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# The Doors of Social Robot Perception: The Influence of Implicit Self-Theories

**D. D. Allan · Andrew J. Vonasch · Christoph Bartneck**

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**Abstract** Understanding people's perceptions and inferences about social robots and, thus, their responses toward them, constitutes one of the most pervasive research themes in the field of Human-Robot Interaction today. We herein augment and extend this line of work by investigating, for the first time, the novel proposition that one's implicit self-theory orientation (underlying beliefs about the malleability of self-attributes, such as one's intelligence), can influence one's perceptions of emerging social robots developed for everyday use. We show that those who view self-attributes as fixed (entity theorists) express greater robot anxiety than those who view self-attributes as malleable (incremental theorists). This result holds even when controlling for well-known covariate influences, like prior robot experience, media exposure to science fiction, technology commitment, and certain demographic factors. However, only marginal effects were obtained for both attitudinal and intentional robot acceptance, respectively. In addition, we show that incremental theorists respond more favorably to social robots, compared to entity theorists. Furthermore, we find evidence indicating that entity theorists exhibit more favorable responses to a social robot positioned as a servant. We conclude with a discussion about our findings.

**Keywords** Implicit self-theories · Mindset · Human–Robot interaction · Social Robots · Robot anxiety

D. D. Allan, Andrew J. Vonasch, Christoph Bartneck
University of Canterbury
Private Bag 4800
8140 Christchurch, New Zealand
E-mail: dwain.allan@pg.canterbury.ac.nz

## 1 Introduction

Understanding how individuals perceive of, and respond to, social robots is a central theme of vital and continuing importance in the field of Human-Robot Interaction (HRI; HRI, 2020; Dautenhahn, 2007). Recent research suggests that this topic has special urgency given the expanding place of robotic technologies in daily life (Haegele, 2016; Beraldo et al., 2019; de Graaf et al., 2019; Liang and Lee, 2017; Morsunbul, 2019; Horstmann et al., 2018; Robb et al., 2020), and unfolding debate concerning the introduction of automation (e.g., cars, drones, robots) in society and culture (Horowitz, 2016; Floridi, 2017; Gnambs and Appel, 2019; Złotowski et al., 2017; Yogeeswaran et al., 2016). This, in turn, has lead to a reasonable degree of consensus regarding the pressing need for research to advance understanding of the underlying factors that influence people's perceptions and inferences about social robots (Appel et al., 2020; Andrist et al., 2015; Bartneck et al., 2020; Ferrari et al., 2016; Reich-Stiebert and Eyssel, 2015; Strait et al., 2017).

Cumulative research thus far has established that individual difference variables[1] (e.g., prior robot experience, personality dispositions, and demographic characteristics) strongly affect the perceptions people have of social robots (see Eurobarometer, 2012; Kuo et al., 2009; Bartneck et al., 2007; Mutlu et al., 2006; Morsunbul, 2019).

Here, we seek to contribute to this line of work by proposing that implicit self-theories – underlying beliefs about whether self-attributes are fixed or are malleable – may also play an influential role in shaping perceptions and responses to social robots. In so doing, we offer the first direct empirical account of this proposition.

The remainder of this article is structured as follows: In the next section, we present the theoretical framework before outlining the development of the study's hypotheses. We then describe the method and results followed by a discussion of findings, including limitations and directions for future research. We finish with a conclusion.

### 1.1 Theoretical framework and hypotheses

#### *1.1.1 Implicit self-theories*

Research has consistently demonstrated that people hold differing beliefs about the fixed or mutable nature of a variety of self-attributes such as intelligence (Blackwell et al., 2007; Dweck et al., 1995; Robins and Pals, 2002), personality (Erdley et al., 1997; Chiu et al., 1997b), morality (Chiu et al., 1997a; Huang et al., 2017), emotions (King and dela Rosa, 2019; Tamir et al., 2007; De Castella et al., 2013), and relationships (Knee, 1998; Knee et al., 2003; Ng and Tong, 2013), among others. These types of beliefs are referred to as implicit self-theories (Dweck and Leggett, 1988; Molden and Dweck, 2006) – or, more colloquially, mindsets. [2] They are described as implicit

[1] Some have argued (e.g., Collins, 2019; Xu, 2019), in particular, that individual difference research in HRI is, at present, only partly understood and warrants further investigation.

[2] The term "implicit self-theories" is used herein, rather than "mindset," as the latter is an ambiguous term with numerous conceptualizations and diverse meanings (see, for example, Freitas et al., 2004;

because most individuals are unaware of them and as self-theories, since they are, in essence, falsifiable ideas about what a particular trait or self-attribute is and how it might work (Dweck and Yeager, 2019). Implicit self-theories are not to be confused with other well-known and distinctly different theories such as implicit knowledge of beliefs (Clements and Perner, 1994) implicit theories of the self (Greenwald et al., 2002) and implicit Theory of Mind (Clements, 2000).

Broadly speaking, implicit self-theories exist on a spectrum from the incremental theory (incremental theorists), which assumes that self-attributes are responsive to change through concerted effort and education, to the entity theory (entity theorists), which assumes that self-attributes are largely fixed and immutable (Dweck, 2008).

More than 40 years of correlational and experimental studies provide evidence that these contrasting theories regarding the nature of self-attributes influence how people select and process information, form judgements, and act in consequence of these valuations (Dweck, 2013; Dweck and Sorich, 1999; Burnette et al., 2013; Plaks et al., 2001; Haimovitz and Dweck, 2017).

Clearly a detailed examination of this large literature is well beyond the scope of this article, however a thorough review of implicit self-theories can be found in Dweck and Yeager (2019). In essence, what this literature demonstrates is that implicit self-theories compel people toward a theory-consistent experience of reality (Dweck, 2008; Priester and Petty, 2016).

Consistent with this notion, there is a vast and ever-increasing evidence base showing that implicit self-theories have downstream impacts on a vast array of human activity and experience (Mathur et al., 2014).

For instance, in the domain of financial decision making, Rai and Lin (2019) found that individuals who held an incremental theory were marked by the tendency to prefer risk-seeking investments. By contrast, entity theorists appeared to prefer risk-averse investments. In addition, this research found that, at least in the context of financial decision making, incremental theorists are more prone to adopt a promotion-focus, whereas entity theorists may orient towards a prevention-focus (see also Montford et al., 2019). These findings are in line with prior work showing that individuals who adhere to incremental theories exhibit greater optimism, perseverance, and resilience in the face of setbacks (see Mangels et al., 2006; Hong et al., 1999), and a future temporal focus (e.g., Price et al., 2017), in that they set goals to improve their abilities in the future (Dweck and Leggett, 1988). As contrasted with, entity theorists who have been repeatedly shown to be more sensitive to negative events (Robins and Pals, 2002; Elliott and Dweck, 1988) adopt poorer stress mitigation strategies (Doron et al., 2009), and hold a present temporal focus (Dweck and Leggett, 1988), that is they are more concerned with signaling their traits in the present (Sevincer et al., 2014).

In the context of brand evaluation, Park and John (2010) found that entity theorists were particularly attracted to luxury brands (e.g., Victoria's Secret), in large part because such brands provide entity theorists with the means through which to signal positive self-traits (e.g., attractiveness). Contrastingly, incremental theorists were

Gollwitzer, 2012; Murphy and Dweck, 2016a; Rucker and Galinsky, 2016). Accordingly, the terms "incremental theories" and "entity theories," are used here, instead of "fixed" and "growth" mindsets (see also Wheeler and Omair, 2016).

uninfluenced by such brands. Similarly, advertising appeals that highlight a brand's signaling abilities have been shown to be more popular with entity theorists, whereas incremental theorists systematically prefer advertising appeals that focus on aspects of self-improvement (see Park and John, 2012).

In a similar context, Yorkston and colleagues (2010) found that individuals who hold an entity theory are less likely to accept a brand's attempt to extend into new and diverse product categories (e.g., Subaru extending into motorized scooters). The authors explain that these findings are a byproduct of entity theorists belief that a brand's expertise, personality, and image is fixed and unable to change (see Jain and Weiten, 2020, for review).

In research on social media marketing, incremental theorists were found to be more inclined to follow brands that they had never used before. In contrast, entity theorists were more prone to follow brands they already use (Song et al., 2019). This finding is in keeping with previous observations, showing that incremental theorists are motivated toward new possibilities while entity theorists tend to confirm prior choices (e.g., Dweck, 2013) and seek to maintain the status quo (Quintanilla, 2011; Kam, 2011; Plaks and Stecher, 2007).

More recently, a small but gradually increasing number of scholars have examined the relationship between implicit self theories and technology use. For instance, Sharifi and Palmeira (2017) demonstrated that incremental theorists showed more favorable responses to a technology product (a smart ring) perceived as complex. Whereas entity theorists indicated aversion toward the product. The same product, however, when perceived as simple, induced similar reactions from both incremental and entity theorists. These results, in particular, seem consistent with other research showing that incremental theorists gravitate towards effortful engagement (e.g., Dupeyrat and Mariné, 2005) in order to learn new tasks, which may predispose these individuals to accept technology (Solberg et al., 2020) more readily, and perhaps more germane to the current work, adopt radical technological innovations (Hafeez, 2019)

In the case of information technology continuance Fong et al. (2018) reported that incremental theorists were more inclined than entity theorists, to use, and continue to use, an app to make hotel reservations (Fong et al., 2018). This finding appears consistent with prior studies showing entity theorists tend to hold negative effort beliefs (e.g., Murphy and Dweck, 2016b; Hong et al., 1999; Knee, 1998), and are lower in personal innovativeness (Aldahdouh et al., 2018), which is a determinant of technology adoption in general (Jin, 2013).

Cumulatively, these data give credence to the possibility that implicit self-theories could exert influential effects in the context of social robots.

What is perhaps most important to note, however, is that this is by no means a foregone conclusion. Indeed, social robots, owing in part to their humanlike embodiment (see Ferrari et al., 2016; Haring et al., 2018), perceived agency and experience (see Gray and Wegner, 2012), social capabilities (see Collins, 2019) and capacity for eliciting affective responses (see Damiano and Dumouchel, 2018), have been identified as a distinctly different class of product (see de Graaf et al., 2016; Severson and Carlson, 2010), and one that defies clear categorisation (see Kahn et al., 2011; Strait et al., 2019). This has lead several researchers (e.g., de Graaf et al., 2019; Damholdt

et al., 2020), to argue that it is erroneous to accept, without question, that the fundamental propositions of the social sciences, will invariably apply to social robotics and HRI research (see also Wullenkord and Eyssel, 2020). In this view, preliminary evidence is required to substantiate whether implicit self-theories influence people's perceptions and responses to social robots. Thus, the present study aimed to provide this critical data.

### *1.1.2 Hypotheses*

In the present research, we explored whether an individuals' implicit self-theory orientation affects his or her perceptions of emerging social robots developed for everyday use.

As detailed above, entity theorists, but not incremental theorists, tend to show more risk aversion (Rai and Lin, 2019), a preference for maintaining the status quo (Quintanilla, 2011; Kam, 2011; Plaks and Stecher, 2007), and less favorable reactions towards novel technology products (Sharifi and Palmeira, 2017; Fong et al., 2018). Furthermore, entity theorists, more so than incremental theorists, are low in personal innovativeness (Aldahdouh et al., 2018), which in turn, is a negative predictor of social robot acceptance (De Graaf et al., 2015). Therefore, we posit the following hypotheses:

H1. Entity (vs. incremental) theorists will exhibit more (vs. less) robot anxiety.
H2. Incremental (vs. entity) theorists will exhibit more (vs. less) attitudinal acceptance toward social robots.
H3. Entity (vs. incremental) theorists will exhibit less (vs. more) intentional acceptance[3] toward social robots.

Related to robot acceptance, a pivotal question in HRI is which role do people expect a social robot to perform?

Past research has shown that people consider the role of a social robot to be that of an assistant, domestic tool, or servant (Dautenhahn et al., 2005; Ray et al., 2008; Takayama et al., 2008; Ezer, 2008; Cagiltay et al., 2020), rather than as a social companion (Bernotat and Eyssel, 2018; de Graaf et al., 2019). Additionally, there is evidence suggesting that individual difference factors may play an important role in determining the different functions that people expect a social robot to fulfill (see Copleston and Bugmann, 2008; Ezer, 2008; Nomura et al., 2009; Eyssel and Hegel, 2012; Bernotat and Eyssel, 2018). Interestingly, a recent paper on implicit self-theories (Han et al., 2019) reported that participants with different self-theories responded disparately to advertising messages for a travel brand anthropomorphized as a partner (vs. servant). Specifically, entity theorists responded more favorably to a brand anthropomorphized as a servant, whereas incremental theorists preferred a partner brand.

[3] Following (Bernotat and Eyssel, 2018), attitudinal and intentional robot acceptance were assessed as different dimensions of robot acceptance. According to Ezer (2008), attitudinal robot acceptance refers to one's positive beliefs regarding a robot more generally, whereas intentional acceptance refers to an individual's intention to purchase or use a robot.

It seems plausible that entity theorists' desire for effortlessly attained benefits (Dweck and Leggett, 1988; Elliott and Dweck, 1988), and partiality for signaling their superiority (Dweck, 2008), led them to be more accepting of a brand anthropomorphized as a servant. Likewise, incremental theorists' preference for process and effort (Hong et al., 1997; Levy and Dweck, 1998), most probably resulted in more favorable responses toward the brand-as-partner option. Based on this rationale, then, it would be of interest to explore whether this relationship exists in regard to social robots.

Hence, an additional aim of the present research was to extend beyond this work, and build on previous HRI findings (i.e., preferred robot role classifications), to examine the relation between the implicit self-theory endorsed by participants and their evaluations of a social robot presented as either a collaborative assistant[4] or a personal servant. Formally, we hypothesize:

H4. Incremental (vs. entity) theorists will evaluate a robot described as a collaborative assistant (vs. servant) more (vs. less) favorably.

Consistent with the recommendation of Wullenkord and Eyssel (2020), who argue that HRI research should consider covariate influences, measures of gender (Eyssel et al., 2012), age (Kuo et al., 2009), education (Eurobarometer, 2012), media exposure to science fiction (Sandoval et al., 2014), technology commitment (Halperin et al., 2011), and prior robot experience (Bartneck et al., 2007) were assessed. These variables have been routinely shown to impact individuals' perceptions of robots (see Schermerhorn et al., 2008; Enz et al., 2011; Bartneck et al., 2020). Therefore, they were considered as covariates.

## 2 Method

All hypotheses, design, planned sample sizes, and the analysis plan were preregistered and are publicly available at `http://osf.io/m84q7/`. We deviated from our preregistration in several ways. First, we did not include age as a covariate. This deviation occurred because age was not recorded in the dataset due to a technical error. Second, we did not conduct the preregistered analyses on or with the predicted interaction (implicit self-theory + robot role) and therewith we did not directly test Hypothesis 4. The reason for this is that the manipulation check failed to show that the manipulation of robot role was successful (described later in Section 3.2.1), therefore, the predicted interaction could not be established. Thus, these analyses were no longer appropriate, much less meaningful. We did, however, run part of this protocol as a post-hoc exploratory analysis, the results of which are publicly available at `https://osf.io/abkwp/` and will not be discussed further in this article. Finally, we conducted other exploratory analyses which were not specified in the preregistration.

[4] For the purposes of this study, the role of "assistant" was used rather than "partner." The rationale for this is the empirical evidence on robot role, which has repeatedly shown that people distinguish between the two roles (servant vs. assistant). In contrast, there appears to be much less evidence for partner role type perceptions in the HRI literature (e.g., Dautenhahn et al., 2005)

## 2.1 Participants

A total of 251 participants recruited through Amazon's Mechanical Turk (AMT) participated in an implicit self-theory (continuous)$\times$2 (role: Servant, assistant) between-subjects study, which was compiled and hosted on Qualtrics. Four participants who either failed to pass the attention check (Robinson et al., 2019), the validity indicator (Chmielewski and Kucker, 2020), or who asked to withdraw their data, were excluded from the dataset before any analyses were conducted. Out of 247 participants in the final sample, 45.34% were female. Participation was restricted to those who resided in the United States, had completed $>$50 surveys with prior HIT approval ratings of 98% or greater (Robinson et al., 2019). Most participants (65.47%) had undergraduate education (some college education) while 15.38% had post-graduate degrees and 9.72% had high school education.

## 2.2 Procedure

The research protocol was approved by the Human Research Ethics Committee of the University of Canterbury (HEC 2019/53/LR-PS), and all participants provided consent before beginning the study. After reading the instructions, participants were asked to complete a measure of implicit self-theory (Levy et al., 1998), described later in Section 2.3.1, after which they were randomly assigned to read one of two written descriptions briefly describing a new generation of social robots modified from (de Graaf et al., 2019). Those in the assistant condition read that a social robot is, in essence, a collaborative assistant (e.g., "social robots work with you, helping you to achieve your goals, and performing the role of a collaborative assistant"; "Because a social robot is a collaborative assistant it can assist you as you go about accomplishing your daily tasks"). By contrast, participants in the servant condition read that, social robots are designed to be servants (e.g., "a social robot works for you, executing tasks on your behalf, and ultimately performs the role of a personal servant; Because a social robot is a servant it can do chores in and around the home based on your preferences"). A written description rather than video or pictures was used, as previous research suggests that a robot's appearance can affect individuals' perceptions regarding its function (Goetz et al., 2003; Walters et al., 2009) which may, in turn, result in unfavorable judgments (Haring et al., 2018; Reich-Stiebert et al., 2019). Indeed, written descriptions are widely accepted and used in HRI studies (Reich-Stiebert and Eyssel, 2015; de Graaf et al., 2019). Upon reading the manipulation text, participants completed the dependent measures and provided demographic information. Finally, participants were debriefed and compensated $1.50 for their participation.

## 2.3 Measures

### *2.3.1 Implicit Self-Theory*

Implicit self-theory was assessed using an 8-item measure from (Levy et al., 1998). On a 6-point scale (1 = strongly disagree, 6 = strongly agree), participants indicated

their agreement with four items representing entity beliefs (e.g., “Everyone is a certain kind of person, and there is not much that they can do to really change that”), and four items representing incremental beliefs (e.g., “People can change even their most basic qualities”). The four incremental items were reverse-scored and averaged with the four entity items to create a single measure of implicit self-theory with higher (vs. lower) scores reflecting an incremental (vs. entity) implicit self-theory. It is crucial to note that this self-report scale is the most widely used and well validated method of measuring domain-general implicit self-theories (e.g., Levy and Dweck, 1998) in experimental settings (Mathur et al., 2016). As such, this measure has demonstrated efficacy in a range of domains including those related to stereotypes (e.g., Levy et al., 1998), advertising (e.g., Mathur et al., 2013), financial decision-making (e.g., Montford et al., 2019), performance appraisals (e.g., Heslin et al., 2005), and consumer behavior (e.g., Yorkston et al., 2010). The Cronbach’s alpha was 0.95.

#### *2.3.2 Manipulation Check*

Two items modified from (Kim and Kramer, 2015) assessed the extent to which participants perceived a social robot as a servant (e.g., “A Social Robot is like a servant to the consumer”) versus as an assistant (e.g., “A Social Robot is like an assistant to the consumer”). Agreement with items was indicated using a 7-point Likert scale (1=strongly disagree, 7=strongly agree).

#### *2.3.3 Robot Anxiety (H1)*

Robot anxiety was assessed with the 14-item NARS (Negative Attitudes toward Robots Scale; Nomura et al., 2004). Respondents indicated agreement with items (e.g., “I would hate the idea that robots or artificial intelligences were making judgments about things”) on a 5-point scale (1=strongly disagree, 5=strongly agree) with higher scores indicating more negative attitudes. This scale has been used in previous research to measure robot anxiety (e.g., Bernotat and Eyssel, 2018; Bartneck et al., 2007; Xia and LeTendre, 2020). The Cronbach’s alpha was 0.89.

#### *2.3.4 Attitudinal Robot Acceptance (H2)*

Five items adapted from (Ninomiya et al., 2015) assessed participants’ likelihood of acceptance. Agreement with items (e.g., “It is good if a social robot can do the work of a human,” and “I would want to boast that I have a social robot in my home”), was indicated on a 7-point scale (1=strongly agree, 7=strongly disagree). The Cronbach’s alpha was 0.88.

#### *2.3.5 Intentional Robot Acceptance (H3)*

Four items from (de Graaf et al., 2019) measured participants’ intentions to use a robot (e.g., “Assuming I have a robot, I will frequently use it in the future,” and ”I think a social robot would be useful to me”). As well, one item asked participants to indicate their likelihood of purchase (i.e., “Assuming a social robot is affordable, I

will likely purchase one in the future"). The five items were measured on a 7-point scale (1 = strongly agree, 7 = strongly disagree). The Cronbach's alpha was 0.95.

#### *2.3.6 Robot Evaluation (H4)*

A three-item, seven-point scale modified from (Han et al., 2019) assessed participants' evaluations of the social robot (i.e.,"very unfavorable/very favorable," "very bad/very good," and "very negative/very positive"). Higher scores correspond to higher endorsement. The Cronbach's alpha was 0.94.

#### *2.3.7 Covariants*

*Prior Robot Experience.* Three items adapted from (Reich-Stiebert and Eyssel, 2015) measured participants' prior experience with robots (e.g., "Have you ever used, or are you currently using a robot at home or at work?"). A prior robot experience score was computed by taking the mean response to the three items.

*Media Exposure to Science Fiction.* One item adapted from (Liang and Lee, 2017) evaluated participants' media exposure to science fiction. Respondents indicated agreement with this item (i.e., "How often do you watch television shows and movies related to science fiction and fantasy?") on a 7-point scale (1=very often, 7=never).

*Technology Commitment.* Technology Commitment was assessed with the English version of the Technology Commitment scale (Neyer et al., 2012). The scale consisted of 12 items, assessing interest in, and acceptance of new technology (e.g., "I am very curious about new technical developments"). Agreement with items was indicated on a 5-point scale (1=strongly agree, 5=strongly disagree). The Cronbach's alpha was 0.81.

## 3 Results

Data for this study are available via the Open Science Framework and may be accessed at `http://osf.io/v8cbm/`

### 3.1 Data Analyses

To test the predictions, we conducted four linear regression analyses with implicit self-theories (entity vs. incremental) as the predictor variable[5]. We used robot anxiety, attitudinal robot acceptance, intentional robot acceptance, and robot evaluation, as dependent variables. The regression model was run separately for each hypothesis.

[5] As described in Section 2.3.1, higher (vs. lower) scores on the implicit self-theories measure indicate more (vs. less) of an incremental (vs. entity) theory. Therefore, positive (vs. negative) statistically significant effects indicate an association between incremental (vs. entity) theory and the dependent variable of interest.

In every regression, individual differences in prior robot experience, media exposure to science fiction, technology commitment, as well as gender and education were included as covariates. Subsequently, we re-ran the same series of regression analyses without covariates. As well, separate regressions and simple slope analyses were performed as part of an exploratory analysis.

The predictor variable was centred prior to being entered into the model (Li et al., 1998). Regression diagnostic tests were then conducted for examining the validity of the model. The initial diagnostic analysis identified one extreme outlier due to high leverage in Cook's distance. With this outlier removed, the statistical assumptions of the model were met (Aiken et al., 1991).

## 3.2 Main Analyses

### *3.2.1 Manipulation Check*

Independent sample t-tests results indicated that participants in the servant condition scored significantly ($t(244) = 6.09, p < .001$) higher on servant role perceptions ($M = 5.57, SD = 1.36$) than those in the assistant condition ($M = 4.45, SD = 1.53$). However, participants in the assistant condition did not score significantly ($t(244) = -1.50, p = .134$) higher on assistant role perceptions ($M = 5.81, SD = 0.917$) than those in the servant condition ($M = 5.59, SD = 1.34$). Therefore, our manipulation of robot role type was not entirely successful. Hence, and as discussed in Section 2, we could not perform the planned test of Hypothesis 4, as this required a successful manipulation of robot role.

### *3.2.2 Robot Anxiety (H1)*

According to H1, entity theorists were expected to report more robot anxiety than incremental theorists (H1). We found a statistically significant main effect of implicit self-theory on participants' ratings of robot anxiety ($\beta = -0.08, SE = 0.03, t = -2.48, p = .014$; see Figure. 1). That is, having an entity (vs. incremental) self-theory was significantly correlated with more (vs. less) robot anxiety. Consequently, H1 was supported. Regarding the covariates, a statistically significant main effect of participants' media exposure to science fiction, ($b = -0.06, SE = 0.02, t = -2.35, p = .019$), and a significant main effect of technology commitment ($b = -0.57, SE = 0.07, t = -7.96, p < .001$) was observed. Moreover, participants' education level ($b = -0.33, SE = 0.16, t = -2.00, p = .046$) had a significant effect on their level of robot anxiety.

### *3.2.3 Attitudinal Robot Acceptance (H2)*

According to H2, we expected incremental theorists to indicate more attitudinal robot acceptance than entity theorists. A statistically nonsignificant main effect of implicit self-theory ($\beta = -0.07, SE = 0.07, t = 1.03, p = .303$) was observed. That is, having an incremental (vs. entity) self-theory was marginally correlated with more (vs.

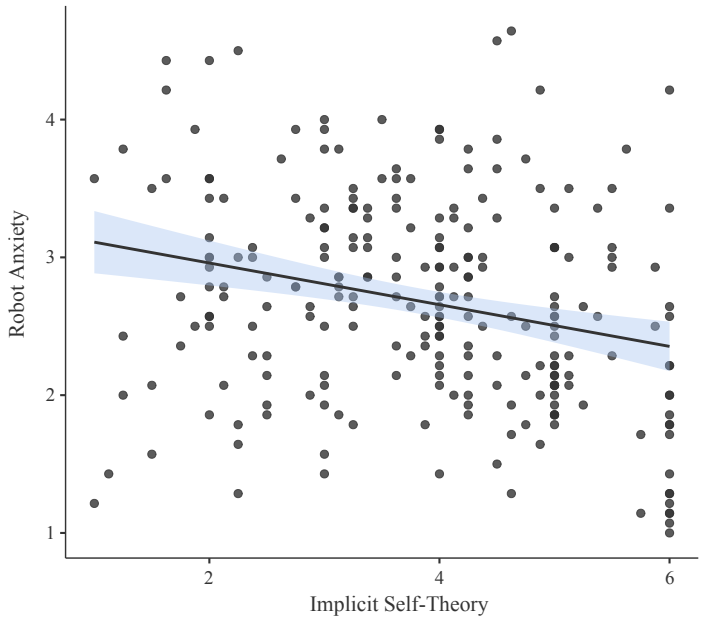


**Fig. 1** Scatterplot with the correlation line between implicit self-theory (lower scores indicate more of an entity theory) and robot anxiety. Confidence bands indicate 95% confidence intervals (CIs).

less) attitudinal robot acceptance. Thus, H2 was not supported. Participants' media exposure to science fiction tended to influence their attitudinal robot acceptance ($\beta = 0.14, SE = 0.06, t = 2.39, p = .017$). Moreover, participants' self-rated technology commitment had a statistically significant effect on their attitudinal robot acceptance ($\beta = 0.49, SE = 0.16, t = 3.04, p = .003$). No other significant effects were revealed.

### *3.2.4 Intentional Robot Acceptance (H3)*

According to H3, we predicted that entity theorists would indicate less intentional robot acceptance than incremental theorists. A statistically nonsignificant main effect of implicit self-theory, ($\beta = 0.06, SE = 0.07, t = -0.86, p = .386$) was observed. That is, having an entity (vs. incremental) self-theory was marginally correlated with less (vs. more) intentional robot acceptance. Thus, H3 was not supported. In regard to the covariates, participants' intentional robot acceptance was influenced statistically significantly by their media exposure to science fiction ($\beta = 0.13, SE = 0.06, t = 2.23, p = .026$). In addition, participants' self-rated technology commitment had a significant effect on their intentional robot acceptance ($\beta = 0.68, SE = 0.16, t = 4.17, p < .001$). No other significant effects were revealed.

| | | Implicit Self-Theory | Robot Anxiety | Attitudinal Acceptance | Intentional Acceptance |
|---|---|---|---|---|---|
| Implicit Self-Theory | Pearson's r | — | | | |
| | p-value | — | | | |
| Robot Anxiety | Pearson's r | -0.256 | — | | |
| | p-value | <.001 | — | | |
| Attitudinal Robot Acceptance | Pearson's r | 0.118 | -0.629 | — | |
| | p-value | 0.064 | <.001 | — | |
| Intentional Robot Acceptance | Pearson's r | 0.12 | -0.598 | 0.759 | — |
| | p-value | 0.061 | <.001 | <.001 | — |
| Robot Evaluation | Pearson's r | 0.132 | -0.453 | 0.614 | 0.695 |
| | p-value | 0.038 | <.001 | <.001 | <.001 |

**Table 1** Correlations between implicit self-theory and robot anxiety, attitudinal robot acceptance, intentional robot acceptance, and robot evaluation (N = 246)

#### *3.2.5 Robot Evaluation (H4)*

According to H4, entity theorists were expected to prefer a robot described as a servant (vs. assistant), whereas incremental theorists were expected to prefer a robot described as an assistant (vs. servant). However, as explained above, we did not test this interaction directly, and therefore by extension, Hypothesis 4, due to the manipulation check failure. However, a statistically nonsignificant main effect of implicit self-theory, on participants' robot evaluation ($\beta = -0.07, SE = 0.06, t = -1.22, p = .223$), was observed. That is, having an incremental (vs. entity) self-theory was marginally correlated with a less (vs. more) favorable robot evaluation. Considering the covariates, a statistically significant main effect of participants' technology commitment, ($\beta = 0.48, SE = 0.14, t = -3.40, p < .001$) and gender, ($\beta = -0.33, SE = 0.16, t = -2.03, p = .043$) was observed. No other significant effects were revealed.

### 3.3 Exploratory Analysis

To gain a further understanding of the relationship between participants' implicit self-theory and their perceptions of emerging social robots, we ran the same regression analyses without covariates (see Table 3.3 for correlations).

Unsurprisingly, results show that implicit self-theory remains significant for robot anxiety ($\beta = -0.15, SE = 0.03, t = 4.14, p < .001$). However, a statistically significant main effect of implicit self-theory on robot evaluation ($\beta = -0.13, SE = 0.06, t = -2.09, p = .038$) appears. That is, having an entity (vs. incremental) self-theory was significantly correlated with a less (vs. more) favorable robot evaluation. Moreover, attitudinal robot acceptance ($\beta = -0.13, SE = 0.07, t = -1.86, p = .064$), and intentional robot acceptance ($\beta = -0.14, SE = 0.07, t = -1.89, p = .061$), narrowly failed statistical significance.

As a secondary exploratory analysis we sought to examine the relationship between implicit self-theory and robot role. To do so, we ran a similar model but included the manipulation check scores (servant vs. assistant), with implicit self-theory (entity vs. incremental), and their interaction as independent variables. We used the same dependent variables as above (i.e., robot anxiety, attitudinal robot acceptance, intentional robot acceptance, and robot evaluation). The results revealed a significant interaction ($\beta = -0.05, SE = 0.02, t = -2.85, p = .005$) of implicit self-theory and robot-as-servant role in predicting robot evaluation. To probe the nature

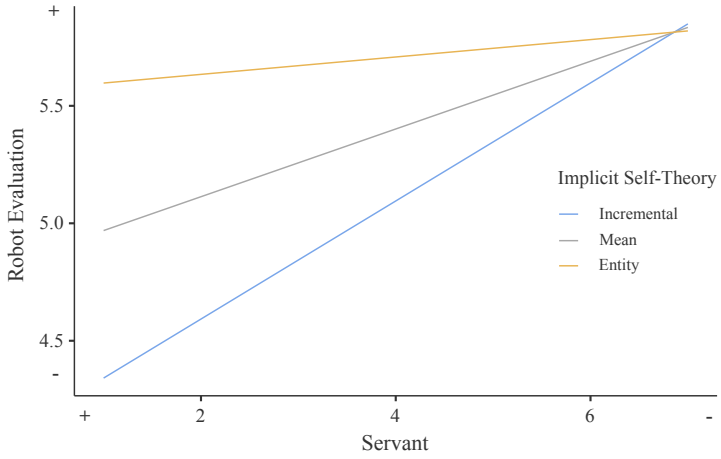


**Fig. 2** Linear regression lines depicting a significant interaction between implicit self-theory and robot-as-servant role in predicting robot evaluation.

of this interaction, a simple slope analysis was performed for "high" (1 SD above the mean), "medium" (mean), and "low levels" (1 SD below the mean) of robot-as-servant role perceptions (see Figure. 2). For the incremental theorists, higher levels of robot-as-servant role perceptions ($M = 5.80, SE = 0.15, 95\%CI = [5.49, 6.11]$), were not associated with more favorable evaluations than low levels of robot-as-servant role perceptions ($M = 5.69, SE = 0.15, 95\%CI = [5.40, 5.98]$). However, for the entity theorists, higher levels of robot-as-servant role perceptions ($M = 5.74, SE = 0.15, 95\%CI = [5.43, 6.04]$) were associated with higher robot evaluations than low levels of robot-as-servant role perceptions ($M = 4.96, SE = 0.17, 95\%CI = [4.62, 5.30]$). Thus, whereas incremental theorists had no preference for a servant or assistant, entity theorists responded significantly more favorably to a robot positioned as a servant. This finding, though not definitive, provides some partial support for H4. In contrast to this, no significant interaction effects were found for the other dependent variables.

## 4 Discussion

The present research provides initial evidence that one's implicit self-theory orientation influences one's perceptions of emerging social robots developed for everyday use. Specifically, we find that those who view self-attributes as fixed (entity theorists) showed greater robot anxiety than those who view self-attributes as malleable (incremental theorists). Notably, this was true even when controlling for a number of important covariates.

Importantly, although the regression results for Hypothesis 2 and Hypothesis 3, followed the expected pattern, both narrowly missed statistical significance. Consequently, these hypotheses were not supported. That said, given how close to significant these findings were, it is conceivable that the study was slightly underpowered.

This explanation can be tested in future research by replicating our design, with a larger sample size.

The above notwithstanding, an exploratory analysis showed that the effect of implicit self-theory on robot evaluation was significant when not controlling for covariates. That is, incremental theorists rated both robot types (i.e., servant and assistant) more favorably than entity theorists. This finding falls in line with recent research, showing that the incremental theory is positively associated with technology acceptance (Fong et al., 2018) and use (Solberg et al., 2020) more broadly, and greater endorsement of radical technological innovations (Hafeez, 2019) in particular.

Furthermore, the results indicated that entity theorists' evaluation of a social robot was higher when they thought of it as a servant. This finding appears consistent with that of Han et al. (2019) and lends partial support for Hypothesis 4, which stated in part, that entity theorists, relative to incremental theorists would prefer a robot positioned as a servant.

This study is the first, to the best of our knowledge, to have empirically examined the effect of implicit self-theories on individuals' evaluations of social robots. In turn, this study expands our understanding of human factors affecting HRI, thereby adding to the existing literature, by identifying a meaningful psychological variable that appears to influence how humans perceive and evaluate social robots. As such, the present study answers the call of researchers for further work on individual difference factors and psychological variables in the field of HRI (Eyssel, 2017; Collins, 2019; Matthews et al., 2020; Robert et al., 2020; Hinks, 2020).

### 4.1 Limitations and future directions

The primary limitation in this study is that the robot role manipulation check was unsuccessful, and, in consequence, we could not directly test Hypothesis 4. It is unclear whether this is due to the manipulation, the measure, or both. One possible explanation is that there may have been an order effect, arising from the fact that the servant item in the manipulation check questionnaire was presented first in both conditions. If this were the case, participants in the assistant condition may have mistakenly assumed that a robot positioned as a servant was equivalent to one positioned as an assistant.

A further possible explanation could be that some participants did not read the manipulation text or only skimmed through, and were, thus, not exposed to the experimental manipulation. This explanation is consistent with previous findings, which have demonstrated that inattention and low-effort are typical of Mturk samples to varying degrees (see Ford, 2017; Chandler et al., 2013; Hauser et al., 2018). Nevertheless, future studies should attempt to replicate and explore this effect further as it was unanticipated.

Another limitation of the present study lies in the fact that we utilized written descriptions of social robots. Even though this was a methodological decision, intended to avoid biasing participants towards any particular kind of robot appearance (see Reich-Stiebert and Eyssel, 2015; Haring et al., 2014), there would almost certainly have been some variability in the way participants imagined robot embodiment

and appearance (Rueben et al., 2020), which may have influenced some participant's responses to the measures we used. Consequently, future research may examine this issue with real social robots, such as NAO (see Gouaillier et al., 2009), and with richer stimulus materials (e.g., videos, images, actual human-robot interactions).

Another issue worth noting is that we did not test all individual difference variables common to HRI research e.g., individual differences in age (Kuo et al., 2009), culture (Bartneck et al., 2007; Bernotat and Eyssel, 2018; Haring et al., 2014), mind perception (Gray and Wegner, 2012), personality traits (Santamaria and Nathan-Roberts, 2017) anthropomorphism (Duffy, 2003) and occupation (Gnambs and Appel, 2019). Thus, it is important for future studies to examine how such variables may relate to, or interact with implicit self-theories.

Additionally, we did not manipulate participants' implicit self-theory orientation. This is is a well-established practice and, in fact, used in the majority of existing studies on implicit self-theories (e.g., Dweck and Leggett, 1988; Hong et al., 1999; Levy et al., 1998; Yorkston et al., 2010). Past research has consistently shown that experimentally primed self-theories' bias preferences in a comparable manner to those found in studies measuring them as chronic orientations (Molden and Dweck, 2006). More importantly, the act of inducing implicit self-theories, allows researchers to assess their causal role, that is, to rule out the possibility that results may be explained by other variables related to measured levels of entity or incremental theory endorsement (see also Yorkston et al., 2010; Park and John, 2012). Future work would benefit from replicating the present findings with an experimental manipulation of implicit self-theory. As such, it may establish causal evidence of the effects reported herein (Chiu et al., 1997b).

Moreover, our findings are obscured by the sample used in this study, which was drawn from Mturk. Although extant research suggests Mturk samples produce valid and reliable data (Bartneck et al., 2015; Buhrmester et al., 2011; Huff and Tingley, 2015) of equal or greater quality than student subject pools (Kees et al., 2017) there is a small but growing body of research that has documented potential issues with using these samples (Chmielewski and Kucker, 2020) such as those noted earlier. In particular, Mturk samples are shown to be more technologically-savvy (see Munger et al., 2018), and more well-educated (see Aruguete et al., 2019) than the general public, which was confirmed in our data. Specifically, all of our participants were relatively astute with respect to general technology use, which has been previously shown to promote favorable attitudes toward social robots (Reich-Stiebert and Eyssel, 2015). Furthermore, our sample consisted of highly educated individuals with more than four-fifths having some college or greater education. Previous research has shown that more educated individuals relative to less educated individuals, tend to hold more positive views about robots (Gnambs and Appel, 2019). This is consistent in our data with higher educated participants' showing less robot anxiety. A related limitation is that every participant self-selected to take part in a study about social robots. Thus, it may be the case that the sample was subject to self-selection bias. In consequence, their view of social robots, could differ from those of the general population. Additionally, it appears that the participants in our sample, are somewhat skewed toward the incremental end of the implicit self-theory spectrum. Therefore, a replication with more diverse samples is desirous.

Finally, in addition to the above-mentioned limitations that should be addressed, the current study provides direction for future research. One interesting avenue for researchers to explore might be the relationship between one's implicit self-theory orientation and their perceptions of trust toward social robots (Schaefer, 2016; Kok and Soh, 2020; Lewis et al., 2018).

Past research posits, for example, that an individuals' trust in a robot is diluted by any functional, mechanical, or programming errors it might exhibit (e.g., Rossi et al., 2017, 2018; Robinette et al., 2017). In such instances, it is entirely possible that future research may find that entity theorists' who focus on outcome (Levy and Dweck, 1998), and are less tolerant of transgressions (Haselhuhn et al., 2010), will lose trust in a robot that displays such errors (Park and John, 2018). Comparatively, incremental theorists who focus on learning goals (Molden and Dweck, 2006), and value effort processes (Levy and Dweck, 1998) over flawless performance (Dweck, 2008) will be less likely to lose trust in a robot that errs. Future studies could test these predictions by having individuals interact with a social robot that makes errors (e.g., Rossi et al., 2020) and by assessing implicit self-theory and trust evaluations (e.g., Haselhuhn et al., 2017).

To be sure, there are numerous opportunities for future studies to build on our findings and to further examine the impact of implicit self-theories on people's perceptions of social robots, thus making this a fruitful and interesting new area for HRI research.

## 5 Conclusion

We investigated the unexplored notion that an individuals' implicit self-theory orientation (underlying beliefs about the malleability of one's self-attributes, such as intelligence and ability), can influence his or her perceptions of emerging social robots developed for everyday use. Those who believe that self-attributes are fixed (entity theorists) expressed greater robot anxiety than those who believe that self-attributes are malleable (incremental theorists). This effect was robust even when controlling for other influential covariates, such as prior robot experience, media exposure to science fiction, technology commitment, and demographic factors (i.e., gender and education). By contrast, marginal effects were observed for attitudinal and intentional robot acceptance. Crucially, our results show that incremental (vs. entity) theorists exhibit more favorable responses to social robots overall, whereas entity theorists evaluate social robots more favorably when they think of them as servants. Taken together our findings, although preliminary, provide the first empirical support, to our knowledge, for the proposition that implicit self-theory influences, at least to some degree, one's perceptions and inferences about social robots. Further research is currently underway to assess the potential utility of this theoretical construct to the field of HRI.

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## Conflict of interest

The authors declare that they have no conflict of interest.

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