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I Am My Robot: The Impact of Robot-building and Robot Form on Operators

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ABSTRACT

As robots become more pervasive, operators will develop richer relationships with them. In a 2 (robot form: humanoid vs. car) x 2 (assembler: self vs. other) between-participants experiment (N=56), participants assembled either a humanoid or car robot. Participants then used, in the context of a game, either the robot they built or a different robot. Participants showed greater extension of their self-concept into the car robot and preferred the personality of the car robot over the humanoid robot. People showed greater self extension into a robot and preferred the personality of the robot they assembled over a robot they believed to be assembled by another. Implications for the theory and design of robots and human-robot interaction are discussed.

Categories and Subject Descriptors
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

General Terms
Design, Experimentation, Human Factors, Theory.

Keywords
Human-robot interaction, robots, robot form, anthropomorphism, humanoid robots, self, self extension, robot personality

1. INTRODUCTION
Human-robot interaction research is in a prime position to address age-old philosophical questions of the “self.” The Computers as Social Actors (CASA) paradigm [16][17] suggests that people respond to robots as social actors, entities with their own identities that are separate from a person’s sense of self. When interacting with autonomous robots or robots tele-operated by another person, people respond in much the same way they respond to other people (for a review, see [7]). In contrast, tele-operation and other immersive interactions through robots enable interactions between humans and robots that, in the moment of using the robot, may make people feel like the robot is part of one’s self. These extensions of one’s sense of self into robots are of primary interest to the current investigation.

A person is particularly likely to extend one’s sense of self into objects that one controls, creates, or personalizes [2]. As such, we posit that creating artificial life alters the ways that people feel toward the robots they build. This is comparable to the ways that people feel differently toward their own creations as opposed to the creations of others. However, because robots are typically somewhat autonomous agents, they introduce a new set of considerations for how people come to engage with robots as though they were a part of themselves vs. independent social actors. When it comes to designing for human-robot interaction, one must be informed by how people will perceive and interact with robots that are designed merely to be tools as opposed to robots that are designed to be agentic beings.

The current study explores two important aspects of human-robot interaction that influence the degree to which a person will extend one’s sense of self into a robot: whether or not the person built the robot and whether the robot takes on a more or less anthropomorphic form. This work is situated within larger research issues of self extension and robot form, which are discussed in the following section.

2. RELATED WORK

2.1 Self Extension
Objects can be extensions of the self. Self-extended objects differ from valued objects or objects people are attached to in that the former represent and maintain the sense of self [2].

In Kiesler and Kiesler’s study of self extension [13], people who decorated a rock for themselves rather than for sale characterized the rock as having a personality more similar to their own. However, in a particularly important finding of this work, the researchers found that participants who decorated their rock with a face were less likely to extend their sense of self to the object. That is, people may perceive humanlike physical attributes as indicators of a unique identity, thereby making people less likely to view humanoid objects as extensions of the self.

Self extension also affects people’s attitudes and behaviors with regards to an object. Related literature on avatars shows that avatars that are chosen by the player, as opposed to being assigned to the player, increase the player’s emotional responses to the avatars [15]. People feel a unique claim to self-extended objects, and feel personally threatened when the objects are copied or destroyed [3]. People who experience the theft or destruction of self-extended objects may mourn for the objects in much the same way they grieve for the loss of loved ones, entities also closely associated with the sense of self [18]. Thus, robots may be responded to as an extension of oneself.

Conversely, robots may also be viewed as autonomous social actors, as reflected in the CASA paradigm [16][17]. This paper addresses two factors—robot form and operators' experiences building a robot—that might determine whether people respond to robots as extensions of one's self or as separate social entities.

2.2 Robot Form

Robots generally take on one of four aesthetic forms: anthropomorphic (human-like appearance), zoomorphic (animal-like appearance), caricatured (exaggerated traits), or functional (form follows function) [7]. When interacting with robots of all forms, people demonstrate many social responses. For example, people use human-specific language for all types of robots (e.g., automatic doors [12]). However, these linguistic responses do not necessarily carry over into more abstract judgments about robots [8].

The degree of anthropomorphism in robotic form affects how people interact with robots. Experimental research has demonstrated that more anthropomorphic robots are praised more and punished less in collaborative human-robot team interactions [1]. More anthropomorphic forms of robots also increase feelings of utility and being understood [2]. Anthropomorphic forms of robots are perceived to be more sympathetic, friendly, and intelligent than functional robots [11]. A recent functional magnetic resonance imaging (fMRI) study that measured activation in the regions of the brain dedicated to modeling the minds of others demonstrated that brain activity increases with increased anthropomorphism. This suggests that people are more likely to perceive desires and intentions in anthropomorphic robots [14]. It also suggests that more anthropomorphic forms of robots are more likely to elicit a perception of the robot as having its own identity rather than as an extension of self. In some cases, matching anthropomorphism to the robot's task, making more social robots more humanlike in appearance, can improve the interaction [10].

Of particular relevance to the current study is how the degree of robot anthropomorphism influences the relationship between humans and robots. Findings from previous work suggest that more anthropomorphic forms of robots facilitate stronger social bonds between people and robots [6]. This is why anthropomorphism is sometimes promoted as an effective way of designing robots that interact with people [5].

3. STUDY DESIGN

We used a 2 (robot form: humanoid vs. car) x 2 (assembler: self vs. other) between-participants experiment design. All participants assembled and operated a robot. The robot they assembled and operated had either a humanoid or car form. Participants were told either that they would operate the robot they assembled or a physically identical but different robot assembled by someone else.

We were interested in determining how robot form influenced self extension. Because Kiesler and Kiesler [13] found that humanlike physical indicators minimized self extension into an object, we believed that humanoid form would indicate a unique identity to participants and anticipated that self extension would be lower for humanoid robot participants. We were also interested in participants' attitudes towards the robot and were particularly interested in how people felt about the robot's personality, because this would indicate how much they liked the robot. While research suggests that people who *encounter* robots prefer anthropomorphic forms, we anticipated that for people who *operate* robots, the increased self extension into the car robot would promote an extension of positive self-concept. Likewise, perceptions of the humanoid as an independent identity would produce distrust and disliking of the robot.

Because much of an operator's time spent interacting with a robot is dedicated to tasks other than operating it, such as transporting and repairing it [4], we were interested in learning more about how these experience affected self extension into robots, as well as attitudes towards robots. People are more likely to self-extend into objects they create [2], so we anticipated that people would self-extend more into robots they assemble and prefer the personalities of robots they assemble.

This analysis led to four research hypotheses:

H1. People will self-extend more into the car robot than the humanoid.

H2. People will prefer the personality of the car robot over the humanoid.

H3. People will self-extend more into a robot they assemble than a robot assembled by another.

H4. People will prefer the personality of a robot they assemble over a robot assembled by another.

3.1 Participants

Fifty-six undergraduate students participated in the study. Gender was balanced across conditions (28 male and 28 female). Participants were given course credit or a $15 gift certificate.

3.2 Materials

We used Lego® Mindstorms® NXT because participants could assemble much of the robot in a limited period of time with relative ease. For the assembly portion of the study, the pre-programmed motor, wires, and the array of components were laid out, including some partially assembled components. Component size and number were similar for the humanoid and car designs. Participants controlled the robot using a simple remote they attached to the robot. Pressing the button started the robot moving when the robot was stopped, and stopped it when it was moving.

A key feature of Lego® Mindstorms® NXT is that it enabled us to create humanoid and car robots that were nearly identical in size, material, and speed. This careful control of extraneous variables enabled us to manipulate only form, so that the only difference between the humanoid robot and the car robot was their form.

Participants were given a complete set of instructions to assemble the robot. The instructions included images of each component, as well as arrows and written instructions describing each step of the assembly process. All participants completed the assembly process in between six and sixteen minutes (M=9 min 49 sec, SD=3 min, 34 sec).

We created a game board that was a reinforced cardboard square measuring 0.76 meters x 0.76 meters. Around the edge of the board were colored squares, each with a point value in it. Squares were one of five different colors, with each color representing a different point value. In the center of the board was a black diamond, indicating the robot's starting point. In the area between the black diamond and border of squares, there were images of bombs. The bombs were strategically located so that in most cases, the robot could not move from the diamond to a square without touching one of the bombs (see Figure 1).

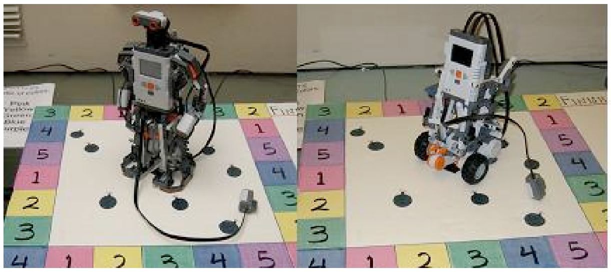

Figure 1. Experiment set-up: Humanoid and car robots

A laptop was used to control sound effects. The interface displayed a timer, a list of detonation times, a checklist that updated automatically with each detonation, and buttons to play the bell and explosion sounds. The laptop was connected to small computer speakers, which were positioned facing participants 0.9 meters way. When participants hit a square, the researcher played a bell sound. When a bomb was detonated, the researcher played an explosion sound.

All questionnaires were administered on a desktop computer using a standard questionnaire interface.

3.3 Procedure

Participants were welcomed to the lab by a researcher and given consent forms. If participants consented, they were seated at a computer and asked to complete a pre-questionnaire about their personality traits. They were then asked to move to a table that had the unassembled parts of a robot laid out before them. Participants were given a set of instructions with images that explained how to assemble the robot. They were told that the assembly portion of the study was not a test, but simply a way for them to understand how the device worked. Participants were instructed to follow the instructions and when they were finished, to turn on the robot and test it by guiding it in a straight line from a start line to a finish line two feet away. All participants were able to build the robot with minimal help from the researcher.

After participants finished assembling and testing the robot, the researcher told them they would be playing a game with the robot. The researcher explained that the goal of the game was to collect as many points as possible and described the rules of the game.

Participants started by placing the robot on the black diamond in the center of the game board and pointing it at any square they chose. They used the remote to make the robot move. When the robot touched a square, they received those points and a bell sound was played. If participants had already touched the square they would hear a bell, but would receive no points. Once the bell was played, participants stopped the robot, picked it up, placed it on the diamond, and repeated the process.

Participants were told that the bombs were pre-set to detonate after being touched a pre-determined, unspecified number of times. Participants were instructed to avoid the bombs as best they could, since each detonation would deduct 30 seconds off the ten minutes they had to complete the game. To ensure that all participants had similar experiences with detonations, detonations were actually pre-determined with a schedule. Detonation occurred the first time the participant touched a bomb after the two minute, three minute, five minute, and seven minute marks.

Because all participants detonated four bombs, participants played for a total of 8 minutes. The researcher then said the time was up and asked participants to take a seat at the computer and answer some questions about their experiences. When participants were finished, the researcher debriefed them, explaining the purpose of the study and providing contact information for any follow-up questions or concerns.

3.4 Experimental manipulations

The independent variable *form* had two levels: humanoid and car. In the humanoid condition, participants assembled a robot with parts that resembled a head, torso, two arms, and two legs. This robot moved by shuffling its "legs." The car robot was assembled from the same Legos® and was a nearly identical size. Its main body was a box shape and moved with wheels. In both conditions, the researcher referred to the robot as "the device" and made no comments regarding its form, the manipulation, or the other condition. In the questionnaire, participants were asked to indicate what the study was about, and no participants mentioned robot form.

The independent variable *assembler* had two levels: self and other. In the self-assembler condition, participants assembled the robot and then guided the robot they assembled in the game. In the other-assembler condition, after assembling the robot and before the start of the game, participants were told that all participants needed to guide the same robot in the game. The researcher then removed the participant's robot, walked behind a curtain dividing the room in two, and reemerged with a "different" robot. In fact, the researcher did not switch the robot and instead brought back the robot the participant had assembled. This aspect of the experimental design ensured that only the participant's perception of who assembled the robot was manipulated. In the questionnaire, no participants said they thought the study was about the impact of assembling a robot.

3.5 Measures

3.5.1 Self extension attitudinal measures

We measured trait overlap between participants and the robot to determine how our manipulations affected participants' extension of their self concepts into the robot. At the beginning of the study, participants completed a pre-questionnaire featuring a modified version of Wiggin's [19] personality test. Participants rated how well thirty words, such as "bigheaded" and "funny," described them. They indicated their responses on ten-point scales ranging from "Describes Very Poorly" to "Describes Very Well." When participants completed the questionnaire following the task, they rated the robot they guided through the minefield on the same thirty traits. For each participant, we calculated the absolute value of the difference between the participant's rating of themselves and the robot on each trait. These thirty scores were summed to create one trait overlap index. The index was very reliable (Cronbach's α=.86). This technique is similar to that used by Galinsky and Moskowitz [9] to determine how imagining oneself as another increased overlap in the concepts of self and other, and used by Kiesler and Kiesler [13] as a measure of self extension into an object.

Participant attachment was determined by participants' responses to a single item: "How would you feel if the device you assembled was destroyed?" They indicated their responses on a five-point scale ranging from "Awful" to "Delighted."

Robot control was an index of two items from the questionnaire: "Who was more responsible for your general performance on this task?" and "Who had more control over your general performance on this task?" Participants indicated their answers on ten-point scales ranging from "Me" to "The Device." Lower scores on this index indicated that participants attributed greater control to themselves and higher scores indicated that participants attributed greater control to the robot. The index was very reliable (α=.83).

Sense of team was determined by participants' responses to a single item on a ten-point scale ranging from "Describes Very Poorly" to "Describes Very Well." Participants were instructed to think about the device they guided through the minefield and indicate their agreement with the statement, "I felt that the robot and I were a team."

3.5.2 Robot personality measures

Robot friendliness was an index of nine items. Participants indicated how well the following words described the device they guided through the game: "cheerful," "enthusiastic," "extroverted," "happy," "helpful," "kind," "likeable," "outgoing," and "warm." Participants rated each item on a ten-point scale ranging from "Describes Very Poorly" to "Describes Very Well." The index was very reliable (α=.90).

Robot integrity was an index of five items. Participants indicated how well the words "helpful," "honest," "pretenseless," "reliable," and "trustworthy" described the device they guided through the game on ten-point scales ranging from "Describes Very Poorly" to "Describes Very Well." The index was very reliable (α=.73).

Robot malice was an index of five items. Participants indicated how well the words, "disobedient," "dishonest," "unkind," "harsh," and "incompetent" described the device they guided during the game, on five ten-point scales ranging from "Describes Very Poorly" to "Describes Very Well." The index was very reliable (α=.74).

4. RESULTS

All statistical analyses were conducted using analysis of variance (ANOVA) with robot form and assembler as independent variables.

4.1 Self extension results

As predicted by H1, there was greater overlap (smaller differences between participant traits and robot traits) for car robot participants, M=3.90, SD=0.86, than for humanoid robot participants, M=4.26, SD=0.53, $F(1, 52)$=4.04, p<.05, partial η^2=.13. As predicted by H3, self-assembly participants felt more overlap with the device they guided during the game, M=3.81, SD=0.66, than did other-assembly participants, M=4.35, SD=0.70, $F(1, 52)$ = 9.44, p<.01, partial η^2=.15.

As predicted by H3, self-assembler participants reported they would feel worse if their robot was destroyed, M=2.46, SD=0.69, than did other-assembler participants, M=3.00, SD=0.72, $F(1, 52)$=4.02, p<.01, partial η^2=.13.

Humanoid robot participants attributed greater relative control to the robot, M=3.96, SD=2.66, than car robot participants, M=2.14, SD=1.59, $F(1, 52)$=5.47, p<.05, partial η^2=.10, demonstrating support for H1. There was a near-significant main effect of assembler on robot control, $F(1, 52)$ = 1.66, p<.08, partial η^2=.06. As predicted by H3, other-assembly participants attributed greater control to the robot, M=3.59, SD=2.74, than self-assembly participants, M=2.60, SD=1.83.

Self-assembly participants felt more like they were a team with a robot, M=5.18, SD=3.28, than did other-assembly participants, M=2.96, SD=2.30, $F(1, 52)$=8.34, p<.01, partial η^2=.14, showing support for H3.

4.2 Robot personality results

As predicted by H2, a significant main effect of robot form on robot friendliness was found, $F(1, 52)$=4.25, p<.05, partial η^2=.08, with car robot participants rating the robot as being more friendly, M=2.58 SD=1.70, than did humanoid robot participants, M=2.20, SD=1.63. Consistent with H4, self-assembly participants rated the robot as friendlier, M=2.67, SD=1.65, than other-assembly participants, M=2.12, SD=1.10, $F(1, 52)$=4.23, p<.05, partial η^2=.08. The ANOVA also revealed a significant interaction $F(1, 52)$=4.90, p<.05, partial η^2=.09. Post-hoc analyses (Tukey's LSD) revealed that participants who used a car robot they assembled themselves, M=3.22, SD=1.93, rated the robot as being more friendly than participants who operated a car robot assembled by another, M=1.94, SD=1.17, a humanoid robot participants assembled themselves, M=2.11, SD=1.11, or a humanoid assembled by others, M=2.29, SD=1.04.

Consistent with H2, car robot participants rated the robot, M=7.96, SD=1.01, as having more integrity than did human robot participants, M=7.56, SD=0.81, $F(1, 52)$=4.20, p<.05, partial η^2=.08.

As predicted by H2, humanoid robot participants rated the robot, M=2.92, SD=1.28, as being more malicious than did car robot participants, M=2.03, SD=1.01, $F(1, 52)$=8.94, p<.01, partial η^2=.15. Analysis also revealed a significant main effect of assembler on robot malice, $F(1, 52)$=4.78, p<.05, partial η^2=.08, such that other-assembly participants rated the robot as being more malicious, M=2.8, SD=1.52, than did self-assembly participants, M=2.15, SD=0.74, showing support for H4.

5. DISCUSSION

5.1 Summary and interpretations of results

All four hypotheses were supported by the data. As predicted by H1, people showed greater self extension with the car than the humanoid robot. People who built and operated the car demonstrated greater trait overlap and attributed the robot less control over game performance than people who built and operated the humanoid. These findings provide further evidence that people perceive humanoid form as an indicator of unique identity and are less prone to treat the robot as an extension of the self.

Perceiving the humanoid as a unique identity rather than a self extension may explain why people perceived the car to have a better personality than the humanoid. As predicted by H2, people rated the car as being friendlier and having more integrity, while the humanoid was more malicious. People operating the humanoid may have been suspicious or critical of the robot, perceiving it as an independent actor and a threat to their performance as compared to a directly-controlled object.

Strong support was shown for H3. People who assembled the robot they operated showed greater trait overlap with the robot, were more attached to it, and felt more like a team with the robot. Not only do people become more attached to the robot, reporting that they would be more upset if it was destroyed, they also perceive the robot to be more like themselves. These findings indicate that the experience of building a robot encourages people to perceive the robot as an extension of the self.

H4 was also supported by these data. People who assembled the robot they operated evaluated the car more positively than the humanoid, rating the car friendlier and the humanoid more malicious.

5.2 Implications for theory

The results of this study suggest that people are more likely to experience an extension of self into less anthropomorphic forms of robots than humanoid ones. The humanoid robotic form elicited responses from people that suggest these robots are attributed a unique identity that is separate from that of their human operator. These findings inform our understanding of how people perceive and interact with agentic objects, such as robots, that have varying degrees of anthropomorphic form.

Regarding the experience of building the robot, these results demonstrate that people self-extend more to a robot if they build it themselves. Though it may be argued that people become more attached to the robots they build because they have more familiarity with the robot's inner workings, the current study demonstrates that this factor is not necessary for forming more positive associations with a robot. In all conditions, participants built a robot, so they were familiarized with the inner workings of the robot. However, the mere belief that the robot they used in the subsequent activities was the one that they built, as opposed to one that someone else built, affected self-extension and feelings of attachment to the robot. This suggests that there is something fundamental about using the robot one built.

5.3 Implications for design

These findings have implications for the design of robots. For example, they provide goal-specific guidelines and highlight the fact that no specific form is uniformly optimal. Promoting self-extension is desirable when self-extension improves the interaction, but is difficult to achieve with humanoid robots. For example, when a tele-operated robot serves as a medium or a representation of an individual, as would be the case with doctors using robots to examine patients remotely, a non-humanoid form may improve the interaction.

In other cases, self-extension may have undesirable consequences. When operators control robots in hostile environments or when a robot is likely to fail at a high-stakes task, as is often the case with search and rescue or hostage negotiation, minimizing self extension could reduce the negative impact on operators' mental and physical health. Because people are more likely to perceive humanoids as having independent identities, using a humanoid form would encourage operators to disassociate themselves from the robot's experiences.

Planning operators' interactions with robots before they guide them can improve the interaction. If self-extension is desirable, operators should play a role in the building of the robot, if possible, or personalize the robot in some way. When minimal self-extension is desirable, this study's results suggest that operators should use a robot they do not recognize, even if it is nearly identical to the robots they have used in the past. Alternatively, existing robots could be altered in some fundamental yet non-functional way, such as changing their appearance or voice, to become somewhat unfamiliar to the operator.

5.4 Limitations

There are several limitations to this study. First, our participant pool was limited to college students living in the United States. Replicating this study with people of different ages, backgrounds, and cultures is an important next step. Second, both our robots were assembled from one material--Lego® Mindstorms®. Future studies should vary features of the robot, such as material and size. Third, we studied interactions between humans and robots in a lab setting, using only one task. Interactions in more natural settings featuring different tasks may produce different results. Fourth, participants spent only a brief period of time with the robots, and participants' responses were measured shortly after the interaction. Future studies should examine both long-term interactions and long-term effects of interactions.

6. CONCLUSIONS

Designers' considerations of emotional and attitudinal responses to robots generally focus on people the robot encounters, such as disaster victims or hospital patients. Design for operators tends to be limited to creating necessary features and interfaces that are easy to use. This study indicates that an operator's experience with a robot before operating it and the robot's form affect the operator's attitudes toward the robot. Specifically, people who build the robot they operate extend themselves into the robot and attribute the robot with positive traits. Anthropomorphic form inhibits the tendency to extend the self into a robot, as anthropomorphic robots are perceived to have a more unique identity than functional robots. These results suggest that designers of robots should consider not only the responses of people a robot encounters, but the responses of operators as well.

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