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Loneliness during COVID-19 influences mind and likeability ratings in the Uncanny Valley

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Abstract. To combat the spread of the COVID-19 virus, countries enforced quarantines, physical and social restrictions on people. These restrictions left many feeling isolated and lonely due to prolonged quarantines and lockdowns. This raises questions about using robots as social support to alleviate these symptoms, while still complying with restrictions and regulations. Since acceptance of social robots as companions has traditionally been low, an event like COVID-19 could change acceptance of robots as social companions as loneliness can influence the likelihood of anthropomorphizing nonhuman agents. Here, we aimed to see if loneliness, due to COVID-19 restrictions, influence the Uncanny Valley pattern that prior work has shown. As such, participants saw robot images that varied in physical human-likeness and were asked to evaluate them regarding trustworthiness, mind perception and likability. The measurements were obtained once before COVID-19 (in 2016) and once at the peak of the pandemic in September 2020. Results show that ratings of mind perception and likability were significantly impacted by the pandemic, with less pronounced UV patterns for those who experienced the COVID-19 pandemic. However, no differences in the UV pattern was observed on trust. Post-hoc analyses also illustrated that people were more likely to judge machinelike robots negatively, which could be due to increased loneliness/anxiety. These data suggest that loneliness attenuates UV patterns that are observed in "Uncanny" robots and that people have more favorable attitudes towards humanlike robots when feeling lonely, which provides important considerations for the use of humanlike robots as social companions.

Keywords: Uncanny valley, mind perception, trust, likability, Loneliness

1 Introduction

COVID-19 has been a global threat for people since the beginning of 2020. Despite the fact that pandemics are not novel, the specific economic, political, social and healthcare impacts of COVID-19 are unprecedented. As of September of 2021, the Center of Disease Control (CDC) showed that there have been more than 42 million confirmed cases of COVID-19 in the US and more than 214 million worldwide, with numbers still on the rise. To combat the spread of the virus, countries have been recommending measures such as washing hands, wearing masks, social distancing and restricting unnecessary physical presence. Furthermore, many schools, businesses and public spaces moved their activities to online platforms [1]. Although social distancing measures can alleviate the spread of the virus, they have a significant impact on people's mental health. Specifically, loneliness during -or after- isolation caused by restrictive COVID-19 policies can cause negative effects, such as depression, helplessness and anxiety, which can lead to severe mental trauma in some people [1]–[5]. Saltzman and colleagues [6] investigated the potential impact of COVID-19 on loneliness and unhappiness, and showed that human social support is an effective coping strategy to alleviate loneliness and feelings of isolation. Thus, although people are protecting themselves and others from COVID-19 infections via social distancing, this intervention may have long-term negative consequences on people's mental health and wellbeing, which needs to be addressed.

Social robots could potentially address this issue given that they can serve as companions with complex social capabilities, while not posing risks of infection. Indeed, human-robot interaction (HRI) studies have found that companion robots can minimize feelings of loneliness by establishing different types of supportive relationships [7] and that certain degrees of social support can be established between robots and humans [8], [9]. These positive effects of social robots are particularly seen in older care homes, where the introduction of social robot companions leads to a general increase in well-being [10] and higher social engagement in dementia patients through interactions with the robot itself, as well as other patients as they engage with the robot together [11]. Interestingly, the introduction of social robots not only decreased stress levels in older patients but also in the care takers as a response to the increase in social engagement of their patients [12]. Social robots have also been successfully applied to other healthcare contexts: they can assist children and adults struggling with mental health issues to accomplish everyday tasks like going to a doctor's appointment [13], [14] or support stroke patients during their recovery process [15].

While positive effects of social robots on well-being have consistently been reported in the context of healthcare applications, the general population seems more reluctant to accept social robots as companions and do not easily engage in human-like interactions with them ([16] for a review). Neuroscience has shown that when we interact with other humans, areas in the brain that are specialized in processing social information are activated, which leads to an increased motivation to interact socially [17]. In order to fully activate these areas, our interaction partners need to be believed to have a mind - capable of having internal states like emotions, intentions and motivations (i.e., mind perception; [18]). Mind perception is not exclusive to agents who have a mind (e.g., humans), but it can also be ascribed to agents without actual minds, such as robots [18], [19]. The degree to which mind is perceived in nonhuman entities is modulated by their physical appearance [20]–[22], and robots that physically resemble humans are likely to be perceived to have sophisticated mental capacities, are evaluated more positively, make us feel socially more connected to them and lead to increased engagement in HRI [23].

Effects of physical human-likeness on social interactions are often examined with a spectrum of images that range from very machine-like to perfectly human-like [20],

[24], [25]. Pak and colleagues [26], for instance, found increased trust in anthropomorphic compared to automated aids, and Lusk and Atkinson [27] reported that participants performed better when solving complex problems with an embodied human-like agent than with a disembodied machine-like agent. While these positive effects of physical human-likeness are observed when subjective ratings are used as outcome measures, the results are not nearly as straight forward when looking at cognitive performance in joint tasks ([28]; for review): For instance, Abubshait and colleagues [21] found that performance on a social attention task (i.e., identifying targets previously cued (or not) by the eye gaze of a social agent) was comparable across agents of all degrees of human-likeness, with the exception of a 60% human agent who showed a significantly stronger detrimental effect on performance than all the other agents. In line with this finding, Wiese and colleagues [29] showed that the presence of any kind of social agent had a facilitatory effect on performance during a sustained attention task (i.e., pressing a button when an agent of any kind of physical human-likeness is looking at a gun (but not a hairdryer), with the exception of a 70% human agent – which lead to a stronger vigilance decrement than very machinelike or perfectly human-like agents. Follow-up studies showed that processing the 70% human agent was associated with increased categorical uncertainty [30] and that pre-exposure to the agent images (which allowed participants to process them in more detail and resolve potential perceptual conflicts) [21], [29], suggesting that reduced performance on joint tasks with very human-like but not perfectly human agents may be due to uncertainty regarding the human nature of the agent.

The finding that agents with very human-like, but not perfectly human appearance have negative effects on HRI is in line with the Uncanny Valley (UV) theory [31]. It states that increasing the physical human-likeness of nonhuman entities initially increases ratings of warmth, familiarity, likability and/or eeriness, followed by a drop of these measures at around 70% of physical humanness, followed by a recovery and thus, an increase of agent ratings when physical humanlikeness reaches 100% human [32]. While the UV effect traditionally is related to feelings of eeriness and likability (or lack thereof), it can also extend to measures of trust [25] and mind perception [33], [34]. Since it was first proposed, the UV hypothesis has stimulated many controversial debates, due to scarce reliable and empirical supporting evidence ([32]; for review), and the majority of studies reporting a linear relationship between physical human-likeness and agent assessments instead [20], [24], [35]. Even to date, there is still a lot of inconsistency when comparing studies that look at the effect of varying levels of human-likeness on agent evaluations.

One explanation to these contradicting results could be due to the stimuli being used with evidence for a UV pattern when wild-type robot faces were used as stimuli [25], but no uniform evidence for an UV pattern with point-light figures [36] or morphed images [24]. In addition, individual differences in the observer [37] also seem to impact the evaluation of nonhuman agents: specifically, it was shown that – among other factors – higher compared to lower levels of anxiety and personal distress were associated with higher eeriness ratings for agents falling into the UV. It was also shown – although not in the context of the UV - that an increased need for social connection due to experimentally induced loneliness makes people perceive more human-likeness in nonhuman agents, and evaluate them more favorably (i.e., puppets: [38], robots: [39]). Specifically, people who reported feelings of loneliness were more likely to attribute human traits (e.g., free will) to inanimate objects (e.g., alarm clocks) in an attempt to fulfill their need for social connection [38]. Moreover, reminding people of their close relationships with humans reduced the extent to which nonhuman entities were anthropomorphized (e.g. [40]. People who were experimentally induced to feel lonely also attributed human traits to social robots [39]. Taken together, these studies suggest that negative emotional states, such as anxiety or loneliness, have an impact on how nonhuman agents are perceived. What has not been examined yet is how sustained aversive states induced by global disasters like the COVID-19 pandemic affect the non-rectilinear relationship between people's subjective assessments of nonhuman agents and the agents' human like physical appearance (i.e., the uncanny valley). However, in order to examine the potential of using companion robots to provide social support in times of crisis, it is absolutely essential to investigate how aversive emotional states associated with isolation and uncertainty affect people's perception of agents of varying levels of human-likeness.

To fill this gap and to build upon the unique circumstances caused by COVID-19, we explored whether and how people's evaluations of agents of varying degrees of human-likeness are changed during the pandemic compared it to pre-pandemic conditions. To do so, we compared data collected in September 2020 to the data of an identical experiment that was run before the COVID-19 pandemic in September 2016 [34]. In addition, we used the UCLA loneliness scale for the COVID-19 sample and assessed whether loneliness levels reported at the height of the pandemic influenced agent assessments.

2 METHODS

2.1 Participants

Data from 69 students (46 females, M Age = 20.5) from George Mason University's student population were collected online in September 2020 and constitute the COVID-19 group. Five participants were excluded from data analysis for not completing the survey, which left the data of 64 participants for analysis. Participants received one course credit after completion via the university's participant pool (i.e., SONA system). The sample size was based the prior study [34] and kept equal to ensure sound comparisons. The PreCOVID-19 group consisted of 64 participants (33 females, M Age = 35), were participants collected online via MTurk and were not restricted to university students (see [34] for more details). Overall, data from 128 participants were included in the current study. Both studies were approved by GMU's Internal Review Board (IRB).

2.2 Agent Stimuli

The stimuli used in this experiment consisted of six images of agent faces that varied in physical humanlikeness from mechanistic robot to humanoid robot to human; see Figure 1. The images were originally created by [25]. They were presented upright at a size of 274 x 338 pixels and were offset to the left; see Figure 2. The trust, mind perception and likeability ratings were presented underneath the agent images.

Fig. 1. We used six robot faces that participants assessed. The assessments were regarding whether the faces are trustworthy, whether they have a mind and weather they are likeable.

2.3 Procedure

All aspects of the experiment were programmed and presented in Qualtrics. Upon providing consent via Qualtrics, participants assessed different "robot faces" based on three measurements: trust, mind ratings and likability. The order of the measurements were assessed in separate blocks and were randomized between the participants. The order of the items within the measurements were counterbalanced and randomized for each face and the order of the faces was randomized; see Figure 2. The rating scales were presented underneath the robot images. After completing the agent assessments, participants filled out the Revised UCLA loneliness scale (only the COVID-19 group). The PreCovid-19 group also completed individual difference questionnaires at the end of the task which were not included in the present study as the current research question is not concerned with individual differences in the UV, while the prior study was [34].

2.4 Trust

The trust measurement was based on [25] where participants were instructed that they have 100$ to share with each robot. Once they decided how much of the $100 to share with the robot, the money is given to the robot and tripled. Then, the robot will split the money how they see fit between itself and the participant. (For example, if the participant gives the robot $10, the robot will receive $30, and then split that $30 between the two of them). Any amount that the participant does not give to the robot is awarded to the participant. After deciding how much money goes to each robot, the imaginary money will be distributed according to the robots' decisions, and bonuses will be paid. Participants were not told how much money each robot gave to them to ensure that the sequence of presenting the robots did not influence their responses. As such, the amount of money that the participants gave to the robot was an index of how much they perceived it as trustworthy, with higher amounts correlating to more trust and lesser amounts meaning that participants did not trust the robot faces as much.

2.5 Mind Perception

The mind perception questionnaire was based on prior work that measured mind perception [41]. Here, participants were asked how much mind perception was perceived to each robot face (e.g., ‘Rate how strongly you feel this robot has a mind’, ‘Do you think this robot likes to hang out with friends?’). The questions measured how much we perceived each robot to be able to experience internal states such as thoughts, emotion and feelings. The participants were asked to answer the questions on a scale of 1-to-7, with 1 being “Strongly disagree” and 7 being “Strongly Agree”. Scoring was done by averaging all the items together. Higher mind perception ratings indicated more mind perception and vice-versa. There were a total of six robot images and six questions, putting the task at 30 questions total.

2.6 Likability

Here, participants were asked whether they thought each robot face was likable, which was based on Mathur and colleagues’ work [25]. The question asked about each face’s friendliness, enjoyableness and creepiness on a scale of -100-to- 100, with -100 being less friendly/more creepy, and 100 being more friendly/less creepy. Scoring was done by averaging all the items with higher likability scores suggesting higher likability. The likability section was used to ensure that we were replicating prior Uncanny Valley patterns with question that were traditionally used to measure the Uncanny Valley (e.g., creepiness and likability).

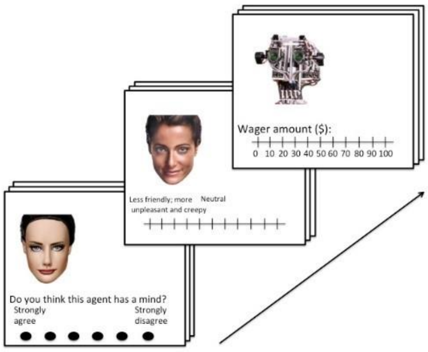

Fig. 2. Participants assessed the robot faces in a blocked manner with the order randomized within each block. The order of the blocks was also randomized between participants.

2.7 Loneliness Survey

Participants in the COVID-19 group completed a loneliness questionnaire after completing the agent assessment task. The survey assessed their level of loneliness and examine whether variations in the UV were due to loneliness scores. Specifically, we used the revised UCLA Loneliness scale [42], [43], which included statements such as

'I lack companionship' and 'There is no one I can turn to'. All items were answered with either 'Never', 'Rarely', 'Sometimes', or 'Often', which were scored with 0, 1, 2, or 3, respectively. Loneliness scores were created by summing the total of each participant's responses with higher scores indicating higher loneliness scoring for items 1, 4, 5, 6, 9, 10, 15, 16, 19 and 20 were reversed. This survey had a total of 20 items.

2.8 Analysis

The analysis of the data was borrowed from the method described in prior work [34], [36]. This method used a nested model comparison to test whether an nth level polynomial function fits the data better than a linear function using model difference statistics (e.g., Chi-Square difference test), and fit indices that penalize us for overfitting the data (e.g., BIC). Prior work suggests that if higher level polynomials fit better than a linear model, then it is considered evidence for the existence of a UV as the UV is characterized by a non-rectilinear pattern [36]. In addition to their method, we also included a dummy coded variable that indicated whether participants were in the PreCOVID-19 or COVID-19 group and an interaction between the dummy coded variable and the polynomial terms. As such, we compared a linear function to quadratic, cubic, quartic and quintic functions. All functions were fit using mixed linear models and contained a random intercept for each participant. This analysis was done to see if including an interaction term changes the model of best fit and to follow with the line of argumentation of prior work to ensure that we were observing an UV before directly comparing the two groups with one another.

After finding the function of best fit, we apply the function of best fit to each participant's individual data and extracted the polynomial derivative (i.e., coefficient) that is second to the leading coefficient (e.g., if the quintic function fits best, we extracted the 4th level coefficient for each participant). Finally, we compared the second-to-leading coefficients between the PreCOVID-19 and the COVID-19 groups using a t-test. By comparing the second-to-leading coefficients, we are able to determine whether the inflection point of each function differed between the groups. If the inflection point differed between the two groups, we can determine that the UV point differed significantly between the groups prior to rising again. This method was repeated for each of the three measurements separately. We used the False Discovery Rate (FDR) method to account for alpha inflation from conducting separate t-tests.

Finally, as a manipulation check, we ran a secondary nested model comparison to test if loneliness scores from the COVID-19 group, as measured via the UCLA loneliness questionnaire, interacted with the physical humanness to predict their assessments (i.e., trust, mind ratings and likability). If the interaction between the loneliness ratings and the physical humanness was meaningful in predicting agent assessments, then it would fit better than a model that does not contain the interaction. Thus, we are able to determine that modulations in the physical humanness-assessment relationship were due to group membership (i.e., PreCOVID-19 vs. COVID-19 group). To do so, we used an OLS regression with a single predictor (i.e., agent type) to predict the agent assessment. Next, we constructed a second OLS regression model that contained agent type, loneliness and their interaction as predictors of agent assessments.

We used an OLS regression model as opposed to the polynomials for ease of interpretation of the analyses since we were not interested in characteristic shape of the relationship, but simply whether loneliness interacted with the physical humanness-agent assessment relationship. Finally, we compared the two models using an F-test to see if including loneliness scores and the interaction term predicted agent assessments significantly, above and beyond the single predictor model (i.e., with only agent type as a predictor). As such, we would predict that the model fit would be significantly better when we include the interaction between the loneliness scores and agent-type.

3 RESULTS

3.1 Trust Results

Results of the model comparison for Trust showed that the quintic model fit significantly different than the linear model and was the best fit as it had the lowest BIC index (BIC = 6883.1, $\chi 2(2) = 19.68$, $p<0.001$); See Table 1 and Figure 3. for the results of the nested model comparison. Since the qui tic function fit the data best, we extracted the quartic coefficient separately for each participant and tested the between group differences using a t-test. The t-test showed no significant differences between the PreCovid-19 and the Covid-19 groups ($t(121.17) = -0.19$, $p = 0.84$, 95% CI [-12.53, 10.31]).

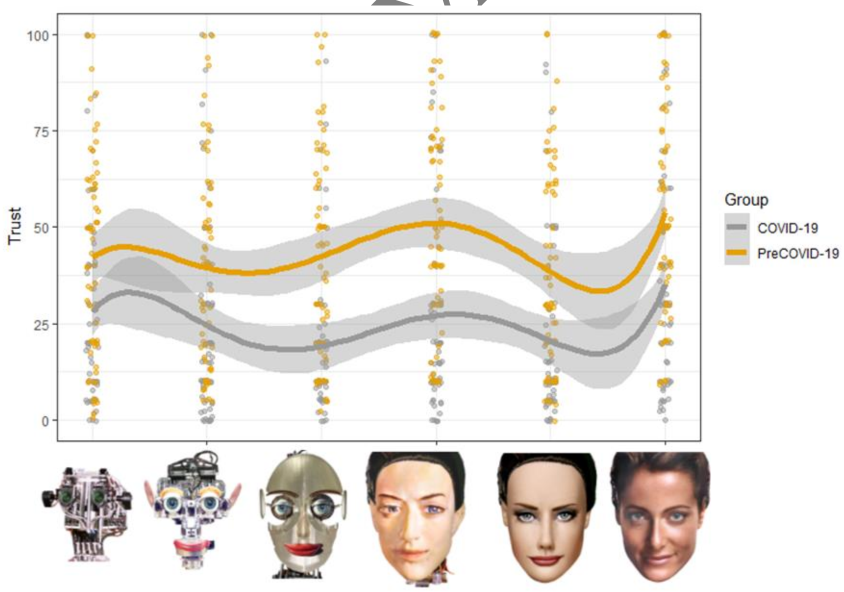

Fig. 3. The analysis showed that the quintic function fit the trust data best. Moreover, there were no detectable differences in polynomial derivatives (i.e., b coefficients) between the ProCOVID-19 and the COVID-19 groups. The shaded region represents the 95% confidence interval.

3.2 Mind Perception Results

Results of the nested model comparison for Mind Perception ratings showed that the quintic model fit significantly different than the linear model and it was the model of best as it had the lowest BIC value (BIC = 2481.8, $\chi 2(2) = 40.17$, $p<0.001$); See Table 2 and Figure 4. for the results of the nested model comparison. Since the quintic polynomial was the best fitting, we fit the function separately for each participant and extracted the quartic term to compare the UV point and tested the between group differences using a t-test. The t-test showed a significant difference between the ProCOVID-19 and the COVID-19 group (t(125.91) = 4.67, p<0.001, 95% CI [0.80, 1.99], with lower polynomial derivative estimates for the PreCOVID-19 group (M = -1.73), compared to the COVID-19 group (M = -0.34).

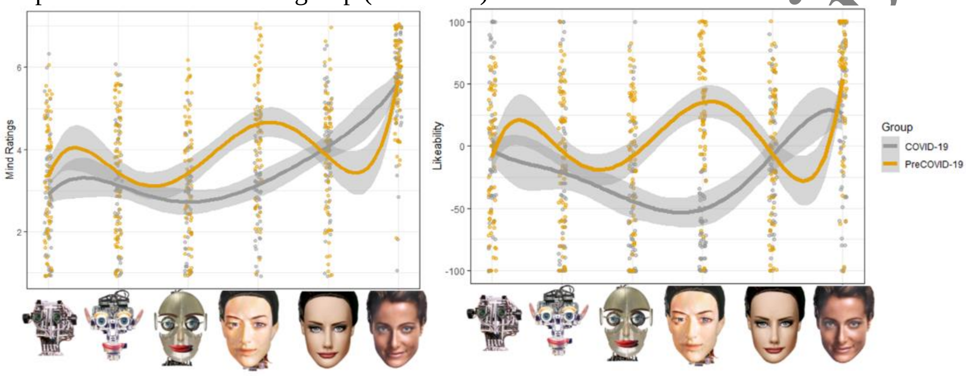

Fig. 4. Results showed that the quintic function fit the mind and likeability ratings best. Moreover, posthoc analyses showed significant differences in the UV point of the faces with a steeper UV for the PreCovid group compared to the COVID-19 group. The shaded region represents the 95% confidence interval.

3.3 Likability Results

Results of the nested model comparison for Likability showed that the quintic model fit significantly different than the linear model and it was the model of best (BIC = 8308.2, $\chi 2(2) = 30.90$, $p<0.001$); See Table 3. and Figure 5. For the results of the nested model comparison. Since the quantic model was the best fitting, we fit the function separately for each participant and extracted the quartic term to compare the UV point and tested the between group differences using a t-test. The t-test showed a significant difference between the two groups (t(111.86) = 5.03, p<0.001, 95% CI [51.77, 119.07]), with lower polynomial derivative estimates for the PreCOVID-19 group (M = 13.8), compared to the COVID-19 group (M = -71.6). P values of all the t-tests were corrected using the FDR method.

Table 1. Model Comparison of Trust

	df	χ2	p	BIC
Linear				6895
Quadratic	2	20.81	<.001	6887.4
Cubic	2	2.52	<.001	6898.2
Quartic	2	21.98	<.001	6889.5
Quintic	*2*	19.68	<.001	6883.1

Table 2. Model Comparison of MP

df	χ2	p	BIC
			2623.5
2	110.93	<.001	2525.8
2	15.61	<.001	2523.9
2	28.08	<.001	2508.7
2	40.17	<.001	2481.8

Table 3. Model Comparison of Likability

df	χ2	p	BIC
			8399.9
2	85.51	<.001	8327.7
2	4.85	.08	8336.1
2	23.61	<.001	8325.8
2	30.90	<.001	8308.2

3.4 Loneliness Survey Results

Since we only find coefficient differences between the PreCOVID-19 and the COVID-19 groups in mind perception and likability ratings, we ran the manipulation check for only these two assessments. The results of the nested model comparison for the mind ratings showed that including the interaction between loneliness ratings and agent type predicted mind ratings above and beyond the single predictor model (F(2) = 3.86, SS = 14.34, p = .02) with the interaction model explaining 28% of the variance compared to 26% of the variance for the single predictor model. The results of the nested model comparison for the likability ratings showed that including the interaction term between loneliness ratings and physical humanness predicted likability ratings above and beyond the single predictor model (F(2) = 3.81, SS = 26914, p = .02) with the interaction model explaining 4% of the variance compared to 2% of the variance for the single predictor model. Although these differences in the variance explained may seem negligible, it is not uncommon to see similar effects in social sciences. Since both models that contained the interaction between loneliness and physical humanness fit better than the model that predicted agent assessments from only physical humanness, we can conclude that the modulation that we observe in the UV pattern is due to participants' loneliness scores. As such, we can conclude that we passed the manipulation check.

3.5 Post-Hoc Analysis

After fitting the models we descriptively observed that participants in the COVID-19 group judged the "machinelike" robots (i.e., robots that are considered to be low on physical human-likeness and do not traditionally evoke eerie/uncanny feelings) lower in mind and likability ratings overall compared to the PreCovid-19 group. To empirically test this observation, we averaged the scores of the first three robots for each of the two groups and compared them using a t-test. Results of the post-hoc t-test examining differences in mind ratings revealed that subjects in the COVID-19 group judged machinelike robots as having significantly less of a mind compared to the PreCOVID-19 group (t(121.22) = -2.16, p =.04, 95% CI [-0.93, -0.04], M PreCOVID-19= 3.40 vs. M COVID-19= 2.91). Similarly, Participants in the COVID-19 group judged machinelike robots as significantly less likable compared to the PreCOVID-19 group (t(125.79)

= -2.03, p =.04, 95% CI [-31.74, -0.40], M PreCOVID-19= -6.97 vs. M COVID-19= -23.1). Both p values were corrected using the FDR method.

4 DISCUSSION

Here, we aimed at investigating if perception of robots of varying degrees of human-likeness is changed during the COVID-19 pandemic. Specifically, we were interested in seeing whether the Uncanny Valley effect that has been shown in previous literature in ratings of trust, likability and mind ratings [25], [31], [34], [37] is changed due to feelings of loneliness. Thus, we asked all participants to judge robots of varying degrees of physical human-likeness on whether they trusted, perceived a mind to- and liked them. After completing these assessments, participants in the COVID-19 group rated their experience with loneliness during the COVID-19 pandemic via the UCLA loneliness questionnaire [42], [43]. The robot images that we used have previously shown a UV pattern on ratings of warmth, eeriness, likability and mind perception [25], [34]).

To examine whether UV was impacted by the COVID-19 pandemic, we compared data collected in September 2020 (during the pandemic) to data collected in September 2016 (before the pandemic); see Abubshait et al., 2017 [34] for the original dataset. Prior work has shown that people who experience loneliness are more likely to attribute human-like traits to nonhuman agents in an attempt to satisfy their need for social connection [39]. As such, we hypothesized that the Uncanny Valley effect should be attenuated for those who experienced loneliness during COVID-19 compared to those who did not. While our hypotheses were not supported for the trust task, we provide evidence for the assumption that loneliness during the COVID-19 pandemic influences the UV pattern for mind perception and likability ratings. Specifically, trust ratings showed that a UV shape was observed as the quintic function fit the data best, which also replicates prior work that shows that the UV pattern is shown when examining trust measures [25], [34]. However, there were no significant differences in the second-to-leading coefficient between the PreCOVID-19 and COVID-19 groups on measures of trust. This means that the inflection point of the UV effect was not different between those who experienced the COVID-19 pandemic and those who did not. With respect to the mind perception and likability ratings, the results showed that the UV shape existed as the quintic function was the best fitting model. Also, analyses for both these ratings showed that the inflection point -as indicated by the second-to-leading coefficient- was significantly different between the PreCOVID-19 group and the COVID-19 group. The differences between the groups were such that very human-like (and traditionally uncanny) faces were perceived as more favorable for the COVID-19 group (i.e., less of an UV pattern) than the PreCOVID- 19 group. These differences are likely driven by the fact that participants in the COVID-19 group were experiencing loneliness as the manipulation check showed that loneliness ratings interacted with physical humanness and significantly explained more variance than physical humanness alone. This suggests that loneliness ratings were critical to understand the variations in ratings between the robot faces for those in the COVID-19 group, which is in line with our hypotheses (excluding the trust data).

The analyses of these data provide two major takeaways. First, the COVID-19 group perceived the uncanny faces as more favorable and having more mind. This effect can potentially be explained by prior work showing that loneliness increases sociality motivation (i.e., our need to have favorable social interaction with others [39]). Moreover, Eyssel and Reich [39] illustrated that these effects can extend to robots, where people who experience more loneliness are more likely to anthropomorphize and judge interactions with robots as more affectively pleasing. With regard to our data, it could be the case that increased feelings of loneliness that were brought on by lockdowns during the pandemic increased people's sociality motivation to interact with and seek social connection with others. As such, people were more likely to anthropomorphize humanlike agents than mechanistic agents. Still, it is unclear why participants who experienced loneliness did not anthropomorphize all the robots to the same extent. The data observed here shows that these participants treated "mechanical" and "humanlike" robots categorically differently. One explanation could be that different agents of the categories would be influenced by loneliness differently, which is supported by prior work that suggests a categorical threshold that is observed between agents of varying physical humanness, which influences agent assessments [30]. However, this interpretation should be examined by future work.

Post-hoc analyses showed that the COVID-19 group judged "machine-like" robots more negatively with regard to likability (i.e., less likable/more eerie) and having less of a mind. This specific finding can be explained by prior work that showed that feelings of anxiety and uncertainty can increase people's likelihood to experience eeriness, which is negatively correlated with likability [44]. Since studies have shown that anxiety is correlated with feelings of loneliness [42], it is not surprising that people who experience loneliness could experience more adversity when facing uncertainty. This finding also fits with other studies that show that those influenced by the COVID-19 pandemic are more likely to engage in heuristic thinking [45]. In other words, heuristic thinking that is induced via loneliness could bias their responses to lower likability and mind ratings to resolve any eeriness feelings that could arise from uncertainty.

Together, our findings suggest that adversity during the COVID-19 pandemic biased people towards the extreme sides of the rating scales and away from the middle part of the scale. In other words people were more likely engage in heuristic thinking about these robots when rating them. As a result, machinelike robots were rated towards the left side of mind perception/likability scales (i.e., rated more negatively), while ratings for humanlike robots were biased towards the right (i.e., more positively). This specific finding has been shown in prior work that suggests that humans engage in categorical thinking when rating agents of varying degrees of humanness [24]. While their work did not focus on traits that cause people to be categorically biased in their subjective ratings towards robots (i.e., using only the extreme sides of a rating scale), it does invite questions for future work. For example, are robot/human traits that influence categorically biased responses towards robots? If so, do these translate to interaction with robots? Moreover, we invite future work to examine whether these effects translate to dynamic stimuli/real robots or are they solely observed in static images? Also, since we did not collect loneliness data in our PreCovid-19 group, it remains unclear to when extent this is correlated with our effects, which future work should address.

This experiment set out to examine the effects of loneliness that people experienced during the COVID-19 pandemic on the Uncanny Valley. Thus, we examined if the UV that prior work has shown is evident in people who were affected by the pandemic. The study showed that people were less likely to experience feelings of uncanniness when interacting with humanlike agents. However, they also perceived machinelike agents to be less likable and to have less of a mind. This has major implications for Human-Robot Interaction, as designers need to focus more on design implications that influence robots' appearance. For example, it seems that people are more willing to accept human-like robots as interaction partners. Another implication is that people are more critical of machine-like robots. This is an important consideration as people felt more positively towards, and were more likely to perceive minds to robots that are traditionally thought of as "Uncanny" robots. This specific finding marks a positive HRI finding as human acceptance of anthropomorphized and human-looking robots could be on the rise.

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