Psychological Importance of Human Agency

How self-assembly affects user experience of robots

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***Abstract*—Does assembling one's robot enhance the quality of our interaction with it? And, does it matter whether the robot is a utilitarian tool or a socially interactive entity? We examined these questions with a 2 (Assembler: Self vs. Others) x 2 (Expectation Setting/Framing: Task-oriented robot vs. Interaction-oriented robot) between-subjects experiment (*N* = 80), in which participants interacted with a humanoid desktop robot (KT-Gladiator 19). Results showed that participants tended to have more positive evaluations of both the robot and the interaction process when they set it up themselves, an effect that is positively mediated by a sense of ownership and a sense of accomplishment, and negatively mediated by perceived process costs of setting up the robot. They also tended to evaluate the robot and the interaction more positively when they expected it to be task-oriented rather than interaction-oriented. Implications for theory and design of robots are discussed.**

Keywords—self-assembly; expectation setting; social robotics

I. Introduction

Studies in consumer psychology have found that when individuals construct products themselves, they tend to overvalue their (often mediocre) creations. This phenomenon is called the "IKEA effect, in honor of the wildly successful Swedish manufacturer whose products typically arrive with some assembly required" [1]. It has to do with the concept of self-agency. When "self" becomes the source of action, or initiator, individuals will have a richer sense of agency and thus lead to a more positive perception of what they create [2]. Conceptually, sense of agency has been defined "as the state of being in action or of exerting power" [3]. Several studies in human-computer interaction have demonstrated that expression of agency via customization tools on the interface has powerful psychological appeal among users, including more positive attitudes toward the technology [4], a heightened sense of control and identity[5], greater user engagement [6] and product attachment [7].

The study aims to discover whether the process of setting up a robot will generate a sense of agency, and what psychological effects this may have on users' evaluation of robots.

Furthermore, it attempts to determine if the self-assembly effects are more pronounced for social robots compared to utilitarian robots. The ascribed role of a robot may have expectation effects, just like how the physical appearance of a robot must match its intended purpose of use to fit human expectation [8].

In addition to helping market the robot in specific ways, allowing users to assemble their own robots may influence users' expectations as well as their perceptions of the interaction. Previous studies have mainly examined human-robot interaction by asking study participants to spend time interacting with robots that are already set up for them(e.g. [9]). However, in the context of a consumer robotics, this is seldom the case. Robots are not automatically set up for users. In fact, many robots in the marketplace require consumers to finish the initial set up on their own, away from engineers and technicians, and figure out how to use software to program it by themselves. This process calls for time and labor, and users have to experience the process of setting them up, and endure the trial and error that accompany it. In other words, in real life, users' interactions with robots may start well before the stage that has been typically examined in experiments reported in the HRI literature.

In the following section, previous literature is reviewed to introduce the theoretical background and research hypotheses for study. Three areas of research are reviewed—socially interactive robots, sense of agency and expectation setting in the context of human-robot interaction. An experimental study of their psychological effects is presented next, followed by interpretation of the findings, implications for theory and design, limitations and directions for future research.

II. Literature Review

A. Effects of Self-Assembly

Aside from the stated purpose of assembling the equipment, users' own involvement in the "creation" of the robot may have a significant psychological role to play, especially in terms of imbuing a sense of agency among robot users. The concept of agency is multi-dimensional(e.g. [10],[11]), and is central to the issue of "volitional or intentional force" that drives the actions of an entity [3]. Taking the cue from the agency model of customization, sense of agency subsumes the overall feeling of identity and control in an interface that allows a user to act as a source of information and action [2].

Research by [1] has found that when individuals purchase furniture at IKEA, and assemble the furniture by themselves, they report a high degree of satisfaction with their IKEA furniture. Similarly, [12] proposed the "I designed it myself" effect: Individuals tend to perceive a higher value of a self-designed object, purely because s/he has the sense of being the originator of it. In the human-robot interaction context, at least one empirical study has found that individuals who assembled the robot themselves evaluated the robot more positively and showed more self-extension into the robot [13]. Yet, the theoretical mechanisms underlying such positive effects are unclear. Therefore, we propose several mediators: Sense of Ownership, Sense of Achievement and Perceived Process Costs, which were suggested by literature, to further examine the relationship between setting up a robot and individuals' reactions and evaluations of robots.

1) Sense of Ownership

Research on endowment effects suggests that when an object is held in one's endowment, one is more likely to value the object more and consider it as having higher value [14], [15], [16]. Rather than legal ownership, the endowment effect is derived from subjective feelings of owning an object [17]. Simply buying assembled furniture might lead to a much lower degree of subjective feelings of ownership than assembling it oneself [18]. As socially interactive robots become increasingly common in the marketplace and mass manufactured, individuals who purchase robots have to set them up according to the user manual and customize its functionality and aesthetics based on personal preferences. Based on the literature on endowment effects, it can be inferred that these activities—the process of assembling the robot and customizing its settings—can lead to an increased sense of endowment or ownership, compared to purchasing an already full assembled robot.

2) Sense of Accomplishment

One of the reasons for the IKEA effect may be the sense of accomplishment that arises from the process of successfully creating something by oneself [1]. Reference [19] explains, "[W]e invest 'psychic energy' in an object to which we have directed our efforts, time, and attention. This energy and its products are regarded as a part of self because they have grown or emerged from the self". Thus, our sense of accomplishment is a direct outcome of the sense of self-agency felt in the process. It is human nature to have an inherent need for feeling competent. The proud feeling of accomplishment arising from an activity serves to fulfill this need [20] [21]. We can therefore propose that setting up a robot will elicit a sense of accomplishment among users, which in turn may lead to a more positive evaluation of the robot.

3）Perceived Process Costs

In the process of accomplishing a task, individuals have different beliefs about their capabilities to produce designated levels of performance [22]. "Individuals with high assurance in their capabilities approach difficult tasks as challenges to be mastered rather than as threats to be avoided, and attribute failure to insufficient effort or deficient knowledge and skills which are acquirable. In contrast, individuals who doubt their capabilities shy away from difficult tasks which they view as personal threats" [22].

One study found that perceived task difficulty and need for achievement were positively related to goal level, which in turn predicted performance [23]. Reference [1] also pointed out that the IKEA effect has its limits, and noted that "when participants failed to complete an effortful task, the IKEA effect dissipated". They proposed that the tasks should be difficult enough to "lead to higher valuation but not so difficult that customers can't complete them". For individuals who perceive that they have insufficient capability, and the process of setting up costs them too much to figure out how to set up the robot, the effects of self-assembly may be negative rather than positive. Thus, the realization of positive benefits of self-assembly lies in the construal of process costs of the set-up.

B. *Expectation-Setting Effects*

Expectations play an important role in forming impressions and guiding evaluations of products, services, as well as other individuals. Previous studies suggest that individuals' judgment will be affected by their expectations of others' reactions [24]. Service satisfaction research shows that the degree to which a service meets individuals' expectations is a primary determinant of their satisfaction with the service [25]. Consumer expectations of a product also vary according to how the products are described to them. For example, studies have found that product evaluations vary based on which attribute of the product is made salient in advertisements [26].

In human-robot interaction studies, expectation-setting effects have been examined to understand robot users' impression formation. One previous study found that individuals' evaluations of the robot's capabilities are affected by a common expectation-setting strategy: setting lower expectation led to less disappointment and more positive feedback [9]. This study explores a novel expectation-setting strategy, by introducing a robot with different purposes of use, namely as a task-oriented vs. an interaction-oriented robot. Task-oriented robots are designed for performing specific tasks in a defined everyday environment and thereby provide useful service [27]. Efficiency and productivity are the most important traits of task-oriented robots. Interaction-oriented robots, on the other hand, are designed primarily for interaction purposes, for entertainment or fun. As most people do not have much experience with robots, robots may present an ambiguous situation or uncertainty [28], where individuals tend to make judgments based on "heuristics" or mental shortcuts [29]. Individuals may have different expectations and judge the capabilities of the robot according to the stated purpose of use of the robot. Therefore, setting users' expectations about the intended function of the robot can play an important role in framing their interaction with it and their subsequent evaluations of the robot. Whether such framing moderates the expected effects of self-assembly is an open question, but testing for it has the added advantage of potentially extending the external validity of the study.

III. Hypotheses and Theoretical Model

A. *Hypothesis*

H1: Individuals will have more positive evaluations of the robot (**H1a**) and interaction process **(H1b)** when they set up the robot by themselves than when others set up the robot.

H2-H4: The sense of ownership (H2), sense of accomplishment (H4) and perceived process costs (H6) will mediate the effects of assembler on robot evaluations.

H5-H7: The sense of ownership (H3), sense of accomplishment (H5) and perceived process costs (H7) will mediate the effects of assembler on interaction evaluations.

B. *Theoretical Model*

The hypotheses can be visually illustrated as follows:

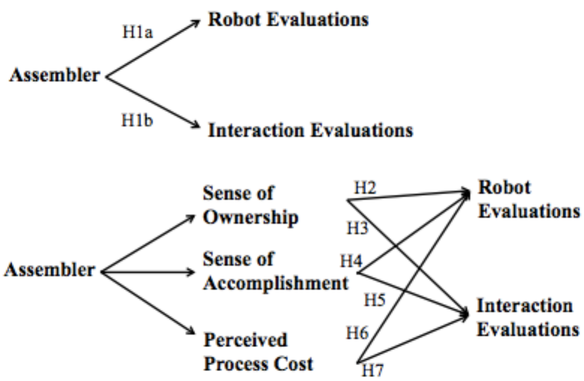

Fig. 1. Hypothesized Relationships

IV. METHOD

A. *Research Design*

In order to test the proposed hypotheses, a 2 (Expectation Setting: Interaction-oriented Robot vs. Task-oriented Robot) × 2 (Assembler: Self vs. Other) fully-crossed factorial between-subjects experiment was conducted. A tabletop humanoid robot called Gladiator, manufactured by Kumotek Robotics (see Fig. 2), was used in this study.

B. *Participants*

A total of 80 undergraduate students at a major university participated in the study in exchange for extra course credit. All of them signed an informed consent form before participating in the experiment, and were randomly assigned to one of the four conditions. Participants ranged in age from 18 to 28 years (M = 20.22, SD = 1.31), with two of them describing themselves as having prior experience interacting with task-oriented robots and one of them having experience with interaction-oriented robots.

C. *Procedure*

1) Expectation Setting

Expectation-setting was manipulated by the manner in which the robot was introduced to the study participants, as either an interaction-oriented (social) or a task-oriented (utilitarian) robot. Participants in the condition involving task-oriented condition were informed that, “This robot is designed to offer simple services to people, such as greeting visitors in the museums or restaurants.” Participants in the condition involving interaction-oriented condition were informed that, “This robot is designed for entertainment purposes, such as dancing performance”. Similar to [9], to ensure that participants would not forget this, a sign with the purpose of use of the robot was left in the room during the participant’s interaction with it.

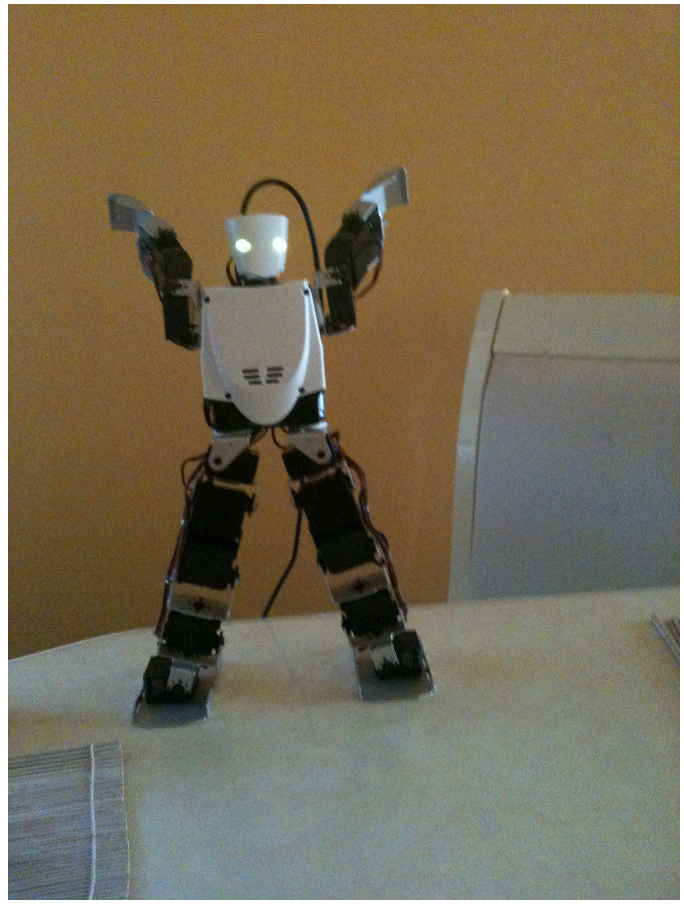

Fig. 2. Kumotek KT-X Gladiator Robot (Tabletop Humanoid)

2) Assembly

In Self-Assembling condition, to assemble the robot, participants were asked to first insert the battery into the robot, and connect the USB cable to the port on the central processing unit (CPU) board behind the robot’s neck and the computer’s USB port. The next step was setting up the robot using “RobovieMaker" programming software that came with the KT-Gladiator 19 robot. A user guide with clear instructions and screen captures was provided by the experimenter. Pretests showed that the user guide was easy to understand and follow for those lacking previous experience with robots. After the participants completed setting up the robot, to test the settings, they were told to make the robot perform two movements, which were predefined commands: Greeting and Dance. After setting up the robot, the participants had 5 to10 minutes to interact with it.

In Other-Assembling condition, the experimenter went through the set-up process by following the instructions on the same user guide. The whole process was completed in front of the participants. After that, the experimenter showed the same two movements of the robot, Greeting and Dance, to the participants, followed by a 5 to 10-minute interaction period between the participants and the robot.

The average time for setting up was 20 minutes and 7 minutes for interaction. After the participants finished the interaction with the robot, they were asked to fill out an online questionnaire with 26 questions.

E. Measures for Mediators

1) Sense of Ownership

Sense of ownership was measured with three items - "I feel like this is my robot," "I feel a very high degree of personal ownership of the robot," "I feel like I own this robot"- each on a 7-point scale from "Strongly Disagree" to "Strongly Agree". These items were adapted from a measure of psychological ownership used in workplace settings [30]. It had high reliability (Cronbach's $\alpha = .90$).

2） Sense of Accomplishment

The sense of accomplishment was measured via three items (adapted from [31]): "When I look at the robot, (1) the feeling I have can best be described is the word 'pride' "; (2) I feel proud of having accomplished something"; (3) "I feel proud because I did a good job" (Cronbach's $\alpha = .85$).

3) Perceived Process Costs

Three items for perceived process costs were adapted from [32]. The items were "The process of setting up robot was … " (1) "exhausting" and (2) "time-consuming" (3) "too difficult for me". All items were measured on 7-point scales, where 1 = strongly disagree and 7 = strongly agree (Cronbach's $\alpha = .84$).

F. Measures for Dependent Variables

1) Robot Evaluations

The measurement of robot evaluations was adapted from [33]. Items of how much the participants liked and felt close to the robot, and believed that the robot could perform other movements/task were asked. All the statements were rated on a 1 to 7 likert-scale, ranging from "Strongly Disagree" to "Strongly Agree" (Cronbach's $\alpha = .79$).

2) Interaction Evaluations

To test the evaluations of the interaction process with the robot, three items were used: "The experience of interacting with the robot was fun", "Given more time, I want to play for a longer time with the robot", and "I enjoyed the time I spent interacting with the robot." The statements were rated on a 1 to 7 likert-scale, ranging from "Strongly Disagree" to "Strongly Agree" (Cronbach's $\alpha = .94$).

V. RESULTS

A. Manipulation Check

To assess whether the manipulation of expectation setting was successful, a single item that "This robot is designed for what purpose" with choice "A. Interacting with people for entertainment and B. Providing simple services to people" was asked. Results showed that 86.42% of the participants successfully identified the robot type in their assigned expectation setting conditions. Specifically, 89.19% of the participants in the task-oriented robot condition successfully identified the robot type compared to 84.09% in the interaction-oriented robot condition.

B. Effects of Manipulations

A series of 2 (Expectation-Setting) X 2 (Assembler) analyses of variance (ANOVA) were conducted for the dependent variables (robot evaluation, interaction evaluation, perceived humanness, perceived process costs, sense of ownership, and sense of accomplishment) separately.

The ANOVA test revealed a main effect for assembler on interaction evaluation that approached significance, $F(1, 76) = 3.24$, $p = .08$, where individuals reported better evaluations of the interaction process when they set up the robot by themselves ($M = 4.64$, $SE = .25$) than when the experimenter set it up for them ($M = 3.99$, $SE = .26$), providing tentative support for H1b. No significant main effect for assembler was found on robot evaluation, thus failing to support H1a.

Another ANOVA revealed a significant main effect for assembler on sense of ownership. Participants reported higher degree of sense of ownership ($M = 2.40$, $SE = .16$) in self-assembling condition than in other-assembling condition ($M = 1.81$, $SE = .16$), $F(1, 76) = 6.85$, $p < .05$. Similarly, ANOVA analysis for sense of accomplishment revealed a significant main effect for assembler as well. Participants felt higher sense of accomplishment ($M = 3.13$, $SE = .19$) in self-assembling condition than in other-assembling condition ($M = 2.57$, $SE = .18$), $F(1, 76) = 4.40$, $p < .05$. A significant main effect for assembler was also found for perceived process costs, where individuals perceived significantly higher process costs ($M = 4.22$, $SE = .22$) when they set up the robot by themselves than when the experimenter set up the robot ($M = 2.99$, $SE = .21$), $F(1, 76) = 15.73$, $p <. 001$.

Additionally, the analyses revealed a significant main effect of expectation setting on sense of accomplishment. Individuals reported higher sense of accomplishment when the robot was task-oriented ($M = 3.22$, $SE = .19$) than interaction-oriented ($M = 2.48$, $SE = .19$), $F(1, 76) = 7.70$, $p <. 05$. The results also indicated that individuals had better evaluation of the robot when they expected the robot to be task-oriented ($M = 4.27$, $SE = .18$) rather than interaction-oriented ($M = 3.70$, $SE = .19$), $F(1, 76) = 4.62$, $p <. 05$. A nearly significant main effect for expectation setting was also found on interaction evaluation, with participants reporting better evaluation of interaction process when they expected the robot to be task oriented ($M = 4.66$, $SE = .25$) than interaction-oriented ($M = 3.97$, $SE = .26$), $F(1, 76) = 3.69$, $p = .06$.

Two multiple regressions were conducted separately (one each for robot evaluation and interaction evaluation as the dependent variable), with perceived humanness, perceived process cost, sense of ownership, and sense of accomplishment as independent variables. Table 1 and Table 2 report the statistics associated with the analyses.

Table 1. *Multiple Regression on Robot Evaluations*

Predictors of Robot Evaluations	
	β^1
Perceived Process Costs	-0.20*
Sense of Ownership	0.24*
Sense of Accomplishment	0.33**

$F(4, 75) = 20.76$, Adjusted $R^2 = .50$, $p < .001$.[1] *$p < .05$; **$p < .01$.

Table 2. *Multiple Regression on Interaction Evaluations*

Predictors of Interaction Evaluations	
	β^1
Perceived Process Costs	-0.31
Sense of Ownership	0.15
Sense of Accomplishment	0.20*

F (4, 75) = 11.55, Adjusted R^2 = .35, $p < .001$.[1] $^*p < .05$.

To explore whether perceived process cost, sense of ownership and sense of accomplishment mediated the effects of assembler on robot evaluations and interaction evaluations, i.e., to test hypotheses H2 through H7, we used indirect-effects estimation based on the product-of-coefficients methods [34] using 5000 bootstrap samples.

First, assembler was entered as the predictor variable (with expectation-setting as covariate), and perceived process cost, sense of ownership and sense of accomplishment as mediators, and robot evaluation as the dependent variable. The SPSS macro used in this analysis was the bootstrap analyses with multiple mediators created by Preacher and Hayes (2008). An examination of the specific indirect effects indicates that the indirect effect through sense of ownership was significantly higher than zero (*b* = .21, 95% CI from .05 to .46), and the indirect effect through sense of accomplishment (*b* = .20, 95% CI from .03 to .50) was significantly positive as well, which supported H2 and H4 respectively**.** The indirect effect through perceived process costs was also significant (*b* = -.16, 95% CI from -.38 to -.01). Therefore, H6 was supported. Figure 3 shows the coefficients for total, direct and specific effects (the indirect effects of assembler on robot evaluaions can be computed by multiplying the path coefficients between the assembler and a given mediator and that between the mediator and robot evaluations; for example, .59 x .35 provides an estimate of the indirect effect via sense of ownership. The product .21 is the indirect effect reported earlier in this paragraph as *b.* The total effect of Assembler on Robot Evaluation is the sum total of the indirect effects (the three *b*'s due to the three mediators) and the direct effect, which is provided in parentheses on the path at the top of the figure. The sum of all three indirect effects is .25, which when added to the direct effect of -.30 provides the total effect of -.05; all these numbers are subject to a minor round-off error).

Fig**. 3.** *Indirect effects of Assembler on Robot Evaluations.* Numbers on the arrows are unstandardized coefficients for each regression. The coefficient in parentheses reflects the direct path after the intervening variables are included in the analysis. Assembler was coded as Self-assembly =1; Other-assembly = 0. * $p < .05$; ** $p < .01$; *** $p < .001$.

In the next step, expectation setting was included as the predictor variable (with assembler as covariate). The bootstrap analyses revealed that the sense of accomplishment is the mediator, since the indirect effect through sense of accomplishment (*b* = .27, 95% CI from .06 to .60) was significant, whereas the indirect effect through sense of ownership (*b* = .12, 95% CI from -.004 to .33), and perceived process costs (*b* = .002, 95% CI from -.08 to .09) were not significant because their 95% CIs contained zero. Figure 4 shows the coefficients for total, direct and specific effects.

Fig**. 4.** *Indirect effects of Expectation Setting on Robot Evaluations.* Numbers on the arrows are unstandardized coefficients for each regression. The coefficient in parentheses reflects the direct path after the intervening variables are included in the analysis. Expectation Setting was coded as Task-oriented robot =1; Interaction-oriented robot =0. * $p < .05$; ** $p < .01$; *** $p < .001$.

The next analyses examined interaction evaluations as the dependent variable**.** When assembler was entered as the predictor variable (with expectation setting as covariate), and perceived process costs, sense of ownership and sense of accomplishment as mediators, results showed that the indirect effects through sense of ownership (b = .23, 95% CI from .02 to .61), sense of accomplishment (b = .21, 95% CI from .03 to .57) and perceived process costs (*b* = -.30, 95% CI from -.68 to -.04) were all significant, thus supporting H3, H5 and H7. When expectation setting was entered as the predictor variable (and assembler as covariate) with all three potential mediators, results indicated that only the indirect effect through sense of accomplishment (*b* = .27, 95% CI from .05 to .70) was significant**.**

VI. DISCUSSION

Overall, the results revealed several significant effects of self-assembly. The sense of agency, which was achieved by asking participants to serve as assemblers, showed significant effects on individuals' sense of ownership, sense of accomplishment and perceived process costs. Specifically, by setting up the robot themselves, participants perceived higher degrees of ownership, accomplishment and process costs, all three of which were associated with their evaluations of the robot and the interaction process. Indirect-effect analyses revealed that sense of ownership, sense of accomplishment, and perceived process costs mediated the effect of assembler on robot and interaction evaluations. In addition, individuals felt a higher sense of accomplishment and tended to provide better evaluations of the robot and interaction process when they expected the robot to be task-oriented rather than interaction-oriented.

A. Theoretical Implications

The results of the study clearly demonstrated that robot users hold higher sense of self-agency when they set up a robot by themselves, which generated more positive evaluations to the robot and the interaction process. As with self-assembling furniture and self-designing products, building a robot also seem to have generated a positive "I designed it myself" effect. The perceived sense of ownership is a significant determinant, which in the absence of actual or legal ownership, could lead to an increase in valuation of the robot. By setting up a robot and familiarizing oneself with the robots' inner workings rather than simply interacting with a pre-assembled robot, individuals indeed get the feeling that the robot is "mine," thereby cueing the "own-ness heuristic" [35] (that which I own is good),, and leading to positive consequences for evaluations of the quality of the robot as well as its interaction with users.

Feelings of accomplishment also mediated the effects of assembler on robot evaluations. Individuals who assembled the robot themselves felt higher degree of accomplishment than those who interacted with the robot assembled by the experimenter. This may indicate an involvement of one's self-esteem in the performance of a task or in an object, which is known as "ego-involvement" effect [36], with positive consequences for consumer satisfaction (e.g.[37]). Specifically, ego-involvement refers to "the evaluations of an ability that is valuable and makes success highly important" and "has enhancing effects on motivation and performance" [38]. Harackiewicz and Manderlink [39] indicated that ego-involvement was associated with task enjoyment when the task was competence-related. Thus, after accomplishing the task of assembling the robot, individuals will likely have an ego-involvement effect that makes them feel better about themselves, thus translating into greater investment on the part of the user and stronger overall user experience.

Perceived process costs, on the other hand, showed negative effects on robot and interaction evaluations. When individuals felt that they put too much time and effort into the assembly, and the tasks were seen as too difficult for them to accomplish, they were less likely to hold positive evaluations. The perceived process costs significantly negatively impacted the sense of agency, as it mediated the decrease in the liking of the robot and user enjoyment of the interaction process. This may be because the perceived effort and task difficulty challenged the performer's self. As Brehm's motivational intensity theory [40] suggests, a person's effort may stop rising when subjective difficulty exceeds his/her abilities. Therefore, user engagement may rise with moderate task difficulty and effort costs until the task is perceived as too difficult to accomplish or does not merit the necessary effort. Since most of the individuals have no prior experience with setting up or interacting with a robot, setting up the robot correctly without help from a professional technician may exceed their self-efficacy for the task. Such results also provide insights for the I-designed-it-myself effect and the IKEA effect—perceived effort and task difficulty could result in negative evaluations of a self-designed or self-assembled product. Our findings suggest that this effect is not simply due to a mental calculation of costs vs. benefits, but due to the undermining of users' sense of agency when process costs are high.

Together, the three mediators lend support to the agency model of customization [2], which argues that technological affordances related to modifiability and tailoring can imbue in users a sense of self as source, which engenders (a) higher involvement in, (b) stronger identity with, and (c) greater control over the technology. Sense of accomplishment speaks to the involvement aspect whereas sense of ownership speaks to the identity aspect of this model. The strong negative effects noted for perceived process costs are probably reflective of the stronger need for control engendered by the self-assembling activity. In this way, our study demonstrates both the positive outcomes as well as the negative reactance that is likely from self-assembly.

Although a previous study [13] has also examined the relationship between self-assembly and self-extension (which refers to the tendency of feeling that the object is part of oneself and having similar traits as oneself), the present study serves to explicate the theoretical explanations for the results: the sense of agency, manifesting itself as a sense of ownership, and sense of accomplishment while being undermined by perceived process costs, constitutes the psychological mechanism underlying the consequences of self-assembly and the tendency for perceived self-extension. The feelings of owning the robot and successfully contributing effort to the assembling process are key reasons behind why self-assemblers would feel better about themselves and perceive the robot as part of them, leading to higher likelihood of extending their own feelings and personalities to the robot.

The sense of agency derived from self-assembly is so strong that the intended purpose or function of the robot does not seem to affect its outcomes, even though our data showed that individuals' differential expectations of robots could influence their perceptions of the robot as well as the interaction experience with the robot. Setting expectations of the robot's role as task-oriented generated more positive feelings of the robot: individuals considered the robot as more favorable and enjoyed their experience with the robot more when they expected the robot to perform a task rather than simply entertain them. These results indicate that individuals might hold different expectations for robots with different purpose of use, which in turn, result in different attitudinal and behavioral reactions to robots, regardless of their actual performance. Specifically, as indicated earlier, participants who were informed that the robot was task-oriented may expect the robot to be more functional and simple, and thus have low expectations of the robot's capability—which were probably positively disconfirmed when the two pre-programmed performances (of greeting people and dancing) showed interactive features of the robot such as talking and bowing to people. According to expectancy disconfirmation model [25], such disconfirmation of expectations has the most immediate influence on satisfaction.

B. Practical Implications

The study tried uncover the mediators that explain the positive effects of self-assembly. Future robot design and marketing can effectively target these mediators in order to imbue greater agency among users, especially in the current climate of "robot fear." The findings provide an alternative to the direct and complete help for setting up a robot provided by some services (e.g., robotsetup.com); a moderate level of self-assembly of a robot could be a good start to human interaction with that robot. Therefore, instead of simply providing a fully-assembled robot, or setting up a robot for the users, letting the robot users set up and customize the robot by themselves will likely generate higher satisfaction of the robot products. However, before introducing a self-assembling robot product into the marketplace, a test of task-difficulty of setting up the robot should be conducted in order to avoid the negative effects of perceived process costs.

Moreover, the study findings also suggest marketing strategies for robot product retailers: letting the customers experience the set-up process before they decide to buy the robot may be more effective than simply providing technical descriptions of the robot. The assembly does not have to be elaborate. Indeed, they should not be because they may risk heightening user perception of process costs. A few simple final steps in assembling the robot can imbue agency among users. The bulk of the robot assembly could be done by the manufacturer, leaving a few superficial parts for the user to assemble—perhaps aspects that are customizable for individual user, to make it their own. This activity, by itself, can imbue agency among users and lead to positive robot evaluations, as long as the assembly is not onerous.

In general, a major design implication of our findings is that robots should be customizable by individual users, and the customization options should go beyond the assembly stage of the human-robot relationship. While self-assembly can provide an initial sense of accomplishment, the sense of ownership discovered in this study can be sustained with tailoring options that users can continue to tinker with, long after the initial set-up. This will likely contribute to an evolving relationship, whereby the robot can be continually fine-tuned to meet the user's changing needs and preferences.

C. Limitations and Future Research

There are several limitations to this study. The use of college students limits the external validity of our findings, as some of the results may not be generalized to other populations from other backgrounds.

Another limitation of the study is that the participants spent only a short period of time with the robot, so the long-term effects are unknown. Meanwhile, besides the measures used in this study, open-ended questions recording the thoughts of participants may provide qualitative information helping us with a richer understanding of the interaction process. Also, other types of robots with different purposes or tasks and different types and levels of self-assembly could be examined in future studies in an effort to generalize the effects of self-assembly and expectation setting.

Future research may benefit from a follow-up experiment that examines the affective responses generated during the interaction process. Specifically, whether the process costs caused frustration or impatience in participants could be among the affective responses to be examined for future research.

As robots become more common and used in a variety of contexts by a diverse range of users with an equally diverse set of goals, they are likely to involve a considerable degree of customizability. But, this affordance can be a double-edged sword in that it can lead to positive outcomes as well as frustration (if the process of customization is overly demanding or tedious). If designed carefully, self-assembled robots are likely to be a source of pride and pleasure for their owners. Future research can ascertain the extent to which these effects stand the test of time and contribute to satisfying human-robot relationships in the long term.

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