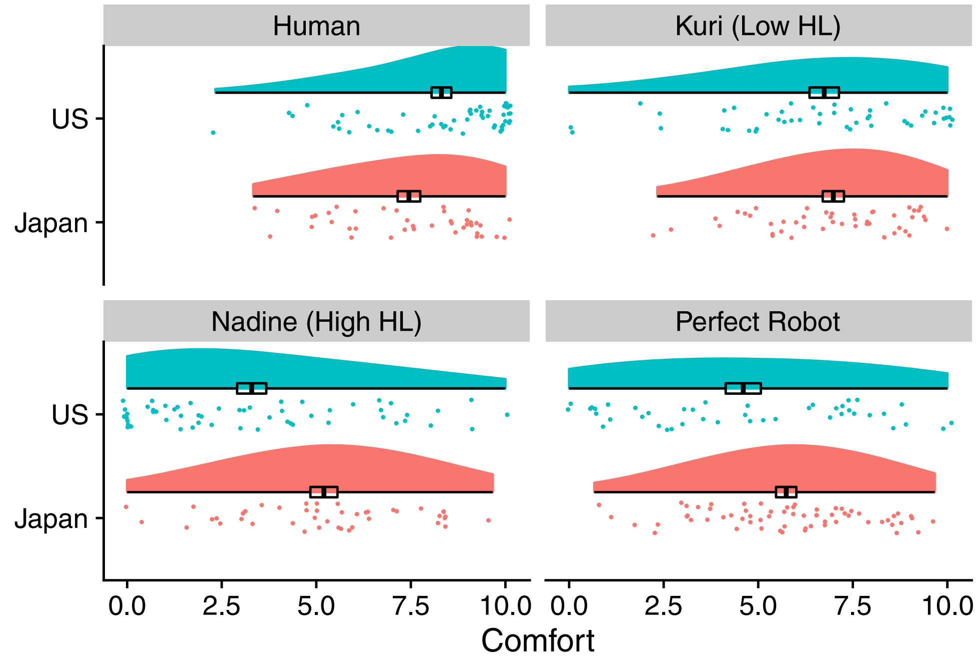

Fig. 3 Results of Study 2

0.79), familiarity with robots (including how many times participants had interacted with a robot in real life [open ended], how much they know about robots and how often they read about or see robots in the news media [0–10 point scales]); and finally how lonely, connected to others, and distant from others they feel (as a measure of loneliness: $\alpha = 0.83$, 1–5 point scales).

5.2 Results and Discussion

We first ran a 2 × 4 ANCOVA with condition, participants' country, and their interaction predicting comfort, with age and gender included as covariates. This revealed a significant interaction, $F(1, 383) = 5.88$, $p < 0.001$, $\eta^2_p = 0.04$. Neither age nor gender had significant effects on comfort, p's > 0.358. Breaking down the interaction first by country, Americans were most comfortable with the human labeled as a human ($M = 8.35$), less comfortable with Kuri, the low human likeness robot ($M = 6.77$), less comfortable still with the perfectly humanlike robot ($M = 4.61$), and least comfortable with the highly but imperfectly humanlike robot, Nadine ($M = 3.34$). Each of these means is significantly different from each other, p's < 0.05. The order of means was the same among Japanese participants, although the differences were smaller: $M_{human} = 7.42$, $M_{Kuri} = 6.97$, $M_{perfect\ robot} = 5.68$, $M_{Nadine} = 5.19$. Each of these means is significantly different from each other with two exceptions: comfort with the human and with Kuri and comfort with Nadine and the perfectly humanlike robot. These results confirm the finding from Study 1 that robot human likeness has a smaller effect on comfort among Japanese people, than among Americans.

Focusing only on the three robot conditions (excluding the human condition), the effect of condition was roughly twice as large among Americans, $F(1, 143) = 18.66$, $p < 0.001$, $\eta^2_p = 0.21$, than among Japanese participants, $F(1, 150) = 8.31$, $p < 0.001$, $\eta^2_p = 0.10$.

Breaking down the interaction next by condition, Americans were marginally more comfortable with the human labeled as a human ($p = 0.067$), no more or less comfortable with Kuri ($p = 0.703$), and significantly less comfortable with the highly humanlike Nadine ($p < 0.001$) and with the perfectly humanlike robot ($p = 0.025$). These results, displayed in Fig. 3, suggest that Americans are less comfortable than Japanese with highly humanlike robots.

Turning to the potential mechanisms for explaining these cultural differences, we focused on the three robot conditions (excluding the human condition from these analyses) and observed that Japanese participants perceived robots in general as more lifelike than Americans ($M_{Japan} = 2.56$, $M_{US} = 2.23$, $t(282) = 3.46$, $p < 0.001$), had interacted with robots in real life nonsignificantly less often than Americans ($M_{Japan} = 1.93$, $M_{US} = 3.21$, $t(297) = 1.41$, $p = 0.160$,) knew significantly less about robots ($M_{Japan} = 2.68$, $M_{US} = 1.72$, $t(297) = 5.22$, $p < 0.001$), were exposed to robots through the media less frequently ($M_{Japan} = 3.86$, $M_{US} = 4.94$, $t(297) = 4.78$, $p < 0.001$), and were lonelier ($M_{Japan} = 2.94$, $M_{US} = 2.50$, $t(297) = 3.82$, $p < 0.001$). We therefore entered each of these variables into a multiple regression along with age, gender, and country to predict comfort; the only significant predictors were country, with Americans being less comfortable overall (β = -0.77, $SE = 0.36$, $p = 0.033$), and perceived animacy of robots ($\beta = 0.69$, $SE = 0.20$, $p < 0.001$).

The results suggest that one possible reason why Japanese people seem more comfortable with highly humanlike robots relative to American people may be that Japanese see robots as more lifelike. This may be due to the contrasting cultural and religious backgrounds of the two countries: Americans tend to see humans and machines as fundamentally and categorically distinct, such that humanlike robots threaten human uniqueness, whereas Japanese culture emphasizes that even inanimate objects can in fact have animacy, such that humanlike robots are less likely to seem threatening to human uniqueness. Our final study tests these ideas more directly.

6 Study 3

The final study shifts the focus from physical to mental human likeness. Specifically, we test whether Japanese and American participants react differently to increasing robots' perceived emotional abilities. We also look for differences between Japanese and American participants' beliefs that robots can specifically have humanlike, animate qualities such as consciousness and souls.

6.1 Method

We recruited 201 American participants from Prolific (mean age = 33, SD = 12, 43% female) and 202 Japanese participants from Shufti (a Japanese crowd-sourcing platform; mean age = 37, SD = 9, 80% female). We control for age and gender in our analyses by including them as covariates. Participants began by completing the animacy subscale of the Godspeed questionnaire [2]. We supplemented this subscale by directly asking participants whether they believe that robots have a mind, a soul, and consciousness on 11-point items anchored by "not at all" and "completely" ($\alpha = 0.89$).

Next, participants saw a picture of the Pepper robot (overall human likeness rating of 42.17 on the ABOT Database) and read that it worked as a customer service representative in stores, hotels, and hospitals. We manipulated whether the robot was described as being able to understand and express emotions, or not being able to do so. We measured comfort with this robot as in previous studies.

All materials used in this study were translated from English to Japanese by a native Japanese speaker fluent in English. Japanese participants then completed the survey in Japanese, and were required to have been born, raised, and to still live in Japan.

6.2 Results and Discussion

An ANCOVA using country, emotion condition, and their interaction as independent variables, plus age and gender as covariates to predict comfort revealed a significant age effect, $F(1, 397) = 5.58$, $p = 0.019$, such that age was positively related to comfort with the robot, $\beta = 0.02$. Most importantly, we observed a significant interaction between country and emotion condition, $F(1, 397) = 10.80$, $p = 0.001$, $\eta^2_p = 0.03$.

Breaking down the interaction, and as shown in Fig. 4, Americans were less comfortable with robots having emotional abilities ($M = 5.86$) than lacking them ($M = 6.78$, $t(397) = 2.75$, $p = 0.006$). This effect remained significant controlling for age and gender, $\beta = -0.92$, $p = 0.010$. In contrast, Japanese participants were *more* comfortable with robots having emotional abilities ($M = 5.64$) than lacking them ($M = 5.02$, $t(397) = 1.90$, $p = 0.058$). This effect was also significant controlling for age and gender, $\beta = 0.63$, $p = 0.044$.

Our theorizing proposes that Japanese people are more likely to perceive robots as similar to humans. This indeed appears to be the case: Japanese people perceived robots to be more animate ($M = 2.55$) than did Americans ($M = 2.09$, $t(388) = 6.77$, $p < 0.001$), and perceived robots to have more of a mind of their own ($M_{Japan} = 2.97$, $M_{US} = 2.25$, $t(382) = 2.99$, $p = 0.002$), more of a soul ($M_{Japan} = 2.93$, $M_{US} = 0.71$, $t(354) = 10.36$, $p < 0.001$), and more consciousness ($M_{Japan} = 3.24$, $M_{US} = 1.38$, $t(368) = 7.74$, $p < 0.001$). Among all participants in the emotional robot condition, the Godspeed subscale was positively correlated to comfort with robots, $r = 0.19$, $p = 0.007$; this correlation was stronger among Japanese participants, $r = 0.32$, $p = 0.001$, than among Americans, $r = 0.16$, $p = 0.100$. Similarly, also in the emotional robot condition, the average of perceived mind, soul, and consciousness was positively correlated to comfort with robots, $r = 0.13$, $p = 0.082$; this correlation was stronger among Japanese participants, $r = 0.25$, $p = 0.019$, than among Americans, $r = 0.08$, $p = 0.418$. This supports our hypothesis that people who are more likely to see robots as life-like (in this case, Japanese people) are more comfortable with robots that have humanlike mental abilities.

These results are broadly consistent with the first two studies in that they demonstrate differences in how American and Japanese people react to increasing robots' human likeness. Increasing physical human likeness decreases Americans' comfort much more than it decreases Japanese comfort; increasing mental (emotional) human likeness decreases Americans' comfort and actually increases Japanese comfort. Japanese participants are more likely to perceive robots as fundamentally humanlike, which in turn increased comfort specifically with robots that have emotional abilities.

7 Conclusions and Discussion

The results presented here are the first experimental evidence that Japanese and American people react differently

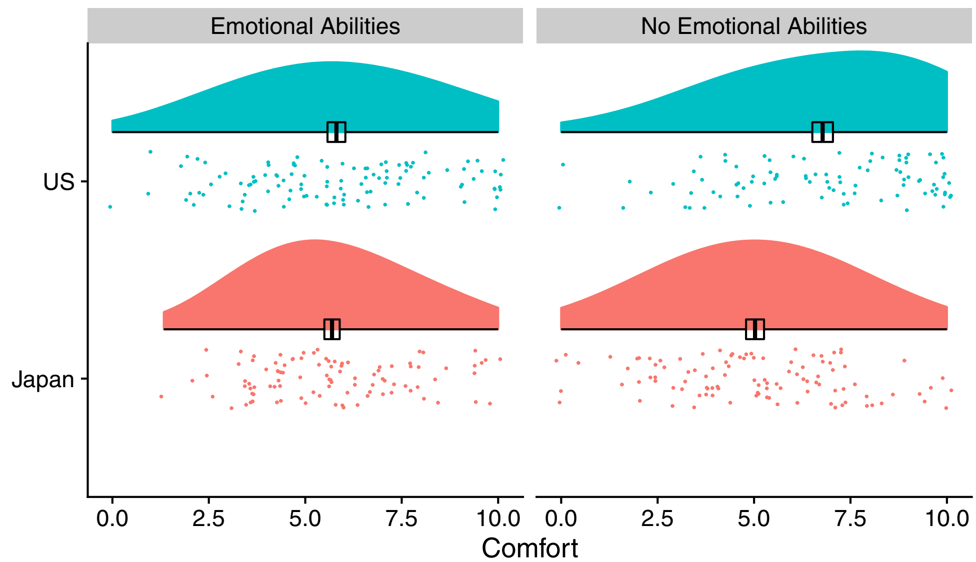

Fig. 4 Americans are more comfortable with robots lacking emotion, but Japanese are left comfortable with them

to increasing robots' human likeness. While some research has explored Japanese-American differences in evaluations of robots, most of it has been non-experimental survey work, and no research has specifically manipulated robots' physical and mental human likeness across these two cultures. As robots in both countries are becoming more humanlike, and as companies in both countries attempt to deploy robots in new settings, our results contribute to understanding when and why such robots are likely to be accepted by people.

The interaction pattern that we consistently observed in this research suggests that Americans (vs. Japanese) are more comfortable with robots low in human likeness, but less comfortable with robots high in human likeness. Companies designing and deploying humanlike robots should therefore be aware of how their robots' physical appearance and mental abilities are likely to be perceived by their target demographic.

The results presented here are limited in several ways. First, participants did not interact with robots in real life but instead only saw pictures and read descriptions of the robots. Peoples' reactions may be different when they come face to face with robots and future research studying such in-person interactions would therefore be valuable. Second, our analysis focused on mean differences as is standard practice in this field, but this is nevertheless a limitation insofar as it may mask important heterogeneity among participants' responses. The use of raincloud plots helps to address this by visualizing heterogeneity in each condition, illustrating that there are always numerous exceptions that go against the mean differences (i.e., Americans reporting more comfort than Japanese with highly humanlike robots, or vice versa). Future research can therefore dive deeper into what demographic or psychographic factors within a given culture can explain this heterogeneity, potentially identifying interesting moderators of the effects reported here.

Third, while we focused on human likeness (both physical and mental) as a key factor in shaping people's reactions to robots, we did not address other factors that may also be important and related to human likeness. For example, a robot's functionality—or how many tasks it can perform and how well it performs them—is clearly related to but distinct from human likeness. The more humanlike a robot looks, for example, the more people may expect it to perform more useful tasks, which may set up expectations that could be unmet. Future research can therefore study how human likeness affects expectations for functionality, as well as how functionality affects people's comfort and other reactions to robots independent of the robot's human likeness.

Finally, the ongoing COVID-19 pandemic has accelerated the deployment of robots in society [27], highlighting the importance of research into how such robots are perceived. Robots have the potential to improve outcomes for individuals, firms, and society as a whole—both during public health crises and beyond—but this potential is limited is people are not comfortable with their use. The research reported here contributes to this effort by shedding light on how culture and robots' human likeness interact in shaping people's comfort with robots.

Declarations

Conflict of interest The authors have no conflicts of interest to declare.

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