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The Doors of Social Robot Perception: The Influence of Implicit Self-theories

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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

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 [1,26]. Recent research suggests that this topic has special urgency given the expanding place of robotic technologies in daily life [10,57,60,75,93,101,123], and unfolding debate concerning the introduction of automation (e.g., cars, drones, robots) in society and culture [48,52,74,151,153]. 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 [4,5,9,47,121,143].

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 [7,42,88,101,105]).

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 studys 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] Some have argued (e.g., [22,150]), in particular, that individual difference research in HRI is, at present, only partly understood and warrants further investigation.

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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 [12,38,126], personality [18,41], morality [17,76], emotions [28,84,145], and relationships [85,86,107], among others. These types of beliefs are referred to as implicit self-theories [35,99] or, more colloquially, mindsets.[2] They are described as implicit 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 [37]. Implicit self-theories are not to be confused with other well-known and distinctly different theories such as implicit knowledge of beliefs [21] implicit theories of the self [59] and implicit Theory of Mind [20].

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 [33].

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 [14,34,36,62,115].

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 [37]. In essence, what this literature demonstrates is that implicit self-theories compel people toward a theory-consistent experience of reality [33,117].

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 [96].

For instance, in the domain of financial decision making, Rai and Lin [119] 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 [100]). 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 [73,94]), and a future temporal focus (e.g., [116]), in that they set goals to improve their abilities in the future [35]. As contrasted with, entity theorists who have been repeatedly shown to be more sensitive to negative events [39,126] adopt poorer stress mitigation strategies [30], and hold a present temporal focus [35], that is they are more concerned with signaling their traits in the present [138].

In the context of brand evaluation, Park and John [111] 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 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 [112]).

In a similar context, Yorkston and colleagues [152] 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 [78], 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 [141]. 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., [34]) and seek to maintain the status quo [81,114,118].

More recently, a small but gradually increasing number of scholars have examined the relationship between implicit self theories and technology use. Sharifi and Palmeira [139] 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., [32]) in order to learn new tasks, which may predispose these individuals to accept technology [140] more readily, and perhaps more germane to the current work, adopt radical technological innovations [61]

[2] The term "implicit self-theories" is used herein, rather than "mindset," as the latter is an ambiguous term with numerous conceptualisations and diverse meanings (see, for example, [51,54,103,131]). Accordingly, the terms "incremental theories" and "entity theories," are used here, instead of "fixed" and "growth" mindsets (see also [147]).

In the case of information technology continuance Fong et al. [49] reported that incremental theorists were more inclined than entity theorists, to use, and continue to use, an app to make hotel reservations [49]. This finding appears consistent with prior studies showing entity theorists tend to hold negative effort beliefs (e.g., [73,85,104]) and are lower in personal innovativeness [3], which is a determinant of technology adoption in general [79].

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 [47,66]), perceived agency and experience (see [58]), social capabilities (see [22]) and capacity for eliciting affective responses (see [25]), have been identified as a distinctly different class of product (see [56,137]), and one that defies clear categorisation (see [80,142]). This has lead several researchers (e.g., [24,57]), 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 [148]). 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 [119], a preference for maintaining the status quo [81,114,118], and less favorable reactions towards novel technology products [49,139]. Furthermore, entity theorists, more so than incremental theorists, are low in personal innovativeness [3], which in turn, is a negative predictor of social robot acceptance [29]. 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 [15,27,46,120,144], rather than as a social companion [11, 57]. 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 [11,23,44,46,110]). Interestingly, a recent paper on implicit self-theories [64] 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.

It seems plausible that entity theorists desire for effortlessly attained benefits [35,39] and partiality for signaling their superiority [33] led them to be more accepting of a brand anthropomorphized as a servant. Likewise, incremental theorists' preference for process and effort [72,89], 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 regards 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 [148], who argue that HRI research should consider covariate influences, measures of gender [45], age [88], education [42], media exposure to science fiction [133], technology commitment [63], and prior robot experience [7] were assessed. These variables have been routinely shown to impact individuals perceptions of robots (see [9,40,136]). Therefore, they were considered as covariates.

[3] Following Bernotat and Eyssel [11], attitudinal and intentional robot acceptance were assessed as different dimensions of robot acceptance. According to Ezer [46], 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.

[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., [27]).

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 Sect. 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.

2.1 Participants

A total of 251 participants recruited through Amazon's Mechanical Turk (AMT) participated in an implicit self-theory (continuous)×2 (role: Servant, assistant) between-subjects study, which was compiled and hosted on Qualtrics. Four participants who either failed to pass the attention check [127], the validity indicator [19], 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 [127]. 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 by the University of Canterbury Ethics board (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 [90], described later in Sect. 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. [57]. 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 [53,146] which may, in turn, result in unfavorable judgments [66,122]. Indeed, written descriptions are widely accepted and used in HRI studies [57,121]. Upon reading the manipulation text, participants completed the dependant 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. [90]. 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., [89]) in experimental settings [97]. As such, this measure has demonstrated efficacy in a range of domains including those related to stereotypes (e.g., [90]), advertising (e.g., [95]), financial decision-making (e.g., [100]), performance appraisals (e.g., [70]), and consumer behaviour (e.g., [152]). The Cronbach's alpha was 0.95.

2.3.2 Manipulation Check

Two items modified from Kim and Kramer [83] 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; 109]. 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 of robot anxiety (e.g., [7,11,149]). The Cronbach's alpha was 0.89.

2.3.4 Attitudinal Robot Acceptance (H2)

Five items adapted from Ninomiya et al. [108] 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. [57] 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. [64] 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 [121] 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 [93] 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 [106]. 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.

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 [92]. 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 Cooks distance. With this outlier removed, the statistical assumptions of the model were met [2].

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

[5] As described in Sect. 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 dependant variable of interest.

($M = 4.45, SD = 1.53$). 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 Sect. 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 Fig.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. 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

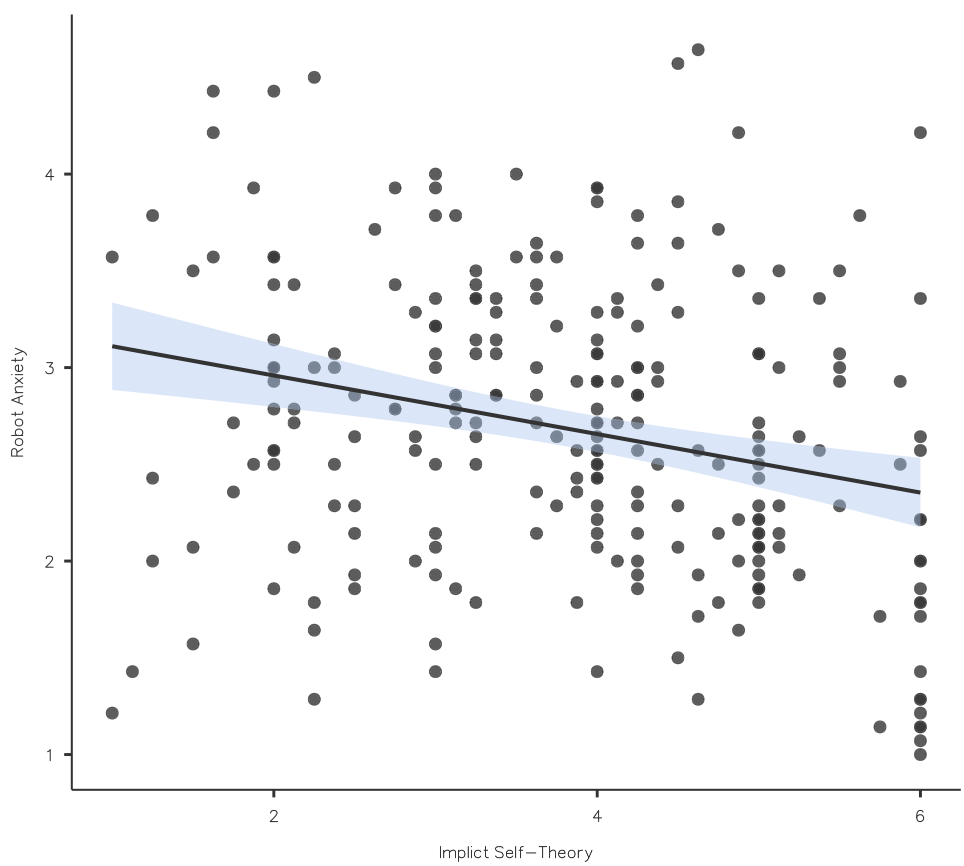

Fig. 1 Scatterplot with the correlation line between implicit self-theory (lower scores indicate more of an entity theory) and robot anxiety. Confidence bands indicate 95% confidence intervals (CIs)

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 regards 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.

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, ($\beta = -0.33, SE = 0.16, t = -2.03, p = .043$) were 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 1 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 dependant 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 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 Fig.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

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

		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

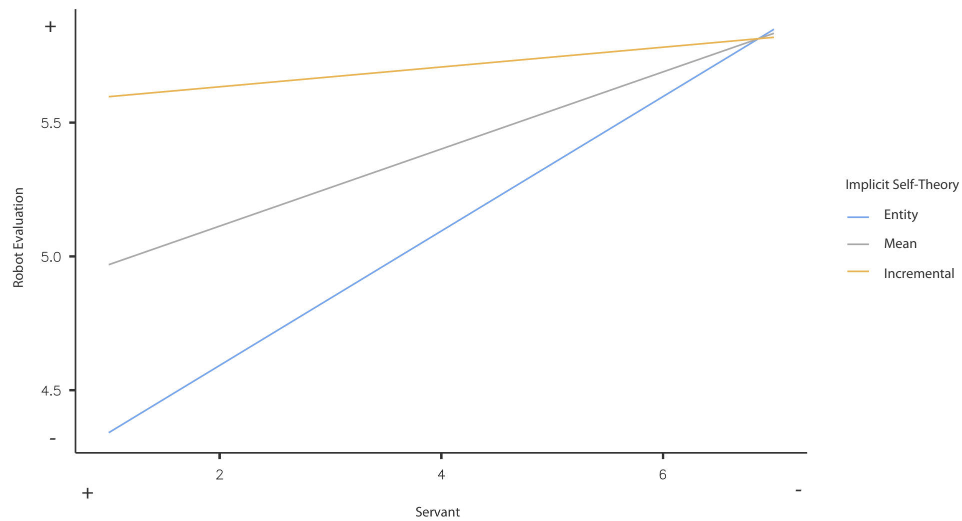

Fig. 2 Linear regression lines depicting a significant interaction between implicit self-theory and robot-as-servant role in predicting robot evaluation

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 ones 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 [49] and use [140] more broadly, and greater endorsement of radical technological innovations [61] 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. [64] and lends partial support for Hypothesis 4, which stated, in part, that incremental theorists, relative to entity 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 [22,43,71,98,124].

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 [16,50,69]). 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 [65,121]), there would almost certainly have been some variability in the way participants imagined robot embodiment and appearance [132], 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 [55]), 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 [88], culture [7,11,65], mind perception [58], personality traits [134] anthropomorphism [31] and occupation [52]. 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., [35,73,90,152]). 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 [99]. 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 [112,152]). 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 [18].

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 [8,13,77] of equal or greater quality than student subject pools [82] there is a small but growing body of research that has documented potential issues with using these samples [19] such as those noted earlier. In particular, Mturk samples are shown to be more technologically-savvy (see [102]), and more well-educated (see [6]), 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 [121]. 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 [52]. 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 [87,91,135].

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., [125,128,129]). In such instances, it is entirely possible that future research may find that entity theorists' who focus on outcome [89], and are less tolerant of transgressions [67], will lose trust in a robot that displays such errors [113]. Comparatively, incremental theorists who focus on learning goals [99], and value effort processes [89] over flawless performance [33] 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., [130]) and by assessing implicit self-theory and trust evaluations (e.g., [68]).

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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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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