심리학석사 학위논문

# Social robots as companions for lonely hearts: The role of anthropomorphism and robot appearances

## 외로운 개인의 소셜 로봇에 대한 의인화 경향성이 구매 의도에 미치는 영향: 로봇 외모의 조절 효과

2022 년 8 월

서울대학교 대학원

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# Social robots as companions for lonely hearts: The role of anthropomorphism and robot appearances

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이 논문을 심리학석사 학위논문으로 제출함
2022년 6 월

서울대학교 대학원
심리학과 인지심리 전공
정 윤 원

정윤원의 심리학 석사 학위논문을 인준함
2022 년 8 월

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# Abstract

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Previous research demonstrated that lonely individuals anthropomorphize nonhuman entities more to compensate for a perceived lack of connectedness. While the inclination is well-replicated across nonhuman agents (i.e., technical devices, animals, computers) it is less examined in the context of embodied social robots. Also, it remains unclear whether the anthropomorphizing tendency influences the purchase intent of individuals with higher levels of loneliness. The present research investigated whether lonely individuals show greater tendency to anthropomorphize social robots and whether the appearances of robots moderates such tendency. We also examined the influence of lonely individuals' heightened anthropomorphizing inclination on their purchasing intent of social robots. In Study 1, we used static photos of robots as stimuli. In Study 2, videos of robots moving and interacting with a human counterpart were used. Both in Study 1 and Study 2, loneliness did not significantly affect the participants' anthropomorphic inferences about social robots. However, in Study2, animal-like robot significantly decreased the lonely individuals' tendency to anthropomorphize the robot than human-like robot, and such moderating effect remained significant even after covariates were included. Also, in Study 2, the likelihood of higher loneliness increasing purchase intent of social robots via anthropomorphism was lower in the case of an animal-like robot than human-like robot. The findings suggest that an inclination of lonely individuals to anthropomorphize social robots, but such tendency varies

greatly in accordance with the varying appearances of the robots. Furthermore, the results indicate that lonely individuals' tendency to engage in anthropomorphic reasoning can be stretched to their behavior as consumers. We draw attention to the potential of social robots as real-life companions, that provide a sense of connectedness for lonely individuals.

***Keywords*** **:** Loneliness, Anthropomorphism, Social Robot, Purchase Intent

***Student Number*** **:** 2020-23244

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# Chapter 1. Introduction

## 1.1. Background

Loneliness arises when individuals feel their need for social connection is not fulfilled to the desired level (Cacioppo & Patrick, 2008; Perlman & Peplau, 1981; Perry, 1990). Lonely people suffer poorer health, with repercussions ranging from depression to higher blood pressure, and a compounded immune system (Alun & Murphy, 2019; Cacioppo et al., 2003; Cacioppo, Hughes, et al., 2006; Hawkley & Cacioppo, 2010; Hawkley et al., 2010). They also face increased medical bills, as a result of such repercussions (Barnes et al., 2021; Meisters et al., 2021). Given that loneliness is not only a painful individual experience but an increasingly serious social problem, tackling loneliness is a critical task.

Loneliness is not equivalent to objective social isolation. Rather, it is the result of a subjectively perceived state of isolation (Cacioppo & Patrick, 2008). Still, single-person households are chiefly at an increased risk of chronic loneliness (Groarke et al., 2020; Pinquart & Sörensen, 2003). When in-person communication is restricted at home for individuals living alone, as against those who co-reside, social robots that are capable of socially meaningful interaction with humans could be a potential source of connectedness (Breazeal, 2003; Breazeal & Scassellati, 1999). Indeed, previous research has shown that social robots can attenuate feelings of loneliness (Banks et al., 2008; Kanamori et al., 2002; Robinson et al., 2013).

Sociality motivation, along with elicited agent knowledge and effectance motivation, constitute three main factors in anthropomorphism (Epley et al., 2007). Sociality motivation prompts lonely individuals to anthropomorphize nonhuman objects or beings, to satiate their unmet need for social connection (Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008). In

line with the theory, it has been reported that loneliness increases the tendency to anthropomorphize nonhuman agents (Bartz et al., 2016; Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008; Eyssel & Reich, 2013; Shin, 2020; Shin & Kim, 2020). However, to date, this tendency is rarely tested using social robots, and the results of few research that employed social robots appear inconsistent. While one study found that loneliness increased the propensity to anthropomorphize social robots, another study reported that trait loneliness lowered this likelihood (Eyssel & Reich, 2013; Li et al., 2020). Therefore, exploring the influence of loneliness on anthropomorphizing social robots with varying appearances will demonstrate if a heightened inclination to anthropomorphize nonhuman agents applies to social robots.

For social robots to be adopted in real life settings, lonely individuals' behavioral intent as consumers is important. Previous research has found that anthropomorphism increases customers' probability of purchasing and that the likability or enjoyment factor mediates this relationship (Han, 2021; Hart & Royne, 2017; Laksmidewi et al., 2017; Wölfl et al., 2019; Yen & Chiang, 2021). However, such associations were not tested against, specifically, social robots. Our investigation makes the first contribution to examining whether lonely individuals' anthropomorphic tendency predicts their purchasing intent regarding social robots. Such an approach will weigh the potential of social robots as practical companions for lonely individuals in need.

In light of the aforementioned reasons, investigating the impact of loneliness on anthropomorphizing social robots carry both theoretical and practical implications for human-robot interaction. Therefore, this study examined the effect of loneliness on anthropomorphism and tested its practical implications regarding the behavioral intent of lonely individuals in the

case of social robots.

## 1.2. Literature Review and Hypotheses

### *Loneliness and social robots*

The need to belong is fundamental to humans (Baumeister & Leary, 1995). Its absence is felt as loneliness, which is not equivalent to objective social isolation but rather arises from a state of subjective social isolation, where one feels emotional distress due to an unmet desire for social connection (Cacioppo & Patrick, 2008; Perlman & Peplau, 1981; Perry, 1990). This can elevate stress hormone levels, increase depressive symptoms, and even prompt cognitive decline and dementia (Adam et al., 2006; Cacioppo, Hawkley, et al., 2006; Holwerda et al., 2012; McQuaid et al., 2021). It is also associated with higher blood pressure, increased heart rate, and compounded immune system (Alun & Murphy, 2019; Cacioppo et al., 2003; Hawkley & Cacioppo, 2010; Hawkley et al., 2010). These grave physical and mental declines lead to higher medical and general practitioner costs (Barnes et al., 2021; Meisters et al., 2021). Thus, loneliness is a distressing personal experience as well as a growing social problem that should be addressed.

Among various risk factors, being unmarried or divorced was positively correlated with loneliness (Beutel et al., 2017; Groarke et al., 2020). Similarly, co-habitation and the quality of social relationships had buffering effects on loneliness, suggesting that living alone poses a significant risk (Pinquart & Sörensen, 2003). For them, social robots could alleviate the pain of loneliness. In human-robot interaction perspective, the term ‘social robot’ refers to an autonomous robotic agent that can trigger and maintain socially meaningful interactions with

humans (Breazeal, 2003; Breazeal & Scassellati, 1999; Lee et al., 2005). Socially meaningful interactions can be achieved by a robot imparting its own intentions and goals, and by eliciting social responses, ranging from humans perceiving the robot as a social agent to creating bonds with it, and building a foundation for companionship between both (Lee et al., 2005). Recent advances with artificial intelligence have made more complex behaviors and lifelike tendencies available to social robots. Therefore, this study investigated the lonely individuals' perceptions and behavioral intents toward social robots.

### *Anthropomorphizing social robots*

Humans can anthropomorphize non-human agents by attributing minds to them (Epley et al., 2013). In other words, anthropomorphizing is attributing humanlike characteristics, motivations, intentions, and emotions in response to the imagined or real behavior of nonhuman agents (Epley et al., 2007), arising unconsciously when anthropomorphic cues are observable (Han, 2021; Kim & Sundar, 2012). However, people do not always anthropomorphize objects, and instead reason about other minds when it appears advantageous for attaining specific goals, but otherwise not (Epley et al., 2013). In such a sense, anthropomorphism is a motivated perception of mind from human or nonhuman objects.

A group of scholars defined two separate dimensions of human traits, attributed to both humans and nonhumans (Eyssel et al., 2011; Haslam et al., 2008; Złotowski et al., 2014). Haslam and other colleagues defined the two dimensions as human nature(HN) and uniquely human nature(UHN) (Haslam et al., 2008; Loughnan & Haslam, 2007), and saw the two dimensions as the foundations of human essence. Here, characteristics of humans shared with other animals are referred to as HN, while UHN characteristics are those unique to humans and

not shared by any other species (Haslam et al., 2008). Gray et al. (2007) also suggested two dimensions of mind perception, which are agency and experience. Experience represents the bodily sensations and feelings, and agency refers to the ability to intend and conduct actions. To a large extent, the notions of humanization and mind perception resemble each other. Agency aligns with UHN dimensions, whereas experience dovetails with the HN dimension (Gray et al., 2012; Gray & Wegner, 2012).

Previous research defined anthropomorphism from a perspective of mind perception or human essence attribution to nonhuman entities (Eyssel et al., 2011; Eyssel et al., 2012; Eyssel & Reich, 2013; Kamide et al., 2013; Li et al., 2020; Zhou et al., 2018). The two-dimensional model enables the investigation of the compartmentalized features of anthropomorphism that essentially influence the relationship between variables of attention (Złotowski et al., 2017). It has been reported that people saw a typical human as high in both agency and experience, mammals as low in agency but high in experience, and robots as high in agency but low in experience (Gray et al., 2007; Gray & Wegner, 2012; Rai & Diermeier, 2015). It is also argued that attributing the perceived experience to robots would help reduce their perceived machine-likeness, and give them a more human-like bearing (Li et al., 2020). Therefore, we presumed that perceived experience, rather than perceived agency, will be the dimension attributed to robots when anthropomorphizing social robots.

***The anthropomorphic tendency of lonely individuals***

Previous research has proposed a three-factor theory of anthropomorphism to understand its mechanism from a psychological perspective (Epley, Waytz, et al., 2008; Epley et al., 2007). It suggests that anthropomorphism is determined by cognitive and motivational factors. The

cognitive determinant is elicited agent knowledge, and the motivational determinants consist of effectance motivation and sociality motivation (Epley et al., 2007). Elicited agent knowledge underpins the fundamental mechanism of anthropomorphism. It relates to the accessibility and applicability of anthropocentric knowledge. Effectance motivation refers to the motivation to explain and comprehend other agents' behavior. The last factor is sociality motivation, which is the desire for social contact and attachment.

Among the three factors, sociality motivation implies that loneliness could influence the tendency to anthropomorphize nonhuman agents. According to the theory, lonely individuals compensate for unrealized connection needs by anthropomorphizing non-human objects (Epley, Akalis, et al., 2008). Indeed, a body of research showed that loneliness increases the propensity to identify the human-like attributes of other entities (Bartz et al., 2016; Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008; Eyssel & Reich, 2013). Lonely individuals generally held animals, technical gadgets, and social robots to have more human-like mental states. Such tendency was also replicated in Korean samples (Shin, 2020; Shin & Kim, 2020).

On the other hand, a recent study reported that trait loneliness lowered the tendency to attribute humanness and the acceptance of human-like social robots (Li et al., 2020). The authors suggested that social robots were possibly perceived as unsettling by dispositionally lonely individuals, who are more prone to interpret their social surroundings as threatening (Cacioppo & Hawkley, 2009; Hawkley & Cacioppo, 2010; Li et al., 2020). Also, when the motivational factors of anthropomorphism are present, anthropomorphism is facilitated; yet, when they are lacking, the tendency to anthropomorphize nonhumans declines (Epley et al., 2013). Given this, the authors also expected that lonely participants were less motivated to efficiently engage or connect with others, inhibiting the influence of the aforementioned two

factors (Li et al., 2020).

As a result, there are conflicting findings on the association between loneliness and anthropomorphism. The differences arose regarding the type of object anthropomorphized. The lonely individuals generally leaned more towards anthropomorphizing simple technical devices and animals (Bartz et al., 2016; Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008; Shin, 2020; Shin & Kim, 2020). However, studies employing robots reported both positive and negative associations between loneliness and anthropomorphism (Eyssel & Reich, 2013; Li et al., 2020). Such inconsistency regarding the impact of loneliness on anthropomorphism of robots needs further investigation, since relatively little research has been carried out with robots. However, in line with the major body of research, we hypothesize that lonely individuals will anthropomorphize social robots to a greater degree.

**H1**: Lonely individuals will show increased tendency to anthropomorphize social robots.

***The effect of social robots' appearances on the anthropomorphic tendency of lonely individuals***

The appearance of robots may partly explain why differences in the relationship between loneliness and anthropomorphism arose. Therefore, we predicted that the robots' appearances will have a moderating effect on this association. The robot used in Li et al. (2020) was more machine-like compared to that used by Eyssel and Reich (2013), which may indicate that machine-likeness decreases the lonely individuals' tendency to anthropomorphize. Moreover, since human-likeness is more likely than animal-likeness to evoke anthropomorphism, we

hypothesized that lonely individuals would anthropomorphize animal-like robots less than human-like ones.

**H2**: The anthropomorphic tendency of lonely individuals will differ by the appearances of social robots.

**H2-1:** Lonely individuals will show decreased inclination to anthropomorphize machine-like robot than human-like robot.

**H2-2:** Lonely individuals will show decreased inclination to anthropomorphize animal-like robot than human-like robot.

***The effect of anthropomorphizing on the likability and purchase intent of social robots***

Social robots are reported to be effective in alleviating loneliness by supplementing the social relationships that that are otherwise perceived to be lacking (Banks et al., 2008; Kanamori et al., 2002; Robinson et al., 2013). Such studies introduced the robots in nursing homes or shelters for the elderly and observed their effect on loneliness. However, for social robots to be employed by lonely individuals in real-world settings, the acceptance of them and their behavioral intentions, specifically purchase intention regarding them, are crucial factors to be considered. Thus, investigating how anthropomorphizing social robots affects the likability and purchase intention will foreground the practical aspect of investigating the relationship between loneliness and anthropomorphism.

Attributing human traits toward social robots has been reported to increase the human counterparts' likability and trust levels (De Visser et al., 2016; Eyssel et al., 2010; Kiesler &

Goetz, 2002). Moreover, many prior studies revealed that anthropomorphism has significant effects on behavioral intentions in a consumer context. Specifically, anthropomorphism has been reported to affect purchase intent (Han, 2021; Laksmidewi et al., 2017; Wölfl et al., 2019; Yen & Chiang, 2021). This relationship is shown to be mediated by a perceived sense of enjoyment or likability (Han, 2021; Hart & Royne, 2017). However, the association was tested against non-robotic anthropomorphic products, web design, and disembodied chatbots. Therefore, research is needed to examine whether the relationship between anthropomorphism and purchase intent, along with the mediation effect of likability, can also be applied to the embodied robot.

Also, whether lonely individuals' greater anthropomorphizing of social robots ultimately leads to increased purchase intent is yet to be tested. Although one study examined the moderating effect of loneliness in anthropomorphism predicting consumer attitudes (Hart & Royne, 2017), loneliness was not the main variable of interest. Moreover, the anthropomorphized subjects used in the study were brands and advertisements, not social robots. Therefore, there is a need to explore the consequence of lonely individuals' anthropomorphizing propensities regarding social robots in the market context. If higher loneliness levels among participants predicts a higher tendency to anthropomorphize social robots, the indirect effect of loneliness on purchase intent (via anthropomorphism) should also be tested for embodied social robots with various morphologies. As a result of the aforementioned rationale, we propose the following hypotheses.

**H3**: Lonely individuals will show increased intent to purchase social robots via anthropomorphism.

**H4**: Robot appearances will moderate the indirect effect of loneliness on the purchase intent of social robots through anthropomorphism.

## 1.3. Overview of Studies

The present study aimed to investigate the effect of loneliness on anthropomorphizing social robots, and whether lonely individuals' anthropomorphic tendency can predict the purchase intent of social robots. Using the two-dimensional model of anthropomorphism, we explored the specific aspects of anthropomorphism that mainly influence the anthropomorphic and behavioral tendencies of lonely individuals. Also, we used three social robots varying in morphology to examine the moderation effect of robot appearances; machine-like, animal-like, and human-like.

We investigated the hypotheses through two studies. In Study 1, still photos of robots were used as stimuli. Given that most of the prior research on the relationship between loneliness and anthropomorphism adopted static images as stimuli, Study 1 aimed to replicate the result against three robots. In Study 2, human-robot interaction videos were used. Considering that social robots are robotic agents that can communicate with humans, viewing the interactive side of the robot is crucial in evaluating the effect of loneliness on anthropomorphism and the likability of the robots in naturalistic social settings. Also, we are more likely to see dynamic robots rather than static robots in our daily life or when making purchase decisions. Therefore, Study 2 tried to reexamine the hypothesis in a human-robot interaction setting.

# Chapter 2. Study 1

## 2.1. Method

### *Participants*

A total of 169 participants were recruited from the crowdsourcing platform prolific, and the participant recruitment system of Seoul National University ('R-point'). Participants conducted all the procedures online, by accessing the system made with Qualtrics online survey builder.

Given that this study was conducted online, extensive quality-control procedures strictly judged the quality of responses. Those who failed to answer an attention-check question (i.e. "For this question, please check 'strongly agree'") properly or completed the survey too quickly was considered not to be fully engaged in the study (Bartz et al., 2016). First, those who failed to answer an attention check question correctly were not able to complete the survey, because the experiment was set to end immediately if one had the wrong response to it. Also, we calculated the average time for attentive participation needed to finish the study. We found that it took 6 to 8 minutes for younger participants and 10 to 12 minutes for older participants to complete the study. Also, when the duration of time needed to select answers to the questions randomly was calculated, it took about 4 minutes and 10 to 20 seconds on average. Therefore, we concluded that a proper response would take around 4 minutes at the minimum, and excluded the responses that took less than 240 seconds to complete.

**Figure 1.**

*Photos of Robots in Three Robot Appearance Conditions Used in Study 1*

### *Apparatus*

3 levels of robot morphology were presented in **Figure 1**. For a machine-like robot, DJI's 'Robomaster S1' was used. For a human-like robot, Softbank Robotics' 'NAO' was used. For an animal-like robot. SONY's 'AIBO' was used. Each robot was taken a photo within the same simple background, cropped into the same sizes, and gray-scaled. Robot stimuli were viewed as between-group designs by participants, where participants were randomly assigned to view one of the three robots.

### *Self-Report Measures*

**Loneliness** We used the Korean-validated version of the UCLA loneliness scale version 3 (Jin & Hwang, 2019; Russell, 1996). Using 4-point Likert scales, ranging from 'never' to 'often',

participants indicated how often each statement explains how they feel. The internal reliability was 0.94.

**Anthropomorphism** To assess the degree of anthropomorphism in each robot, we used a scale based on the 2-dimensional model of mind perception (Gray et al., 2007). A study suggested that several items had less discernible loadings on both dimensions (Malle, 2019), and one study conducted in Korea used the reduced version of the scales consisting of items with more distinguishable loadings on each dimension (Shin, 2021). Therefore, we left out a few items that were relatively vague in determining the two dimensions, resulting in 6 items for each dimension. A 7-point scale ranging from 1 to 7 was used to rate how much the robot appears to possess various mental abilities. The internal reliability was 0.83 for experience and 0.80 for agency.

**Likability** A differential scale consisting of 3 items was used to measure the likability of each robot (Brave et al., 2005). A 7-point scale ranging from -3 to 3 was used to rate which point among adjectives at both extremes best represents the degree of characteristic felt by the robot, such as 'unlikeable - likable'. The internal reliability was 0.92.

**Purchase Intent** We used a single-item measure of purchase intent. Participants used a 7-point scale ranging from 1 to 7 to rate how much do they want to purchase the robot.

Along with the aforementioned measures, a 4-item version of the Perceived Stress Scale (PSS-4) was used to match the research aim presented for blinding (Cohen et al., 1983; Park & Seo, 2010). We also measured variables that may impact the anthropomorphism, likability, or purchase intent of robots: age, gender, household income, and prior knowledge of robots (Blut et al., 2021; Crowell et al., 2019; Green et al., 2022; Halpern & Katz, 2012; May et al., 2017; Schermerhorn et al., 2008; Yam et al., 2020).

***Procedure***

Participants were recruited using the research title modified for blinding; 'The Effect of Stress Level and Recall of Negative Experiences on Evaluation of the Robot'. They completed questionnaires measuring loneliness and stress as filler questions to maintain consistency with the blind research topic. Then each participant was randomly assigned to one of three conditions that reflected three levels of robot appearances. Participants viewed a picture of a robot and completed questionnaires regarding how they felt about the robot. The study ended after responding to questions measuring demographic variables, along with the questions asking about their prior knowledge and familiarity with the robot. Participants were given the promised reward either in the prolific system or in the r-point system.

## 2.2. Results

***Participants***

Among 139 participants who met the quality control conditions, we added the age trimming process. Age has a substantial impact on robot anthropomorphism (Blut et al., 2021; May et al., 2017). While some responses from prolific had larger age pools, responses collected through the R-point system were mostly from undergraduate students. As a result, the age distribution skewed to the younger side. Therefore, we removed participants being 60 years old or more from our final analyses, which were extremely sparse in the final participant pool. As a result, 137 responses ($N_{female}$=74, $M_{age}$=25.84, $SD_{age}$=8.08) were selected. Participants were randomly assigned to 3 robot appearance conditions; animal-like ($N$=45), human-like ($N$=45), and machine-like ($N$=47) conditions. Other descriptive statistics were presented in **Table 1**.

**Table 1.**

*Means and Standard Deviations of Variables by Robot Appearances in Study 1*

| Robot appearances | Loneliness | Anthropomorphism | | Likability | Purchase intent |
|---|---|---|---|---|---|
| | | Perceived experience | Perceived agency | | |
| | *Mean* (*SD*) | *Mean* (*SD*) | *Mean* (*SD*) | *Mean* (*SD*) | *Mean* (*SD*) |
| Animal-like | 2.330 (0.586) | 2.122 (1.163) | 3.307 (1.240) | 1.082 (1.140) | 3.330 (1.398) |
| Human-like | 2.284 (0.604) | 2.063 (1.475) | 4.074 (1.296) | 0.644 (1.293) | 2.733 (1.572) |
| Machine-like | 2.265 (0.549) | 1.475 (0.650) | 2.872 (1.403) | -0.723 (1.254) | 2.489 (1.666) |
| Total | 2.293 (0.576) | 1.881 (1.001) | 3.410 (1.399) | 0.309 (1.443) | 2.847 (1.581) |

*Note*. All variables were standardized, and all values were rounded to three decimal places.

***Effects of loneliness in anthropomorphizing social robots and the moderation effects of robot appearances (H1, H2)***

Bootstrapped multiple regression analyses were conducted to verify the impact of loneliness on robot anthropomorphism and the moderation effect of robot appearances. We used 2000 iterations with seeds set as 123 for reproducibility. `Boot()` from `'CAR'` package and `boot()` from `'boot'` package were used to get bootstrapped regression coefficients, R-squared values, and their BCa 95% confidence intervals (Davison & Hinkley, 1997; Fox & Weisberg, 2018). Three levels of robot appearance were coded as two dummy variables; robot1(machine-like robot compared to human-like robot) and robot2(animal-like robot compared to human-like robot). Since the majority of robot anthropomorphism studies were

conducted using humanoid robots, human-like robot was set as the baseline for comparison between appearance levels.

For the two dimensions of anthropomorphism, there were no significant unique effect of loneliness (perceived experience: $\beta$=.054, *SE*=.141, *CI*=[-.220, .330]; perceived agency: $\beta$=.140, *SE*=.142, *CI*=[-.157, .397]), the robot1-loneliness interaction (perceived experience: $\beta$=-.103, *SE*=.171, *CI*=[-.446, .260]; perceived agency: $\beta$=-.062, *SE*=.230, *CI*=[-.505, .405]) and robot2-loneliness interaction (perceived experience: $\beta$=.049, *SE*=.216, *CI*=[-.404, .441]; perceived agency: $\beta$=-.009, *SE*=.197, *CI*=[-.379, .399]).

***Effects of loneliness and robot appearances on purchase intent of social robots (H3, H4)***

Using the same procedure of bootstrapped multiple regression, we examined whether loneliness had a direct influence on purchase intent. Three levels of robot appearances were coded the same as above. The unique effect of loneliness on purchase intent was not significant ($\beta$=-.218, *SE*=.142, *CI*=[-.522, .037]). Compared to the human-like robot, one standard deviation increase in loneliness predicted 0.387 standard deviation increase in the effect of loneliness on purchase intent for the animal-like robot (**Table 2**). Such moderation effect on loneliness predicting purchase intent were significant (robot2-loneliness interaction: $\beta$=.387, *SE*=.185, *CI*=[.036, .775]), but it was not significant when machine-like robot was compared to human-like robot (robot1-loneliness interaction: $\beta$=.090, *SE*=.198, *CI*=[-.293, .500]).

**Table 2.**

*Bootstrapped Regression Results on Robot Appearances and Loneliness As Predictors for Purchase Intent in Study 1*

| Variables | *β* | *SE* | 95% *BCa CI* |
|---|---|---|---|
| Intercept | -0.076 | 0.147 | [-0.344, 0.237] |
| Robot1(machine-like=1) | -0.155 | 0.217 | [-0.605, 0.260] |
| Robot2(animal-like=1) | 0.373 | 0.198 | [-0.018, 0.760] |
| Loneliness | -0.218 | 0.142 | [-0.522, 0.037] |
| Robot1-loneliness interaction | 0.090 | 0.198 | [-0.293, 0.500] |
| Robot2-loneliness interaction | **0.387*** | 0.185 | [0.036, 0.775] |

*Note*. Contrasts: Robot1(machine-like robot compared to human-like robot), Robot2(animal-like robot compared to human-like robot)

All variables were standardized, and all values were rounded to three decimal places.

Bootstrapped $R^2$ values for the model was 0.082 (95% BCa CI= [0.013, 0.156]).

*= statistically significant at 95% confidence level

Also, we tested the indirect and direct effect of anthropomorphism on purchase intent using PROCESS macro in R (Hayes, 2022). We used 1000 iterations with seeds set as 100 for reproducibility. Prior knowledge of robots, gender, and income were included as covariates of the models. Both perceived experience and perceived agency positively predicted the purchase intent via likability. Only perceived experience had a positive direct effect on purchase intent. See **Table 3** for the detailed results of the models.

Since the effects of loneliness in anthropomorphism and the moderation effects of robot appearances were not significant, we did not conduct a moderated mediation analysis on the effect of loneliness on purchase intent via anthropomorphism.

**Table 3.**

*Effects of Anthropomorphism on Purchase Intent Mediated by Likability in Study 1*

| **Variables** | **Indirect effect** *B* (*SE*) | **95% *BCa CI* of the indirect effect** | **Direct effect** *B* (*SE*) | **95% *CI* of the direct effect** |
|---|---|---|---|---|
| Perceived Experience | **0.158*** (0.047) | [0.062, 0.252] | **0.148*** (0.071) | [0.009, 0.288] |
| Perceived Agency | **0.183*** (0.053) | [0.085, 0.297] | 0.068 (0.073) | [-0.076, 0.212] |

*Note*. Prior knowledge of robots, gender, and income were the covariates of the models.

All variables were standardized, and all values were rounded to three decimal places.

*= statistically significant at 95% confidence level

## 2.3. Discussion

Study 1 revealed no significant relationship between loneliness and anthropomorphism, nor the significant interaction effect of loneliness and robot appearances on anthropomorphism. Thus, H1, and H2 were not supported. This may be due to robots only being presented by still photos. Although several prior research that used mere images as stimuli found a positive association between loneliness and the inclination toward anthropomorphism, the majority of the results were for simple technical devices and animals as pets (Bartz et al., 2016; Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008; Shin, 2020; Shin & Kim, 2020). Technical machines did not have ability to interact with humans, and imagining the possible interaction with animals as pets and a human counterpart would be relatively easier than doing so with the social robots. Sophisticated social robots, however, are not so as prevalent in our everyday lives that their functions would vary tremendously in an imaginer's mind. Merely showing the photos of robots may have made participants

difficult to predict the characteristics and capabilities of robots, therefore failing to instigate the sociality motivation of anthropomorphism more from lonely individuals. Showing the movements and interactivity of the robots would reveal the true nature of lonely individuals' anthropomorphizing social robots. Indeed, previous studies have reported that movements and intentional behavior are important in anthropomorphizing robots (Salem et al., 2011; Tremoulet & Feldman, 2000).

Moreover, since H1, and H2 were not supported, loneliness did not have an indirect effect on purchase intent via anthropomorphism. Therefore, H3 and H4 were not supported. However, there was a moderation effect of robot appearances in the direct relationship between loneliness and purchase intent. The result suggests that by only looking at the picture of robots, lonely individuals showed stronger purchase intent against animal-like robot when compared to human-like robot, but not against machine-like robot when compared to human-like robot. This result may be due to the effect of appraising robots based on their physical appearances. The result is in line with Hart and Royne (2017), which also used a printed advertisement as stimuli. Considering that customers are more likely to make purchase decisions after viewing how a social robot interacts with people, stimuli that highlight the robots' motions and communication skills would be required to thoroughly examine whether participants' loneliness levels affect their desire to buy social robots.

Lastly, although H3 and H4 were not supported, there were a significant mediation effect of likability in anthropomorphism predicting the purchase intent of social robots. Also, the direct effect of perceived experience on purchase intent was significant. While replicating the earlier research on positive attitude or likability mediating the effect of anthropomorphizing social robots on purchase intent (Han, 2021; Hart & Royne, 2017), this opens the possibility of H3 and H4 to be supported in Study 2. In light of formerly listed reasons, we retested the

hypothesis in Study 2 to reveal how people perceive and show the behavioral intent toward the interactive, dynamic social robots.

# Chapter 3. Study 2

## 3.1. Method

### *Participants*

A total of 185 individuals participated in Study 2. Participants were recruited through the participant recruitment system of Seoul National University, and from the students and alumni communities of Seoul National University and Korea University. Participants conducted all the procedures online.

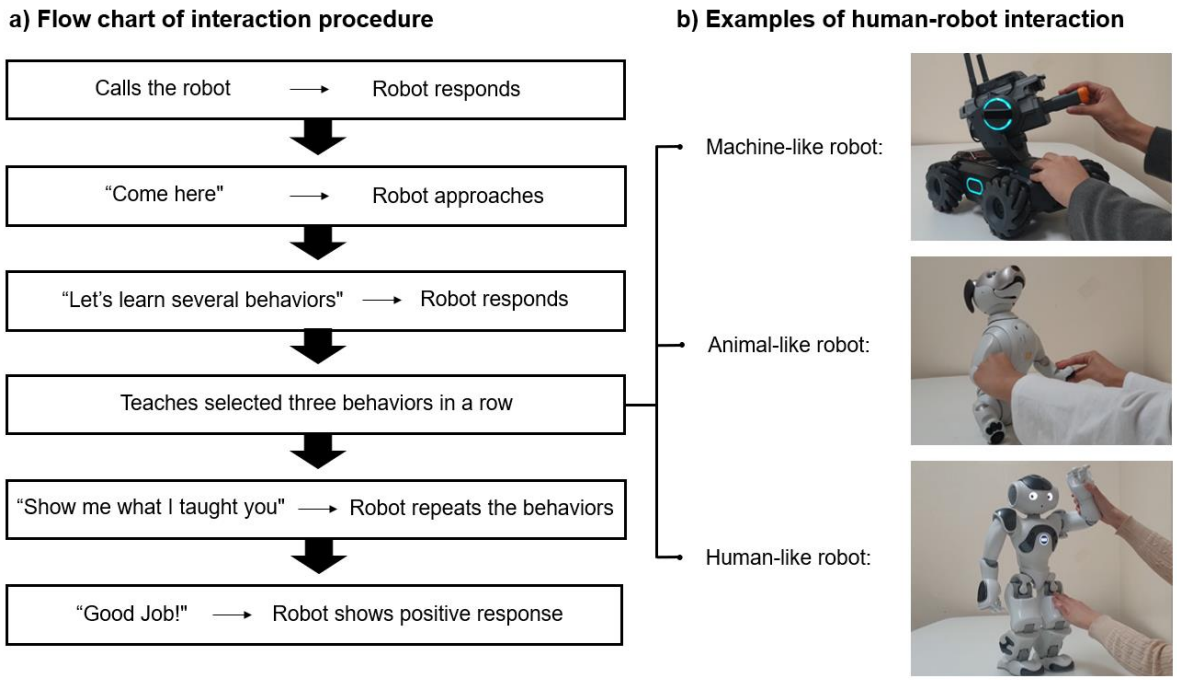
Following the quality control procedures adopted in the Study 1, those who failed one of the two attention-check items (i.e. “For this question, please check ‘strongly agree’”) or completed the survey too quickly were considered to be not fully engaged in the study (Bartz et al., 2016). First, those who failed the attention check items were not able to complete the survey, because the experiment ended immediately if one had the wrong response to it. Also, considering the lengths of videos that participants should have watched, which were around 90 seconds, we concluded that a proper response for Study 2 would take at least 80 seconds more than the marginal response time of Study 1. Therefore, we excluded the responses that took less than 320 seconds to complete.

### *Design and Materials*

In Study 2, the same design was used as Study 1. However, instead of still photos, human-robot interaction videos were used to manipulate robot appearances. In all three conditions, robots learn a series of new behavior, succeed in memorizing them, and get positive responses.

**Figure 2.**

*Flow Chart of Human-Robot Interaction Procedure and Examples of Human-Robot Interaction in Study 2.*




The flow chart consisting of specific interaction procedures is in **Figure 2**. In all conditions, same commands were used to interact with the robots, and the robots responded 1.8 seconds after the human voice. The length of all videos was around 90 seconds.

While interacting with a human, all three robots reflected the different levels of human likeness. The machine-like robot turned its LED light on or off, made a simple alarm-like sound, moved its upper part of the machine body, or moved in any direction to respond. The animal-like robot made dog-like sounds, wagged its tail, or coordinated its body movement to resemble the motion of living dogs. The human-like robot responded verbally and showed gestures using its head or limb. Specifically, in response to the human counterparts' praise, each robot was programmed to show positive response. The machine-like robot blinked its LED light faster,

made an alarm-like sound twice, and quickly rotated left and right. The animal-like robot wagged its tail while barking, and lowered its head and front paw to induce a petting behavior of the human counterpart. Lastly, the human-like robot showed a proud gesture by saying "thank you!". We thought the appropriate positive response of a social robot is important because the emotionality of the robotic agent impacts how people perceive robots as human-like. Not only a human-like robot but an animal-like robot using emotion-expressive responses were deemed as more human-like and more likable (Eyssel et al., 2010; Koschate et al., 2016).

Softbank Robotics' programming software Choreographe was used to program NAO's bodily movements (Pot et al., 2009). Robomaster desktop application was used to program Robomaster S1's interaction scenario. The basic interaction functions of AIBO were used without programming. For NAO and Robomaster, the robots performed the programmed behaviors at once, and human voices in Korean were dubbed into the video afterward. For AIBO, Japanese commands were used to interact with the robot, and human voices were substituted into the same words spoken in Korean to finalize the video.

### *Self-Report Measures*

Same self-report measures were used in Study 1. Cronbach alpha values for each measure in Study 2 were presented in **Table 4.**

**Table 4.**

*Internal Consistency of Measures in Study 2*

| Measures | | Cronbach's α |
|---|---|---|
| Loneliness | | 0.94 |
| Anthropomorphism | Perceived experience | 0.85 |
| | Perceived agency | 0.75 |
| Likability | | 0.9 |

*Note*. All variables were standardized, and all values were rounded to two decimal places.

### *Procedure*

Same procedures were used as Study 1, except that the participants assigned to each robot appearance condition watched the human-robot interaction video as a stimulus.

## 3.2. Results

### *Participants*

Responses from 137 participants ($N_{female}$=84, $M_{age}$=22.803, $SD_{age}$=3.788) were selected as final data for analyses. Participants were randomly assigned to 3 robot appearance conditions; animal-like(*N*=46), human-like(*N*=45), and machine-like(*N*=46) conditions. Other descriptive statistics were presented in **Table 5**.

**Table 5.**

*Means and Standard Deviations of Variables by Robot Appearances in Study 2*

| Robot appearances | Loneliness | Anthropomorphism | | Likability | Purchase intent |
|---|---|---|---|---|---|
| | | Perceived experience | Perceived agency | | |
| | *Mean* (*SD*) | *Mean* (*SD*) | *Mean* (*SD*) | *Mean* (*SD*) | *Mean* (*SD*) |
| Animal-like | 2.052 (.550) | 2.308 (1.125) | 3.920 (1.211) | 0.761 (1.266) | 3.022 (1.719) |
| Human-like | 2.013 (.552) | 1.807 (0.908) | 3.589 (1.344) | 0.267 (1.408) | 2.444 (1.659) |
| Machine-like | 2.214 (.638) | 1.674 (0.718) | 3.594 (1.110) | 1.181 (1.104) | 2.783 (1.699) |
| Total | 2.094 (.584) | 1.931 (0.965) | 3.702 (1.226) | 0.740 (1.310) | 2.752 (1.697) |

*Note*. All variables were standardized, and all values were rounded to three decimal places.

***Effects of loneliness in anthropomorphizing social robots and the moderation effects of robot appearances (H1, H2)***

Bootstrapped multiple regression analyses were conducted to verify the impact of loneliness on robot anthropomorphism and the moderation effect of robot appearances. We used 2000 iterations with seeds set as 123 for reproducibility. Boot() from 'CAR' package and boot() from 'boot' package and were used for bootstrapping regression coefficients, R-squared values, and their BCa 95% confidence intervals (Davison & Hinkley, 1997; Fox & Weisberg, 2018). Robot appearances were coded as two dummy variables; robot1(machine-like robot compared to human-like robot) and robot2(animal-like robot compared to human-like robot).

**Table 6.**

*Bootstrapped Regression Results on Robot Appearances and Loneliness As Predictors for Perceived Experience in Study 2*

| Variables | *β* | *SE* | 95% *BCa CI* |
|---|---|---|---|
| Intercept | -0.101 | 0.147 | [-0.341, 0.235] |
| Robot1(machine-like=1) | -0.147 | 0.185 | [-0.537, 0.200] |
| Robot2(animal-like=1) | **0.470*** | 0.221 | [0.045, 0.896] |
| Loneliness | 0.197 | 0.161 | [-0.053, 0.587] |
| Robot1-loneliness interaction | -0.288 | 0.192 | [-0.699, 0.060] |
| Robot2-loneliness interaction | **-0.500*** | 0.260 | [-1.080, -0.056] |

*Note*. Contrasts: Robot1(machine-like robot compared to human-like robot), Robot2(animal-like robot compared to human-like robot)

All variables were standardized, and all values were rounded to three decimal places.

Bootstrapped $R^2$ values for the model was 0.122 (95% BCa CI= [0.025, 0.219]).

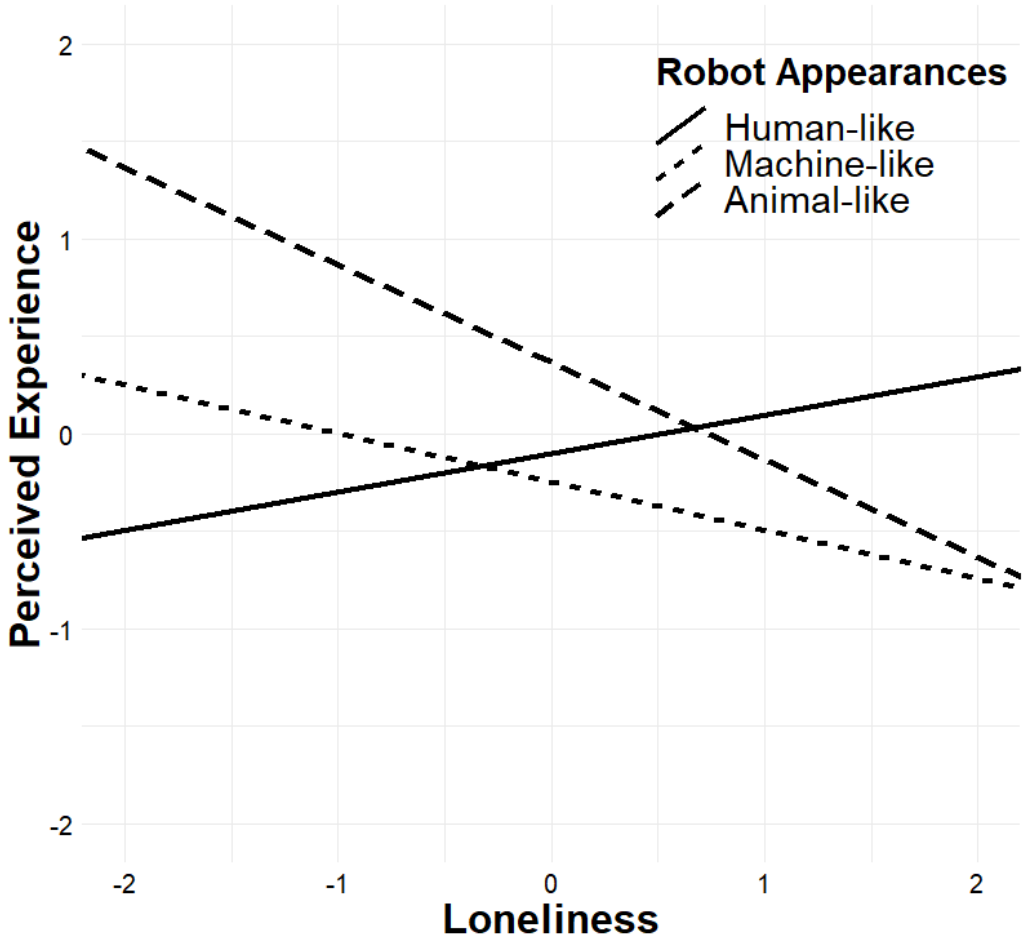
*= statistically significant at 95% confidence level

The unique effect of loneliness on perceived experience and was not significant (*β*=.197, *SE*=.161, *CI*=[-.053, .587]). On animal-like robot, loneliness were significantly more negatively correlated with perceived experience than human-like robot (robot2-loneliness interaction: *β*=-.500, *SE*=.260, *CI*=[-1.080, -.056]). The interaction effect was not significant when machine-like robot was compared to human-like robot (robot1-loneliness interaction: *β*=-.288, *SE*=.192, *CI*=[-.699, .060]). When covariates were introduced, the tendency of animal-like robots to exhibit a stronger negative relationship between loneliness and perceived experience than human-like robots persisted (robot2-loneliness interaction: *β*=-.496, *SE*=.249, *CI*=[-1.070, -.060]). The detailed results of models are presented in **Table 6-7** and **Figure 3**.

There were no significant unique effect of loneliness ($\beta$=.115, *SE*=.180, *CI*=[-.250, .476]), nor the significant moderating effects of robot appearances on perceived agency (robot1-loneliness interaction: $\beta$=-.170, *SE*=.227, *CI*=[-.599, .291]; robot2-loneliness interaction: $\beta$=-.303, *SE*=.231, *CI*=[-.758, .168]).

**Figure 3.**

*Interactions Between Loneliness and Robot Appearances on Perceived Experience in Study 2*




*Note*. All variables were standardized.

**Table 7.**

*Bootstrapped Regression Results on Robot Appearances and Loneliness As Predictors for Perceived Experience with Covariates in Study 2*

| Variable | *β* | *SE* | 95% *BCa CI* |
|---|---|---|---|
| Intercept | -0.060 | 0.166 | [-0.361, 0.287] |
| Age | 0.054 | 0.109 | [-0.152, 0.288] |
| Gender(male=1) | -0.169 | 0.177 | [-0.532, 0.176] |
| Income | -0.033 | 0.086 | [-0.215, 0.133] |
| Prior knowledge on robot | **0.175*** | 0.092 | [0.013, 0.375] |
| Robot1(machine-like=1) | -0.095 | 0.166 | [-0.487, 0.291] |
| Robot2(animal-like=1) | **0.485*** | -0.220 | [0.062, 0.938] |
| Loneliness | 0.167 | 0.160 | [-0.130, 0.521] |
| Robot1-loneliness interaction | -0.253 | 0.199 | [-0.653, 0.127] |
| Robot2-loneliness interaction | **-0.496*** | 0.249 | [-1.070, -0.060] |

*Note*. Contrasts: Robot1(machine-like robot compared to human-like robot), Robot2(animal-like robot compared to human-like robot)

All variables were standardized, and all values were rounded to three decimal places.

Bootstrapped $R^2$ values for the model was 0.153 (95% BCa CI= [0.054, 0.242]).

*= statistically significant at 95% confidence level

***Effects of loneliness and robot appearances on the purchase intent of social robots (H3, H4)***

Using the same procedure of bootstrapped multiple regression, we examined whether loneliness had a direct influence on purchase intent. Three levels of robot appearance were coded the same as above. The unique effect of loneliness (*β*=.036, *SE*=.158, *CI*=[-.247, .366]), and the interaction effect of robot appearances on the association between loneliness and purchase intent was not significant (robot1-loneliness interaction: *β*=-.185, *SE*=.207,

*CI*=[-.588, .209]; robot2-loneliness interaction: $\beta$=.051, *SE*=.232, *CI*=[-.527, .378]).

Also, we tested the indirect and direct effect of anthropomorphism on purchase intent using PROCESS macro in R (Hayes, 2022). Prior knowledge of robots, gender, and income was included as covariates of the models. We used 1000 iterations with seeds set as 100 for reproducibility. Both perceived experience and perceived agency positively predicted the purchase intent via likability, while only perceived experience had a positive direct effect on purchase intent. See **Table 8** for the detailed results of the model.

Lastly, we tested moderated mediation using PROCESS macro in R (Hayes, 2022). We used 1000 iterations with seeds set as 100 for reproducibility. Prior knowledge of robots, age, gender, and income were included as covariates of the models. Since the direct effect of anthropomorphism on purchase intent was significant, likability was excluded from the model for simplicity. Also, since the effect of loneliness on perceived agency and the moderation effect of robot appearances were not significant, we included only anthropomorphism and perceived experience as a mediator of the model. Therefore, using model 7 of PROCESS macro, we expected that loneliness will positively predict purchase intent via anthropomorphism or perceived experience, and robot appearances will moderate the relationship between loneliness and anthropomorphism or perceived experience.

When perceived experience was mediated, the conditional indirect effects were not significant in any levels of robot appearances. The moderated mediation was significant when animal-like robot was compared to human-like robot. See **Figure 4** and **Table 9-10** for the final moderated mediation results.

**Table 8.**

*Effects of Anthropomorphism on Purchase Intent Mediated by Likability on Social Robot in Study 2*

| Variables | Indirect effect *B* (*SE*) | 95% *BCa CI* of the indirect effect | Direct effect *B* (*SE*) | 95% *BCa CI* of the direct effect |
|---|---|---|---|---|
| Perceived Experience | **0.135*** (0.046) | [0.043, 0.233] | **0.250*** (0.069) | [0.115, 0.386] |
| Perceived Agency | **0.225*** (0.545) | [0.119, 0.332] | 0.069 (0.075) | [-0.081, 0.218] |

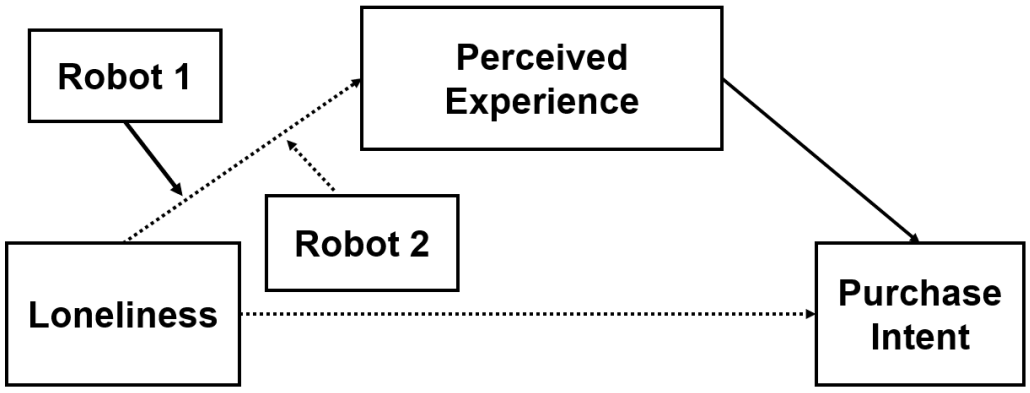
*Note*. Prior knowledge of robots, age, gender, and income were the covariates of the models.

All variables were standardized, and all values were rounded to three decimal places.

*= statistically significant at 95% confidence level

**Figure 4.**

*Overview of the Results on the PROCESS Model7 tested in Study 2*




*Note*. Contrasts: Robot1(machine-like robot compared to human-like robot), Robot2(animal-like robot compared to human-like robot).

Solid lines represent significant relationships, whereas dotted lines represent non-significant relationships.

Prior knowledge of robots, age, gender, and income were the covariates of the models.

**Table 9.**

*Path Coefficient Estimates for the PROCESS Model7 Tested in Study 2*

| Paths | *β* | *SE* | 95% *BCa CI* |
|---|---|---|---|
| X → M | 0.167 | 0.152 | [-0.118, 0.474] |
| W(Robot1) | -0.095 | 0.194 | [-0.479, 0.290] |
| W(Robot2) | **0.485*** | 0.216 | [0.065, 0.891] |
| M → Y | **0.391*** | 0.082 | [0.211, 0.537] |
| X → Y | 0.047 | 0.078 | [-0.108, 0.209] |

*Note*. Contrasts: Robot1(machine-like robot compared to human-like robot), Robot2(animal-like robot compared to human-like robot).

Prior knowledge of robots, age, gender, and income were the covariates of the models.

All variables were standardized, and all values were rounded to three decimal places.

*= statistically significant at 95% confidence level

**Table 10.**

*Summary of the Results on the PROCESS Model7 Tested in Study 2*

| **Variable** | ***Moderated mediation test*** *Index* (*SE*), 95% *BCa CI* | | ***Conditional indirect effect at robot appearance levels*** *B (SE), 95% BCa CI* | | | **Direct effect** B (Boot SE), 95% *BCa CI* |
|---|---|---|---|---|---|---|
| | Robot1 | Robot2 | Human-like | Machine-like | Animal-like | |
| **Perceived Experience** | -0.099 (0.080), CI=[-0.277, 0.035] | **-0.194*** (0.108), CI=[-0.445, -0.016] | 0.065 (0.064), CI=[-0.045, 0.203] | -0.034 (0.045), CI=[-0.124, 0.057] | -0.129 (0.084), CI=[-0.308, 0.015] | 0.047 (0.083), CI=[-0.117, 0.210] |

*Note*. Contrasts: Robot1(machine-like robot compared to human-like robot), Robot2(animal-like robot compared to human-like robot)

Prior knowledge of robots, age, gender, and income were the covariates of the models.

All variables were standardized, and all values were rounded to three decimal places.

*= statistically significant at 95% confidence level

## 3.3. Discussion

Among the two anthropomorphic dimensions, the unique effects of loneliness on both perceived agency and perceived experience were not significant. Therefore, H1 was not supported. However, it is also revealed that animal-like robot significantly decreased the lonely individuals' tendency to perceive experience from the robot than human-like robot, and such proclivity remained significant after covariates were introduced in the model. Thus, H2 was partially supported, and H2-2 was supported, but in an unexpected way. The rejection of H2-1 implies that the machine-like robots' ability to move, interact with a human, and express their feelings was not enough to induce sociality motivation of lonely individuals to anthropomorphize. H2-2 being supported suggests that animal-like mimicking real animal behaviors do not elicit social motivation in lonely people and reduce the desire to anthropomorphize.

The result did not reveal the direct effect nor the moderation effect of robot appearances in the relationship between loneliness and purchase intent. Perceived experience both had direct effects on purchase intent and indirect effects on purchase intent via likability. The final analysis on PROCESS model7 showed that although there was no conditional indirect impact of loneliness on purchase intent, the mediated moderation effect of robot appearances on purchase intent was significant. Therefore, H3 was partially supported, and H4 was supported. The mediating effect significantly decreased in animal-like robot than in human-like robot, reflecting the H2-2 being supported.

# Chapter 4. General Discussion and Conclusion

Using social robots with three different morphologies, our research has examined the effect of loneliness on anthropomorphizing social robots and the moderating effect of robot appearances. We also explored whether the higher anthropomorphizing tendency of lonely individuals predicts increased purchase intent of social robots. Study 1 used photos as stimuli to present three robots, whereas Study 2 used human-robot interaction videos that contains movements, interaction with humans, and positive responses. The association between loneliness and anthropomorphism, along with the moderating effect of robot morphology, was not significant in Study 1. In Study 2, the unique effect of loneliness on participants' anthropomorphic tendency toward social robots were also not significant (H1).

However, regarding the moderation effect of robot appearances on the lonely individuals' proclivity to anthropomorphize social robots, the animal-like robot decreased the lonely individuals' tendency to anthropomorphize than human-like robot in Study 2 (H2). Such tendency remained significant after covariates were introduced in the model. Lonely individuals' decreased proclivity to anthropomorphize animal-like robots shows that animal-like robots resembling the real behaviors of animals do not generate social motivation in lonely people and therefore lessen the desire to anthropomorphize. However, another possible explanation is that the animal-like robot used in this study resembled the real dog too much, which was not the case in the other two robots. Since AIBO was designed to be a 'cute companion dog' for the users by "showing moves and gestures in hundreds of adorable patterns" (SONY, n.d.), the robot mimics not only the appearances of a real dog but also closely reflects the movements, sounds, and behaviors of a dog longing to be petted. For

lonely people who are hypervigilant to social threats (Cacioppo & Hawkley, 2009; Hawkley & Cacioppo, 2010), too much dog-like behaviors may have been perceived as unsettling or even threatening (Li et al., 2020).

Lastly, in loneliness having indirect effect on the purchase intent of human-like social robots through anthropomorphism, animal-like robots had a lower mediation effect than human-like robot (H4). Such result is consistent with H2-2 being supported in Study 2, and may suggest that lonely individuals being motivated to seek a sense of connectedness from social robots led to them viewing more value in the acquisition of a human-like social robot (Hart & Royne, 2017). The outcome, however, conflicts with Study 1, which found that an animal-like robot had a stronger direct impact on purchase intent than a human-like robot. Such a variation could have been impacted by the way stimuli were presented. AIBO's appearance resembling the living dog adorably may have positively impacted the purchase intent when only pictures were present. However, when lonely individuals viewed the behaviors and sound mimicking a real dog yearning for love, the unrest could have caused decrease in the mediation effect.

## 4.1. Theoretical Implications

Among the few studies employing robots as stimuli, comparatively recent versions with more sophisticated appearances were not tested as frequently, and human-like robots were chiefly used to probe the association between loneliness and anthropomorphism (Crowell et al., 2019; Eyssel & Reich, 2013; Li et al., 2020). In the present research, not only human-like, but also animal-like and machine-like robots were engaged. The results suggest that lonely people's inclination to anthropomorphize social robots is not uniform among across all robot

morphologies.

Also, previous studies reported that anthropomorphism positively influences the consumers' purchase intent (Han, 2021; Laksmidewi et al., 2017; Wölfl et al., 2019; Yen & Chiang, 2021). However, no study examined the impact of anthropomorphic inference on purchase intent of social robots, nor used loneliness as an independent variable in predicting purchase intent. Our work makes the first contribution to extending research on the effect of lonely individuals' anthropomorphic tendencies regarding social robots to their behavioral intent as consumers. Combined with the moderating effect of robot appearances, our results strengthen the practical implication of investigating anthropomorphic propensities by testing whether the inclination reveals increased intention to purchase social robots among lonely consumers.

Lastly, based on the inconsistencies in the results of Study 1 and Study 2, we also suggest that photos may not sufficiently capture the lonely individuals' anthropomorphic tendencies towards social robots. Although previous studies that employed solely photographic stimuli discovered a positive relationship between loneliness and the proclivity for anthropomorphism, the majority of the results were for simple technical items and animals as pets. Unlike gadgets or animals as anthropomorphic stimuli, social robots are not yet so commonplace in daily life that their core identity would vary greatly in the participants' imagination. Simply showing photographs of robots makes it harder for participants to conceptualize their traits and capabilities. Furthermore, what distinguishes a robot as a "social robot" can only be seen in interaction videos, not still images. Portraying movement and interactivity in this way is therefore critical to accurately gauging the influence of loneliness on the anthropomorphism of social robots.

## 4.2. Practical Implications

By integrating the literature on loneliness, anthropomorphism, purchase intent, and the latest robot technologies, our work makes several practical contributions. Our study makes the case for deeper examination of anthropomorphic tendencies in the lonely, particularly regarding humanoid robots, as lonely people exhibited higher anthropomorphic tendencies and higher purchase intentions in this context than with animal-like robots. It would be particularly applicable for single-person households with lower in-person communication, where loneliness is a factor than for homes with cohabitants. Also, the results have implications for social robot marketing; anthropomorphic appeals of human-like robots to lonely customers are likely to prove effective.

Our findings also provide implications for social robot design. In previous research, only Li et al. (2020) reported that lonely individuals demonstrated a decreased anthropomorphic tendency. Although the robot used in Li et al. (2020) had a head and torso resembling a human, the robot interacting with the human counterpart only through conversation may have been perceived by the lonely individuals as having unmatching human-likeness. Indeed, the uncanny valley phenomenon is likely to occur when the robot generates a perceptual mismatch; that is, when the realism degrees of the humanlike and artificial elements are discordant (Kätsyri et al., 2015). Although lonely individuals are more likely to seek connectedness from nonhuman entities (Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008; Epley et al., 2007), it should also be noted that lonely individuals are more susceptible to perceiving threats from social environment (Cacioppo & Hawkley, 2009; Hawkley & Cacioppo, 2010). Therefore, together with the result from Li et al. (2020), our findings imply that robots should demonstrate suitable levels of movement and interaction skills so they do

not appear incongruous with their look or overly mimic any existing beings.

## 4.3. Limitations and Directions for Future Study

Although the findings and implications of this study are valuable, they should be regarded with caution due to some limitations. First, the responses were collected using online studies due to COVID-19 safety concerns. Although we conducted extensive quality control measures, the participants might still not have been actively involved in watching the human-robot interaction video in Study 2. Moreover, the participants did not watch the human-robot interaction on-site. Although the machine-like robot was programmed to act like a social robot, it was a drone without the capability to interact with humans.

Also, future studies could reexamine the hypotheses with on-site experiments. Co-located robots were adjudged more attentive, pleasant, and trustworthy than robots presented remotely (Bainbridge et al., 2011; Kiesler et al., 2008; Wainer et al., 2006). With subjects physically interacting with the robot in laboratory settings, the impact of loneliness on anthropomorphism, likability, and purchase intent could be examined, and the increased effect of on-site engagement with social robots could also be evaluated. Furthermore, the relationships could be tested in an experimental field study, increasing the results' ecological validity.

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# Appendix

## Appendix 1: UCLA loneliness scale – Version 3 (Jin & Hwang, 2019; Russell, 1996)

아래의 각 문장이 얼마나 자주 귀하를 설명해줄 수 있는지 체크해 주십시오.

1.* 얼마나 자주 주변 사람들과 잘 통한다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

2. 얼마나 자주 사람들과의 교제가 부족하다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

3. 얼마나 자주 도움을 청할 사람이 아무도 없다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

4. 얼마나 자주 혼자라고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

5.* 얼마나 자주 친구들 모임에 속해 있다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

6.* 얼마나 자주 당신 주위 사람들과 비슷한 점이 많다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

7. 얼마나 자주 당신이 더 이상 아무하고도 가깝지 않다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

8. 얼마나 자주 당신의 흥미와 생각들이 주변 사람과 공유되지 않는다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

9.* 얼마나 자주 자신이 적극적이고 호의적이라고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

10.* 얼마나 자주 사람들과 가깝다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

11. 얼마나 자주 혼자 남겨졌다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

12. 얼마나 자주 다른 사람들과의 관계가 의미 없다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

13. 얼마나 자주 당신을 진정으로 아는 사람이 아무도 없다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

14. 얼마나 자주 다른 사람들로부터 고립되어 있다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

15.* 얼마나 자주 당신이 원할 때에 함께 있어줄 사람을 찾을 수 있다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

16.* 얼마나 자주 당신을 정말 이해해 주는 사람들이 있다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

17. 얼마나 자주 수줍음을 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

18. 얼마나 자주 사람들이 당신과 진정으로 함께 있지 않고 그저 주위에 있는 것이라고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

19.* 얼마나 자주 당신이 얘기할 수 있는 사람들이 주변에 있다고 생각하십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

20.* 얼마나 자주 당신이 도움을 청할 수 있는 사람들이 있다고 느끼십니까?

| 전혀 그런 적 없다 | 거의 그렇지 않다 | 가끔 그렇다 | 자주 그렇다 |
|---|---|---|---|

** 표시 항목은 역산할 것.*

## Appendix 2: mind perception scale (Gray et al., 2007; Malle, 2019; Shin, 2021)

### *2-1. Experience*

영상 속 로봇이 아래의 능력을 얼마나 가지고 있다고 생각하는지 응답해 주십시오.

1. 신체적, 감정적 고통을 느끼는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

2. 배고픔을 느끼는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

3. 즐거움을 느끼는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

4. 두려움을 느끼는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

5. 화를 경험하는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

6. 무엇을 원하거나 희망하는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

***2-2. Agency***

영상 속 로봇이 아래의 능력을 얼마나 가지고 있다고 생각하는지 응답해 주십시오.

1. 다른 존재의 감정을 인식하는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

2. 다른 존재의 감정을 인식하는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

3. 스스로의 욕구, 감정, 충동을 조절하는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

4. 기억하는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

5. 옳고 그름을 구별하고 옳은 행동을 하고자 하는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

6. 다른 존재와 의사소통을 할 수 있는 능력

| 전혀 없다 | 거의 없다 | 별로 없다 | 보통이다 | 조금 있다 | 꽤 있다 | 많이 있다 |
|---|---|---|---|---|---|---|

## Appendix 3: likability scale (Brave et al., 2005)

영상 속 로봇을 보고 느낀 것이 아래 여러 쌍의 형용사들 중 각각 어디에 얼마나 더 가까운지 응답해 주십시오.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **비호감인** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | **호감인** |
| **불쾌한** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | **즐겁게 하는** |
| **매력없는** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | **매력적인** |

# Abstract in Korean

외로운 개인은 스스로가 부족하다고 느끼는 사회적 상호작용을 충족하기 위해 비인간 개체를 더 많이 의인화한다. 그러나, 해당 경향성이 소셜 로봇에 대해서도 적용되는지는 연구가 부족한 실정이다. 또한, 외로울수록 의인화를 더 많이 하는 경향성이 실질적인 사용을 위한 구매의도에 영향을 미치는지의 여부는 연구된 바 없다. 그러므로. 본 연구에서는 외로운 개인이 소셜 로봇을 더 많이 의인화하는지, 그리고 외로운 개인이 증가된 의인화 경향성을 통해 더 높은 로봇 구매의도를 보이는지 탐구하였다. 더불어, 외로운 개인의 의인화 경향성 및 외로움이 구매의도에 미치는 효과를 의인화가 매개하는 것에 있어 로봇 외모의 조절 효과를 조사하기 위해 외모가 다른 세 가지 소셜 로봇(인간형, 기계형, 동물형)을 사용했다. 연구 1은 로봇의 정적인 사진을, 연구 2는 움직임과 인간 상대에 대한 긍정적인 반응을 포함하는 인간-로봇 상호 작용 비디오를 자극으로 활용하였다. 연구 1과 연구2에서 외로움은 소셜 로봇의 의인화에 유의한 영향을 미치지 않았으나, 연구2에서 개인들은 외로울수록 인간형 로봇에 비해 동물형 로봇에 대해서 감소된 의인화 경향성을 보이는 것으로 나타났다. 또한, 연구2에서 의인화를 매개로 한 외로움의 구매의도에 대한 영향은 로봇의 외양에 따라 조절되는 것으로 나타났다. 본 연구는 외로운 개인이 간단한 기계 장치 및 동물을 의인화하려는 경향이 증가하는 경향을 소셜 로봇에도 적용할 수 있으나 이러한 경향은 다양한 형태의 로봇에 따라 크게 달라짐을 시사하였다. 또한 외로운 개인들의 의인화 경향성이 소비자로서의 행동으로 확장될 수 있음을 제시하였다.