Effect of State Loneliness on Robot Anthropomorphism: Potential Edge of Social Robots Compared to Common Nonhumans

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Abstract. Previous studies have widely demonstrated that loneliness will increase people’s anthropomorphic tendency on nonhuman agents. This research extends the effect of loneliness to social robots and differentiates them and common nonhuman agents (e.g., gadgets, animals). Remarkably divergent effects have been verified: experimentally induced loneliness has a positive effect on anthropomorphism of a social robot but not a gadget clocky or an animal. Practical implications are: (1) could prime consumers’ state loneliness when marketing domestic robot products; (2) emphasize humanlike warmth when designing social robots for companion. The findings have found social robots’ edge in providing companionship compared with common nonhuman agents.

1. Introduction
As Aristotle wrote in this book Politics, maintaining social ties with others is one of our basic needs. However, when this need for social connection is unable to be met, people become lonely [1, 2] and inclined to anthropomorphize [3]: adapt to painful loneliness by projecting human attributes onto nonhuman agents. Loneliness has been a social plight that requires attention [4]. In industrialized nations around 33% population suffers from it, with one person in twelve influenced seriously and the proportion still goes on expanding [4]. Herein, robot companion has been emerging as a solution to alleviate this issue [5-7].

The development of Artificial Intelligence (AI) have given multiple human attributes to social robots, who thus become one of the most easily and commonly anthropomorphized nonhuman agents in this age. Just like connection with pets could complement or even substitute interpersonal interactions [8], anthropomorphized social robots are also capable of fulfilling such needs [5, 7, 9-13], especially for people who feel lonely [14, 15].

Hence, focusing on loneliness, for which social robots have a meaningful role to play, this research aims at answering whether loneliness itself has significant effect on people’s perception (i.e., anthropomorphism) of social robots. Will the effect extend to other nonhumans like gadgets or animals? Comparing to these common nonhuman agents, what is the edge of social robots to soothe loneliness? In the remaining content we will answer these questions by introducing related theories, developing our hypothesis, reporting a study that test the hypothesis, and discussing our findings.
1.1. Theoretical Background

Based on the following theories, we built our research hypothesis.

1.1.1. Anthropomorphism Theory. Anthropomorphism begins to attract academic attention as a psychological construct in recent years. It is defined as attributing human characteristics, intentions, psychological states, etc. to nonhuman agents [3, 16]. The “Three-factor Theory of Anthropomorphism” [3] put forward three psychological determinants of anthropomorphism: elicited agent knowledge, effectance motivation, and sociality motivation.

“Elicited agent knowledge” focuses on humanlike features of the anthropomorphized nonhumans. “Effectance motivation” concerns people’s need for effective interaction or their fear of uncertainty. “Sociality motivation”, driven by the experience of loneliness, denotes that our need for social connection has a significant impact on our anthropomorphic tendency. In other words, loneliness affects anthropomorphism by increasing people’s inclination to identify humanlike attributes of nonhumans so as to fulfill their need for social contact resources.

It has been well documented that loneliness influences anthropomorphism of a variety of nonhumans such as animals, gadgets and computers [17-21]. The majority of these studies used experimental manipulations to make participants feel temporarily socially disconnected so as to increase their loneliness. Unlike trait or chronic loneliness (i.e., as a personal characteristic continuity), this state loneliness is a temporary emotional response to socially disconnected situations.

According to the compensation hypothesis [22], similar to feeling hungry, state loneliness level also varies from one time to another. When people become hungry they go for food. When feel lonely, a hallmark of social pain, they take active steps to alleviate this painful experience by seeking comforting psychological connections with others [2]. Hence, state loneliness can serve an adaptive function in that it stimulates reconnection [1] by myriad socially skilled behaviors to gain a sense of interpersonal interaction [23]. For example, daydreaming about one’s significant others supplements social connection after induced loneliness [24].

We conjecture that state loneliness make people more sensitive to the social clues that facilitate reconnection from a social robot (e.g., warmth). However, we also think the effect of state loneliness on other nonhumans (e.g., gadgets, animals) would be different in that there exists difference between robots and other nonhumans.

1.1.2. Social Robots and Common Nonhuman Agents. Research indicates that human/robot and human/animal contrasts are orthogonal [25]. The trichotomy (i.e., humans, animals, and machines) detailed in a previous work [26] and its early support [27] demonstrated that social categories might be differentially linked with humanness and with machines or animals. Some evidence also showed that anthropomorphic tendency on animals is different from the anthropomorphism of machines [28].

Social robots, hitherto usually posited as having humanlike bodies and intelligence, are floating in an ambiguous zone between humans and common nonhumans (e.g., gadgets, animals), and thus cannot simply be categorized as either of the two. We avoid classifying robots as common nonhuman agents since they are quite humanly intelligent compared to gadgets, animals, etc. Hence, to investigate the effect of state loneliness on robot anthropomorphism more thoroughly, it is also necessary to take common nonhuman agents into account.

Anthropomorphism is more than granting behavioral characteristics to nonhumans (e.g., a robot is aggressive); it includes attributing to them traits that individuals instinctively regard as uniquely human [29]. Hence, humanness & human essence might be a useful perspective for discovering new knowledge of anthropomorphism.

1.1.3. Two Humanness Aspects. According to the dehumanization model [30], as human beings, we possess two distinct aspects of humanness: Human Nature (HN) and Unique Human Nature (UHN). HN indicates inborn traits that are central to and prevalent among all humankind, which might also be
shared with other creatures, such as “nervous”. UHN refers to socially acquired traits, usually varying within cultures and populations, that distinguish humans from other species [30-32], such as “polite”.

Social cognition theory [33, 34], also provides some accounts of the underlying process of robot anthropomorphism. This theory proposes two ambivalent aspects of human essence-competence vs. warmth that govern social perception and judgments [27, 33, 35, 36]. The two aspects originated in evolutionary pressures under which social animals must immediately judge whether the other is friend or foe (i.e., warmth), and then whether the other is able to enact their intentions (i.e., competence).

Accordingly, HN, as “experience,” is mainly embodied in primary emotions and warmth, whereas UHN reflects “agency” and high cognitive abilities, such as secondary emotions and competence [37, 38]. Since anthropomorphism is a process of seeing human qualities in nonhuman agents, theoretically, we can anthropomorphize robots by attributing to them these two aspects that bolster the core of humanity. Hence, we can use these two aspects to assess robot anthropomorphism.

1.2. Research Gaps and Hypothesis

There have been research exploring the effect of state loneliness on nonhuman anthropomorphism. However, it requires more empirical support that whether the effect also extends to social robots and whether social robots are anthropomorphized differently from common nonhumans in this situation. By doing so, we could deepen our knowledge about the determinant of robot anthropomorphism and find a way for human-robot confluence. Thus, our hypothesis is:

When people become lonelier than normal (state loneliness), their anthropomorphic tendency on social robots will be enhanced, whereas this positive effect of state loneliness is not remarkable with common nonhuman agents (i.e., a gadget clocky or an animal).

2. Materials and Methods

2.1. Participants and Procedure

224 people (142 females) from nationwide participated in the online experiment. The average age was 29.30 years (SD = 7.47). Firstly, all participants reported their state and trait loneliness before the experiment. After that, they were randomly assigned to two groups: the loneliness-priming group were asked to think back and write about an event where they felt extremely lonely [39]; the control group were ask to describe a day in their daily lives.

Then the two groups completed another two scales that measure their state loneliness level as well as positive and negative emotions to check our priming manipulation. Then they viewed three pictures with brief introduction of a social robot prototype, a clocky, and animals (figure 1) in random order, and rated anthropomorphism of the three nonhuman agents (for animals, they were told to imagine only one animal). At last, their basic demographic information was collected.

![Figure 1. Social robot prototype, clocky, and animals.](image)

We gave participants standard Chinese versions of all psychological scales used in this research and instituted two quality control measures. Participants who failed “attention-check” questions or “time control” [40] were excluded. We only report descriptions of the valid data. All participants gave informed consent and were paid for their participation. We revealed our focus on loneliness in the post-experiment debrief. The research was approved by XX University Institutional Review Board.
2.2. Measures
Participants completed the following scales.

2.2.1. State Loneliness 1. We used a one-item 7-point Likert scale to measure participants’ state loneliness level before the experiment (“How lonely are you feeling at the moment? From 1 (not at all) to 7 (extremely)”).

2.2.2. Trait Loneliness. We assessed the participants’ trait loneliness by UCLA (University of California, Los Angeles) Loneliness Scale Version 3 [41]. α = .92.

2.2.3. State Loneliness 2. We used the De Jong Giervald 6-Item Loneliness Scale to measure state loneliness after the priming manipulation. The scale consists of 6 items (e.g. “I miss having people around me.”) to be rated based on 1 (yes), 1 (more or less), and 0 (no). α = .79.

2.2.4. Positive / Negative Affects. In order to tell state loneliness apart from general negative affects after priming loneliness, we used the international short-form PANAS (Positive And Negative Affect Schedule) to measure the affects that participants might experience after the priming manipulation [42]. It contains 5 positive (e.g. inspired, α = .68,) and 5 negative (e.g. upset, α = .78) affects to be rated on a scale from 1 (never) to 5 (always).

2.2.5. Anthropomorphism. Anthropomorphism was assessed by two scales: the adjective word-series of humanness dimensions [43] and the RoSAS (the Robotic Social Attributes Scale) [44] that measures robots’ humanlike warmth, competence, as well as discomfort.

Considering that the original two adjective word-series (i.e., human nature traits, unique human nature traits) combined both positive and negative traits, which might influence each other on people’s scoring as well as the acquiescence bias [45-47], we adjusted the two series into four separate 7-point Likert scales as follows (1: not at all characteristic of the robot; 7: entirely characteristic of the robot).

Positive Human Nature Traits (HN_pos) HN_pos indicates the five positive human nature traits: Curious, Friendly, Fun-loving, Sociable, and Trusting. α = .83 (robot), .77 (clocky), .61 (animal).

Positive Unique Human Nature Traits (UHN_pos). UHN_pos describe positive traits uniquely belonging to humans: Humble, Thorough, Organized, Broadminded, and Polite. α = .80 (robot), .80 (clocky), .79 (animal).

Negative Human Nature Traits (HN_neg). HN_neg indicates: Impatient, Aggressive, Nervous, Jealous, and Distractable. α = .77 (robot), 76 (clocky), .75 (animal).

Negative Unique Human Nature Traits (UHN_neg). UHN_neg indicates: Cold, Shallow, Stingy, Hard-hearted, and Conservative. α = .78 (robot), .79 (clocky), .76 (animal).

RoSAS (44) consists of 18 adjectives representing three dimensions: warmth (e.g., “compassionate”), α = .86 (robot), .85 (clocky), .66 (animal); competence (e.g., “knowledgeable”), α = .89 (robot), .86 (clocky), .69 (animal); and discomfort (e.g., “scary”), α = .84 (robot), .83 (clocky), .81 (animal). These adjectives are evaluated on 9-point Likert scale from 1 (definitely not associated) to 9 (definitely associated).

3. Results
Loneliness priming was successful: participants reported feeling significantly lonelier in the loneliness priming group (N = 122, M = 4.54, SD = 3.18) than those in the control group (N = 102, M = 3.31, SD = 3.05), t (222) = 2.94, p = .004, d = .40, 95% CI [.40, 2.05]. There was no significant difference between the two groups regarding their state, t (222) = .90, p = .37, or trait loneliness level, t (222) = .80, p = .43, before the experiment. Besides, after the priming manipulation, neither negative, t (222) = 1.90, p = .06, nor positive affect, t (222) = -.40, p = .69, experienced by the two groups was significantly different. The variances in the two groups before and after loneliness priming were equal.
In addition, there was no interaction effect between trait and induced state loneliness on all the dependent variables.

Loneliness priming group perceived significantly more HN_pos of the robot (M = 5.00, SD = 1.15) and of the clocky (M = 4.81, SD = 1.14) than did the control group (M = 4.69, SD = 1.21; M = 4.16, SD = 1.22), 95% CI [.00, .61], t (222) = 1.98, p = .05, d = .28; 95% CI [.33, .95], t (222) = 4.07, p = .00, d = .55. As shown in figure 2.

![Figure 2.](image2.png)

**Figure 2.** HN pos (positive Human Nature) ratings of robot, clocky and animal.

Loneliness priming group (M = 5.44, SD = 1.85) perceived more warmth of the robot than did the control group (M = 4.94, SD = 1.71), this difference, .50, 95% CI [.03, .97], was significant, t (222) = 2.09, p = .04, d = .28. Ratings on clocky warmth between the loneliness priming (M = 5.04, SD = 1.84) and the control group (M = 4.38, SD = 1.66) was also significantly different, t (222) = 2.80, p = .01, d = .38. As shown in figure 3.

![Figure 3.](image3.png)

**Figure 3.** Warmth ratings of robot, clocky and animal.

Additionally, there was no significant difference of perceived animal HN_pos or warmth between the two groups. It is also noteworthy that neither competence nor discomfort was significantly different between the two groups’ ratings for all the three nonhuman agents.

Conducting a mixed design ANOVA, we took nonhuman agent type (i.e., social robot, clocky, animal) as the within-group variable to analyze the effect of state loneliness on anthropomorphism. All effects are reported as significant at p < .001 unless stated otherwise.

Main effect of state loneliness was significant on warmth: F (1, 222) = 5.98, p = .02, r = .16; and HN_pos: F (1, 222) = 12.26, p = .00, r = .23.

Main effect of nonhuman agent type was significant on warmth: F (2, 444) = 169.10; HN_pos: F (2, 444) = 86.05; UHN_pos: F (2, 444) = 33.57; HN_neg: F (2, 444) = 49.22; UHN_neg: F (2, 444) = 5.22.
There was a significant interaction effect between state loneliness and nonhuman agent type on warmth: $F (2, 444) = 4.18, p = .02$. This effect indicates that perceived warmth of different nonhuman agents differed in high and low state loneliness. Contrasts revealed significant interactions. Perceived robot warmth increased as state loneliness increased, while this increase was only pronounced for robot not for animal. $F (1, 222) = 4.66, p = .03$, $r = .14$. As shown in figure 4.

![Figure 4](image_url)

**Figure 4.** Interaction effect between state loneliness and nonhuman agent type on perceived warmth.

### 4. Discussion

Our hypothesis was partly confirmed in that state loneliness enhanced perceived robot warmth but not competence, which is consistent with a previous study that proved emotionality rather than intelligence made robots more humanlike [38]. In social psychology, warmth and competence are two separate dimensions of social perception [33], and judgments about warmth are regularly rendered before competence and attached more importance in interpersonal interactions [44]. The finding could be further explained by compensation hypothesis [22]. The increased robot warmth may result from participants’ motivation to compensate for their state loneliness. When feeling lonely, people are more likely to enjoy robot companion and engage in the parasocial interaction [48], so they take active steps to alleviate this painful feeling by perceiving robots’ warmth as a compensation [49].

This result supports the anthropomorphism theory regarding “sociality motivation” and is consistent with previous research that verified the effect of loneliness activation [50] on attribution of mind and human essence to robots, and the effect of social exclusion [51] on robot persuasiveness. Another supporting evidence is that participants perceived computers more humanlike in the condition of experimentally induced state loneliness than in control condition [20], which is tantamount to what we found with robots.

On the other hand, the difference between social robots and common nonhumans has been proved. Social robots are distinct from animals mainly in that state loneliness enhanced perceived HN_pos and warmth of the robot but not of an animal. This finding suggests although animal warmth was rated higher overall, social robots have exclusive potentials to make full use of people’s state loneliness to facilitate interactions, manifest warmth, provide companionship, and alleviate loneliness.

It is also interesting that state loneliness only had significant effect on no-life nonhuman agents (i.e., social robot and clocky) but not animals, which is consistent with a previous study that found no significant difference between loneliness priming and control group in attributing social traits to cats [20]. Partly because we asked participants to think of an animal and highly likely they chose the ones they liked, leading to a “ceiling effect.” Thus, animal they was rated high in both groups.

One limitation of this research is the psychometric quality of the self-report measurements is limited. In future, we will add behavioral experiments or physiological signs to analyze this issue in a more objective way. Another limitation is the stimuli are pictures. Although have compared three stimuli forms (i.e., a robot picture, an on-site robot, direct human-robot interaction) in a previous study
(in press) showing the effects are similar, we will manage to let our participants to directly interact with robots to explore future research questions.

5. Conclusion
Loneliness is a pertinent factor in understanding the relationship between humans and robots. Robots provide benefits of relieving loneliness, while the development of human-robot confluence require not only technology but knowledge of human cognition, emotion and behavior [52]. We found that experimentally induced state loneliness causally increased robot anthropomorphism in terms of perceived humanlike warmth (but not competence). Hence, improving perceived robot warmth could be a promising direction for robot design.

Moreover, the understanding of human-robot relations can be deepened by comparisons to our relations with animals [53]. We enhanced the understanding by corroborating the distinction between social robots and common nonhuman agents (i.e., a gadget clocky, animals) concerning how they were anthropomorphized. The former has an exclusive advantage in that people feel significantly more warmth from a social robot when they get emotionally lonely. This finding helps discovering social robots’ edge in providing companionship. A practical implication is that robot companies or sellers could induce customers’ state loneliness when marketing robots.

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