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Investigating Older Adults' Trust, Causal Attributions, and Perception of Capabilities in Robots as a Function of Robot Appearance, Task, and Reliability

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INVESTIGATING OLDER ADULTS' TRUST, CAUSAL ATTRIBUTIONS, AND
PERCEPTION OF CAPABILITIES IN ROBOTS AS A FUNCTION OF ROBOT
APPEARANCE, TASK, AND RELIABILITY

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ABSTRACT

The purpose of the current study was to examine the extent to which the appearance, task, and reliability of a robot is susceptible to stereotypic thinking. Stereotypes can influence the types of causal attributions that people make about the performance of others. Just as causal attributions may affect an individual's perception of other people, it may similarly affect perceptions of technology. Stereotypes can also influence perceived capabilities of others. That is, in situations where stereotypes are activated, an individual's perceived capabilities are typically diminished. The tendency to adjust perceptions of capabilities of others may translate into levels of trust placed in the individual's abilities. A cross-sectional factorial survey using video vignettes was used to assess young adults' and older adults' attitudes toward a robot's behavior and appearance. Trust and capability ratings of the robot were affected by participant age, reliability, and domain. Patterns of causal reasoning within the human-robot interaction (HRI) context differed from causal reasoning patterns found in human-human interaction, suggesting a major caveat in applying human theories of social cognition to technology.

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1. INTRODUCTION

When interacting with technology, people focus on human-like qualities of the technology more than the asocial nature of the interaction (Reeves & Nass, 1996; Nass & Moon, 2000) attributing human-like qualities such as personality, mindfulness, and social characteristics. The attribution of human-like qualities makes technology susceptible to stereotyping based on appearance and etiquette (Nass & Lee, 2001; Parasuraman & Miller, 2004; Eyssel & Kuchenbrandt, 2012). For example, when a male or female anthropomorphic computerized aid was included in a trivia task (a stereotypically male task), participants were more likely to trust the male aid's suggestions and ranked the female aid as less competent (Lee, 2008). However, these and similar studies typically have used a task context that involves interacting with a software-based avatar or agent rather than interacting with an anthropomorphic robot. In addition, the measurements of stereotype activation were limited (e.g., measurement of perceptions of likeability or trust) and did not reflect a more commonly used method for measuring stereotypes such as measurements of perceived cognitive or physical capabilities (e.g., Bieman-Copland, & Ryan, 1998).

The purpose of the current study was to examine the extent to which stereotypic thinking was activated by the physical appearance of robots. The application of stereotypic thinking toward robots has been less studied and it is unclear if prior research is generalizable to this new technology context. First, unlike software avatars that are confined to a digital interface, robots occupy the same physical environment as the

individual, which makes them more amenable to human collaboration through physical interaction. Second, robots, by virtue of their design, are naturally more anthropomorphic than disembodied software avatars, which results in a comparatively greater social presence. Taken together, although robots represent a technology subset, there are key differences between robots and the traditionally used software avatars that could differentially affect stereotype activation. The theoretical relevance is that the results of this study will inform the limits of stereotypic thinking by investigating whether stereotypes are applied to robots. The practical relevance is that the current study may inform the design of robots to enhance human-robot interaction, particularly for older adults who tend to be less accepting of technological aids than other age groups (Czaja et al., 2006).

Stereotypes and Aging

In order to make efficient social judgments about others, individuals rely on the use of heuristics. One example heuristic involves placing an individual into a pre-determined schema (i.e., a stereotype). Stereotypes are cognitive shortcuts that result in impressions of others (e.g., Ashmore & Del Boca, 1981). Older adults may be more likely than younger adults to apply stereotypes when they do not have other sources of information available to them (i.e., under situations of ambiguity). Stereotypes are also more likely to be activated in domains that are inconsistent with prescriptive societal gender or age roles (e.g., Kuchenbrandt, Häring, Eichberg, Eyssel, & André, 2014). For example, individuals perceived a female-voiced computer to be more informative about romantic relationships than the male-voiced computer (Nass, Moon, & Green, 1997).

Although gender stereotypes have been studied using anthropomorphic technological aid paradigms, aging stereotypes have been investigated to a lesser degree within this context (however, see Pak, McLaughlin, & Bass, 2014).

Physical appearance is known to play a large role in the activation of aging stereotypes. The link between physical characteristics and stereotypes has been well established in the social cognition literature (Brewer & Lui, 1984; Hummert, 1994; Hummert, Garstka, & Shaner, 1997). Within this context, facial features are considered to be the main source of information used to activate stereotypes. Hummert et al. (1997) found that negative age stereotypes were associated with the perception of advanced age through facial photographs. Overall, these findings suggest that physical cues are major indicators within the context of social judgments.

Stereotypes and other social beliefs can influence the ways in which individuals process information in order to form social judgments, including the types of causal attributions that people make about the performance of others (Fiske & Taylor, 1991). When trying to determine the causality of an event, people tend to use two types of information: dispositional qualities of the individuals involved in an outcome and the influences of the situation itself (Gilbert & Malone, 1995; Krull, 1993; Krull & Erikson, 1995). Potential biases in the attribution process can occur as a function of the valence of the situational outcome, the degree of ambiguity of the situation (or of the information given about causal factors), and the controllability of the situation (Blanchard-Fields, 1994). Blanchard-Fields suggested that, in general, older adults are most likely to make dispositional attributions when the outcome of a situation was negative and the actor's

role in the outcome was ambiguous. When personal beliefs about another individual or situation are violated, older adults are also more likely to make to make dispositional attributions of blame rather than situational (Blanchard-Fields, 1996; Blanchard-Fields, Hertzog, & Horhota, 2012). Just as causal attributions, or the extent to which behavior is attributed to situational or dispositional causes, may affect an individual's perception of other people, it may also similarly affect perceptions of technology. For example, blaming technology for unreliable performance is likely to induce less trust (Moray, Hiskes, Lee, & Muir, 1995; Madhavan, Wiegmann, & Lacson, 2006). Attribution of fault has been studied with automation and has been referred to as automation bias (Mosier & Skitka, 1996). Automation bias has been defined "as a heuristic replacement for vigilant information seeking and processing" (Mosier & Skitka, p. 202) which often results in increased omission errors and commission errors.

Expectations of performance outcomes are influenced by stereotypes. Adults of all ages expect memory performance to decline with age (Lineweaver & Hertzog, 1998). Similarly, older adults' abilities are perceived negatively in domains involving memory (Kite & Johnson, 1988; Kite, Stockdale, Whitley, & Johnson, 2005) and physical well-being (Davis & Friedrich, 2010). In memory taxing situations, older adults are perceived as being less credible and less accurate (Muller-Johnson, Toglia, Sweeney, & Ceci, 2007). The tendency to adjust perceptions of capabilities of others based on appearance, whether unfounded or not, may influence another subjective perception: levels of trust placed in the individual's abilities.

Pak, McLaughlin, and Bass (2014) examined whether the physical appearance of an anthropomorphic aid would activate stereotypic thinking and affect individuals' trust in the aid. They used a medical decision making task that was aided by a variably reliable software avatar dressed as a doctor. The doctor was manipulated to appear to be a younger or older male or female. They found that both younger and older adult participants trusted the older anthropomorphic aids more than the younger aids, the male aids more than the female aids, and more reliable applications than less reliable applications. Critically, however, stereotypic thinking was activated when perceptions of reliability of the aid were low or ambiguous. When the aid had low reliability, the younger female aid was trusted less than younger male agents, reflecting predominant stereotypes about gender and physicians. Also, under medium reliability, the older female aid was trusted less than the older male aid. These results supported the notion that powerful age stereotypes can affect trust in decision aids in the theoretically expected direction. However, their study used a simple measure of stereotypic thinking (trust) rather than a multidimensional approach of perceived capabilities of the automated aid. This study also only indirectly measured causal attributions via patterns of stereotype activation, whereas the current study was designed to directly measure participants' dispositional and situational causal attributions about the robot's behavior.

Factors that Affect Trust in Robots

Trust in technological agents, such as robots, is important because it affects an individual's willingness to accept a robot's input, instructions, or suggestions (Lussier, Gallien, & Guiochet, 2007). For example, Muir and Moray (1996) found a strong positive

relationship between adults' level of trust in an automated system and the extent to which they allocated control to the automated system. Interestingly, Muir (1987) suggests that people's trust in technology is affected by factors that are also the basis of human-human trust. Trust in automation is thought to develop overtime (Maes, 1994) suggesting that trust is influenced by past experiences with the technology. For example, Merritt and Ilgen (2008) describe dispositional trust as the trust placed in a person or automation during a first encounter before any interaction has been made while history based trust reflects the prior experience a person has with another person or automation.

Performance based factors have a large influence in perceived trust in human-robot interaction (HRI; Brule, Dotsch, Bijlstra, Wigboldus, & Haselager, 2014). In fact, a meta-analysis suggests that a robot's task performance was the most important factor in adults' trust in robots (Hancock et al., 2011). That is, if the robot performs reliably, the human will exhibit greater trust towards the robot. The same meta-analysis found that behavior, proximity, and size of the robot also affected trust to a lesser extent. However, human-automation trust literature suggests that appearance can have reliable effects on trust by activating stereotypes (Pak Fink, Price, Bass, & Sturre, 2012). Indeed, studies in the social literature have found that people often judge an individual's levels of trustworthiness based on facial appearance (Oosterhof & Todorov, 2008) and that trust judgments can be formed after only a brief exposure (100 ms) to a face (Willis & Todorov, 2006). It is also important for the robot's appearance to be compatible with its function at face value. Goetz, Kiesler, and Powers (2003) found that people are more likely to accept a robot when its appearance matches its perceived capabilities. This is

thought to be the case because when there is a high level of compatibility between appearance and functionality, users expectations are confirmed, boosting confidence in the robot's performance. However, when appearance and capabilities are incompatible, user expectations are violated, which can result in lower levels of trust (Duffy, 2003).

Because studies of human robot interaction are a new field, there are many gaps in the literature especially regarding the social influences on HRI. First, although there is evidence to suggest that stereotypes can affect performance and interactions with anthropomorphized technological aids, we do not know how pre-existing age stereotypes will affect HRI. Next, it is unclear how trust is moderated by task type or domain. Although the automation literature affirms the important role of reliability on trust, to our knowledge the moderating role of task type or domain on trust in robots has not yet been investigated. Prior research has shown that task domain of automation has large effects on trust (Pak, Rovira, McLaughlin, & Baldwin, in press). Finally, how does stereotyping technology affect perceptions of capabilities and the causal attributions made about performance?

The Current Study

The purpose of this study is to test the generalizability of human-human theories of stereotype activation toward highly anthropomorphic robots. The literature from social cognition and human factors are informative but there are still questions as to whether their results apply to the new domain of physical robots; specifically, whether the robot's appearance, task domain, and reliability of the robot's performance influence trust. Using a method commonly used in the literature (Chen & Blanchard-Fields, 1997; Follett &

Hess, 2002; Ruffman, Murray, Halberstadt, & Vater, 2012), video vignettes were used to assess participants' attitudes towards the robot's behavior and appearance. Each vignette included manipulations of the age of the robot, the domain of the collaborative task, and the reliability of the robot's performance. Dependent variables included measures of stereotype activation: the level of trust participants exhibited toward the robot and the perceived capabilities of the robot. The third dependent variable included causal attributions regarding the robot's performance.

We hypothesized that the robot's appearance, level of reliability, and the task domain would affect trust toward a robot, the causal attributions that the individual makes about the robot's performance, and perceptions of the capabilities of the robot. Specifically, our hypotheses were that 1) trust in the robot would be highest when the task was stereotypically congruent with the robot's appearance (e.g., a younger robot performing a cognitive task instead of an older robot performing a cognitive task) and its performance was reliable. This was hypothesized because age appearance influences people's trust in automation (Pak, Fink, Price, Bass, & Sturre, 2012) and aging stereotypes are less likely to be activated while interacting with the younger robot. 2) Perceived capabilities of the robot were expected to depend on the robot's age appearance. That is, capability ratings were expected to be higher when the robot appeared young compared to when the robot appeared old because adults' capabilities in cognitive and physical domains are expected to decline with age (Davis & Friedrich, 2010; Kite, Stockdale, Whitley, & Johnson, 2005). We also hypothesized that perceived capabilities would be higher when task performance is reliable. Task domain was treated

as an exploratory variable. However, based on automation trust literature suggesting that trust in robots' capabilities might depend on the domain in which they are placed (e.g., industry, entertainment, social; Schaefer, Sanders, Yordon, Billings, & Hancock, 2012; Pak, Rovira, McLaughlin, & Baldwin, in press), 3) we hypothesized that there would be a main effect of task domain such that participants would have more trust in the robot and have higher ratings of perceived capabilities when the robot performs physical tasks. 4) We predicted that there would be a main effect of participant age, robot age, and reliability on dispositional attributions such that older adults would make significantly higher dispositional ratings than younger adult participants, participants would make higher dispositional attributions when the robot appears older, and dispositional ratings would be higher for unreliable task performance than reliable task performance. This is because older adults are more likely to make dispositional (i.e., internal) attributions of blame when an outcome of an event is perceived as negative (the unreliable condition) and when their beliefs are violated (i.e., when an older looking robot performs the cognitive and physical tasks; Blanchard-Fields, Hertzog, & Horhota, 2012).

2. METHOD

Participants

Sixty younger adults ages 18 to 22 ($M = 18.65$, $SD = 1.01$) and 43 older adults ages 65 to 79 ($M = 70.53$, $SD = 3.96$) were recruited for this study. Younger adults were undergraduate college students who received extra credit for participation. Older participants were normatively aging older adults recruited from the community and received $15 for their participation.

Measures

  Individual Difference Measure. The Complacency Potential Rating Scale (CPRS; Singh, Molloy, & Parasuraman, 1993) is a 16-item scale ($\alpha = .87$) that measures complacency towards common types of automation. Participants responded to the extent they agreed with statements about automation on a scale of 1–5. The CPRS score was a sum of the responses where higher values indicated higher complacency potential.

  Subjective Trust. Trust was measured using a single item asking participants how much they trusted the robot portrayed in the vignette. Responses were recorded on a Likert scale from 1 (not at all) to 7 (very much). The larger the participants' ratings, the higher their subjective trust in the robot.

  Perceived Capabilities. Perceived capabilities of the robot were measured using a list of 10 items ($\alpha = .91$) that spanned potential capabilities. Participants were asked, "Based on the robot's behavior in the video you just watched, what other activities could the robot complete?" Participants were asked about further cognitive capabilities and physical capabilities of the robot and ranked their agreement regarding whether the robot could complete similar cognitive and physical tasks. For example, participants were asked, "Based on the robot's performance, could it also recommend stock investment picks?" or "Based on the robot's performance, could it also vacuum a room?" Participants rated the extent to which they thought the robot could perform certain tasks on a 1-7 Likert scale ranging from "Definitely No" to "Definitely Yes" with higher scores indicating increased perceptions of capabilities.

Causal Attributions. Causal attributions were measured using a paradigm adapted from Blanchard-Fields, Chen, Schocke, and Hertzog (1998). Participants were asked to indicate the degree to which either dispositional factors of the characters or situational factors influenced the outcome of the scenario. The measure contained 6 items: 3 items measuring dispositional attributions ($\alpha = .90$) and 3 items measuring situational attributions ($\alpha = .80$). Specifically, participants indicated the extent to which: (a) the robot was responsible for the final outcome, (b) the robot was to blame for the final outcome, (c) the final outcome was due to personal characteristics of the robot, (d) the final outcome was due to characters in the story other than the robot, (e) the final outcome was due to something other than the characters in the story, and (f) both the personal characteristics of the robot and something other than the robot contributed to the final outcome. Participants responded using a Likert scale from 1 (very little) to 7 (very much). In order to classify the extent to which participants attributed performance to either dispositional or situational variables, we averaged the responses from a-c, which represented dispositional attributions of performance and compared them with participant's average responses to d-f, which represented situational attributions of the final outcome. The higher the score on these two aspects, the higher the degree of either dispositional attributions or situational attributions.

Factorial Survey. In a factorial survey, independent variables (i.e., factors or dimensions) are treated as statistically independent, making it possible to identify and separate their influences on judgments (Rossi & Anderson, 1982). In the current study, the dimensions included the robot's age appearance (younger, older), task domain

(cognitive, physical) with two tasks per domain, and aid reliability (low, high). The levels of the dimensions resulted in 16 factorial combinations or scenarios.

The stimuli for the robots were selected to portray a younger adult (Figure 1) and an older adult (Figure 2). Because the current study did not manipulate the gender of the robot, the facial stimuli for both the younger and older condition were female. In order to control for potential confounds for different faces, the faces selected for this study represented an age progression of the same female.

The robot used in this study was the Baxter robot manufactured by Rethink Robotics. Baxter is a manufacturing robot that can complete tasks that involve assembly and object organization (Amadeo, 2014). Adobe Photoshop CC was used to superimpose the facial stimuli onto the robot (Figure 3).

Figure 1. Young-adult appearance condition

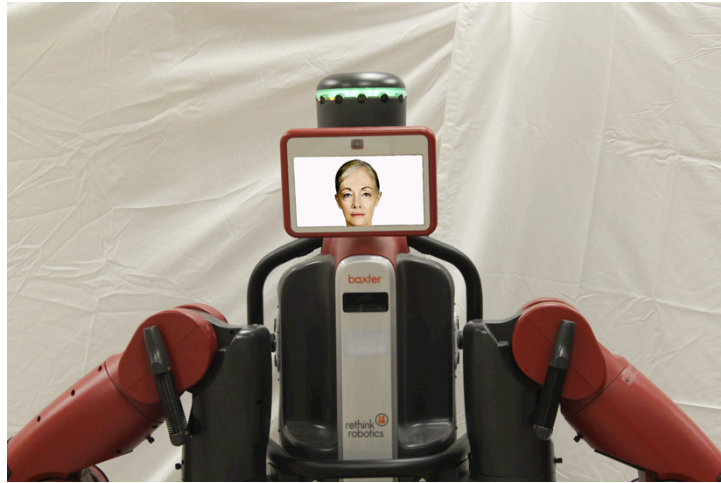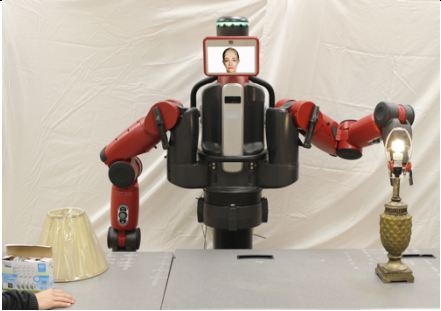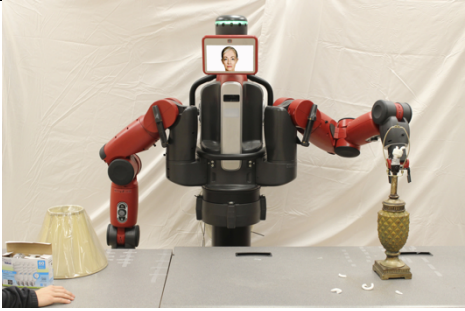Figure 2. Older-adult appearance condition

Figure 3. Robot stimuli

Each factorial vignette contained a slideshow of pictures portraying a human and a robot completing a collaborative task. The opening scenes included a wide shot, introducing the positioning of the human and robot as well as the collaborative task. In order to avoid any age or gender biases of the human actor, only the actor's arms and hands were shown while aiding in the collaborative task. The next shot included a close up of the robot's trunk, arms, and face. Finally, the human and the robot completed the task. The final shot of the slideshow included information about whether the task was performed reliably. If the task was performed reliably, the final shot showed the task successfully completed. If the task was not performed reliably, the final shot showed the final outcome being incorrectly completed or unfinished. For example, in the light bulb changing condition, reliable performance was portrayed with a photograph showing an illuminated, properly installed light bulb in the lamp. In the unreliable condition, the final photograph showed the light bulb broken into pieces on the table.

During the survey, each video vignette was presented in the center of the screen. After participants viewed the video, the questions and rating scales appeared in the lower half of the screen. Scenarios were presented in a random, counterbalanced order. The survey was programmed into the online survey program Qualtrics for administration.

Design and Procedure

The study was a 2 (participant age: younger, older) × 2 (robot age: young, old) × 2 (task domain: cognitive, physical) × 2 (robot reliability: low, high) mixed-model design, with participant age as the between-subjects variable. The within-subjects factors were manipulated in the factorial survey. The task domain dimension had two levels: cognitive and physical. These levels were selected in order to encompass the range of task domains within the HRI literature. Within those two domains, participants viewed the robots completing two separate tasks. That is, the robots completed two different cognitive tasks and two different physical tasks throughout the survey. The two physical tasks included moving boxes from one location to another and changing a light bulb. The two cognitive tasks included sorting recycling and separating laundry (Figure 4).

Physical		
	Success	Failure
Changing a light bulb		
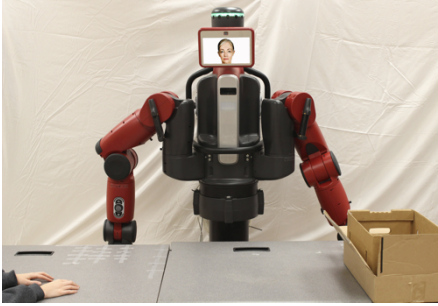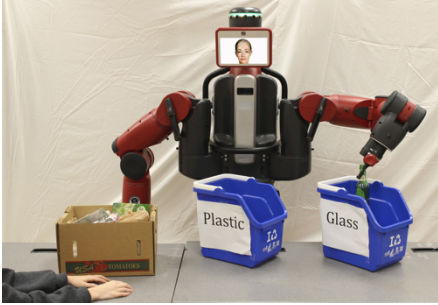
Moving boxes		
Cognitive		
	Success	Failure
Sorting recycling		
Separating laundry		

Figure 4. Task Domain

Following recruitment, the experimenter e-mailed participants a personalized

Qualtrics link in order for them to complete a unique version of the factorial survey. The

survey was completed in their home so no lab visit was necessary. Participants worked

through the survey at their own pace. However, they were instructed to complete the

survey in one sitting. During the survey, participants viewed randomly presented

vignettes and answered each question after the completion of the slideshow. Participants

completed the CPRS at the conclusion of the survey.

3. RESULTS

The following analyses are organized by the specific hypotheses outlined in the

previous sections. A 2 (participant age: younger, older) × 2 (robot age: young, old) × 2

(robot reliability: low, high) x 2 (task domain: cognitive, physical) mixed repeated

measures ANOVA on subjective trust, perceived capabilities, and causal attributions was

conducted. Post-hoc analyses were conducted for significant effects using Bonferroni

corrections. Manipulation checks for perceived age of the robot (t (84) = 14.29, $p < .001$),

perceived reliability of the robot (t (84) = 29.56, $p < .001$), and perceived task domain of

the robot (t (84) = 7.49, $p < .001$) revealed significant differences in the expected

directions.

Participants

Eleven younger adults and seven older adults were eliminated from analysis due

to missing data due to participant drop-out. The remaining 49 younger adults and 36

older adults were included in data analysis. The mean age of the younger group was 18.7

($SD = 1.05$) and the older group was 70.8 ($SD = 4.03$). Descriptive statistics of participant

characteristics are shown in Table 1.

Table 1. Participant characteristics by age group and gender.

| | Younger adults (n = 49) | | | | Older adults (n = 36) | | | |
| | Female (n = 39) | | Male (n = 10) | | Female (n = 22) | | Male (n = 14) | |
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	18.44	0.79	19.6	1.43	69.86	3.8	72.14	4.13
CPRS*[a]	51.54	3.71	52.5	3.78	49.62	5.04	51.33	4.08

*No significant age or gender differences.
[a] Scores could range from 16 indicating low complacency potential to 80 indicating high complacency potential (Singh, Molloy, & Parasuraman, 1993).

Trust

A 2 (participant age: younger, older) × 2 (robot age: young, old) × 2 (robot reliability: low, high) x 2 (task domain: cognitive, physical) mixed repeated measures analysis of variance (ANOVA) revealed a significant 3-way interaction between reliability, domain, and participant age group (F (1, 83) = 5.991, p = .016, η_p^2 = .067. Results were separated by participant age group (young and older) and are displayed in Figure 5. The interaction reveals a significant main effect for reliability in the predicted direction (F (1, 83) = 202.50, p < .001, η_p^2 = .709). The source of the interaction was that, in younger adults, the 2-way interaction of task domain and reliability was not significant. But for older adults, there was a 2-way interaction of task domain and reliability (F (1, 35) = 15.54, p < .001, η_p^2 = .307) such that when reliability was low, older adults reported significantly higher trust ratings for physical tasks (M = 2.69, SD = 2.35) than for cognitive tasks (M = 1.90, SD = 2.05). However, when reliability was high, older adults' trust ratings were significantly higher for cognitive tasks (M = 5.26, SD = 2.62) than physical tasks (M = 4.90, SD = 2.70). This suggests that although younger adult ratings of

trust are resistant to changes in domain and reliability, older adult trust ratings are affected by these changes.
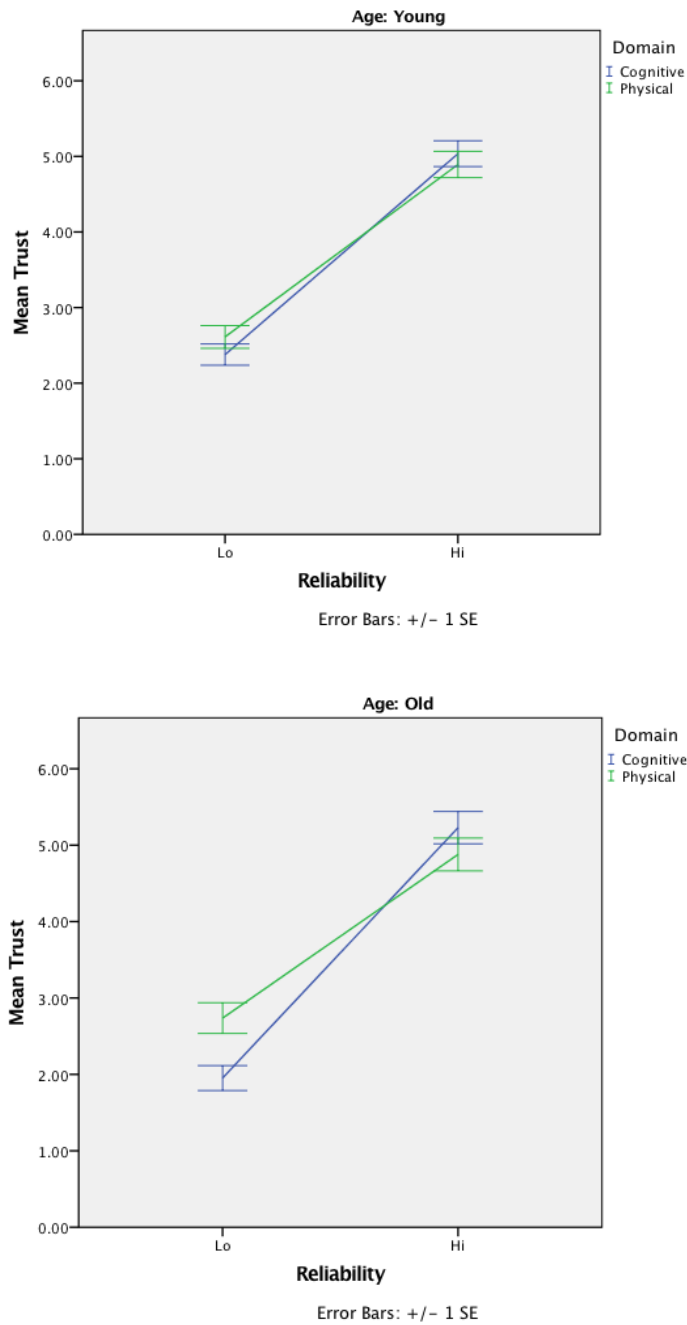
Figure 5. Reliability x task domain x participant age group on subjective trust.

There was another significant 3-way interaction between participant age group, robot age, and task domain (F (1, 83) = 6.637, p = .012, η_p^2 = .074), see Figure 6. Results were separated by participant age group (young and older) and are displayed below. The

source of the interaction was that for younger adults, there were no differences in trust

ratings across the robot age appearance conditions and task domain ($p > .05$). However,

for older adults, there was a 2-way interaction of task domain and robot age ($F(1, 35) =$

15.54, $p = .042$, $\eta_p^2 = 0.1$) such that there were no trust differences by task domain when

the robot appeared young. However, when the robot appeared older, older adults had

higher trust with physical tasks ($M = 3.83$, $SD = 2.16$) compared to cognitive tasks ($M =$

3.47, $SD = 1.95$). Older adults differential trust of robots by task domain only when the

robot appeared older partially supports our hypothesis that subjective trust would depend

on the congruency between age appearance of the robot and task domain.

Error Bars: +/− 1 SE
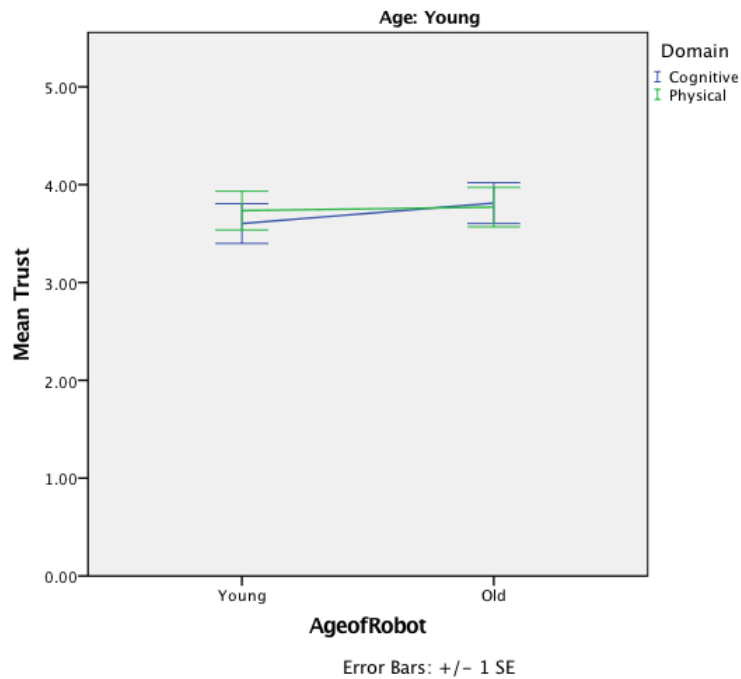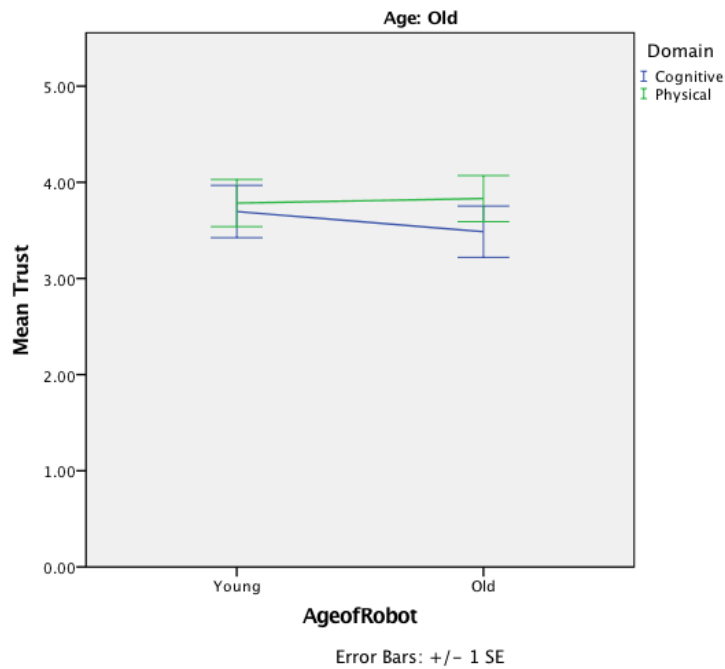
Figure 6. Participant age group x robot age x task domain on subjective trust.

Capabilities

Responses from the capabilities rating scales were summed within each condition to provide a total score of the robot's perceived capabilities. A 2 (participant age: younger, older) × 2 (robot age: young, old) × 2 (robot reliability: low, high) x 2 (task domain: cognitive, physical) mixed repeated measures ANOVA revealed a significant main effect of reliability ($F (1, 83) = 34.418$, $p < .001$, $\eta_p^2 = .293$). In accordance with our hypothesis, participants rated robots that performed a task reliably ($M = 32.07$, $SD = 14.93$) as having higher capabilities than those that performed a task unreliably ($M = 25.36$, $SD = 12.05$). Additionally, there was a significant interaction between robot age and task domain ($F (1, 83) = 11.147$, $p = .001$, $\eta_p^2 = .118$) on perception of capabilities, see Figure 7. Younger appearing robots ($M = 29.16$, $SD = 12.71$) yielded significantly higher capability ratings than older appearing robots ($M = 28.26$, $SD = 12.42$), supporting

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our hypothesis. When the robot appeared young, the robot carrying out cognitive tasks was perceived as having more capabilities ($M = 30.17$, $SD = 13.41$) than when carrying out physical tasks ($M = 28.16$, $SD = 12.26$). However, when the robot appeared older, there were no differences in capability ratings between cognitive ($M = 28.43$, $SD = 12.81$) and physical task domains ($M = 28.09$, $SD = 12.37$). Perceptions of capabilities for cognitive tasks were also significantly higher when the robot appeared younger than when the robot appeared older.
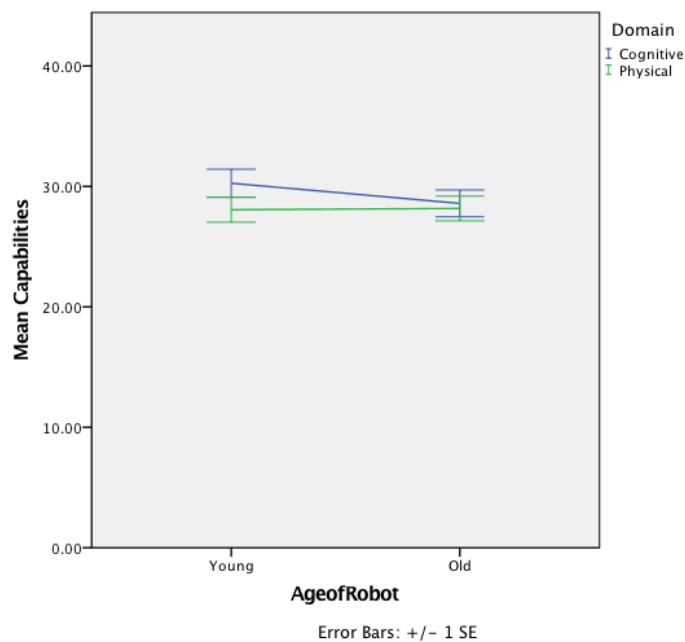
Figure 7. Robot age x task domain on perceived capabilities.
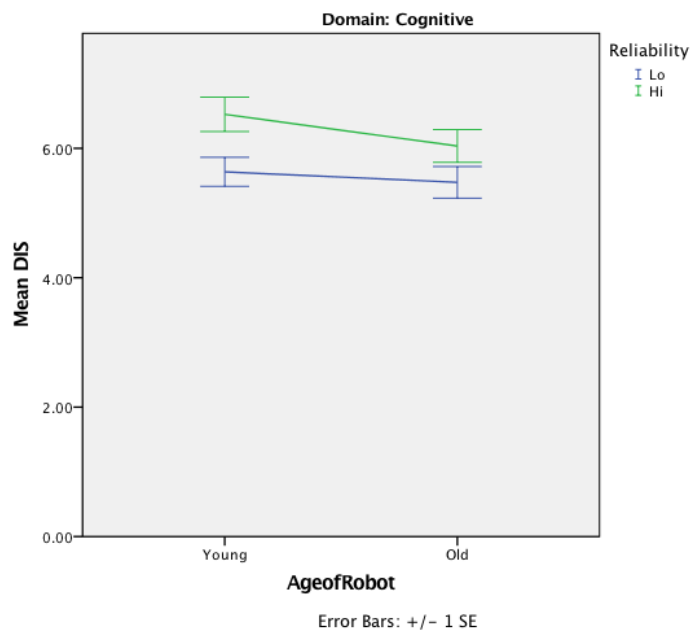
Causal Attributions

To investigate the differential contributions of dispositional and situational influences on causal attributions, the two variables were separated and treated as different dependent variables. A 2 (participant age: younger, older) × 2 (robot age: young, old) × 2 (robot reliability: low, high) x 2 (task domain: cognitive, physical) mixed repeated

measures ANOVA was performed on the three items representing dispositional

attributions, and a separate 2 (participant age: younger, older) × 2 (robot age: young, old)

× 2 (robot reliability: low, high) x 2 (task domain: cognitive, physical) mixed repeated

measures ANOVA was conducted on the three situational attribution items.

Dispositional Attributions. Dispositional ratings indicate the likelihood of

attributing robot task performance to the robot rather than the situation. The repeated

measures ANOVA for dispositional attributions revealed a main effect of participant age

group (F (1, 83) = 5.921, $p < .017$, $\eta_p^2 = .067$), indicating that, contrary to our hypotheses,

younger adults ($M = 6.02$, $SD = 2.65$) made significantly higher dispositional attributions

than older adults ($M = 4.95$, $SD = 3.09$). Additionally, there was a 3-way interaction

between robot age, reliability, and task domain (F (1, 83) = 10.24, $p = .002$, $\eta_p^2 = .110$;

Figure 8). Results were separated by task domain and are displayed below. The source of

the interaction was a significant 2-way interaction between age of robot and reliability

within the cognitive task domain (F (1, 83) = 39.513, p < .001, $\eta_p^2 = .323$) and within the

physical task domain (F (1, 83) = 10.24, $p = .002$, $\eta_p^2 = .110$). For cognitive tasks, when

task performance was reliable, participants made higher dispositional ratings when the

robot appeared young ($M = 6.47$, $SD = 2.45$) compared to when the robot appeared older

($M = 5.98$, $SD = 2.33$). Compared to reliable task performance, participants made

significantly less dispositional ratings for both younger ($M = 5.57$, $SD = 2.04$) and older

appearing robots ($M = 5.39$, $SD = 2.20$) when performance was unreliable. For physical

tasks, there were no significant differences between high and low reliability when the

robot appeared young ($p > .05$). When the robot appeared older, however, participants

made significantly more dispositional attributions when the robot performed the task with
high reliability ($M = 5.20$, $SD = 2.00$) compared to low reliability ($M = 5.02$, $SD = 2.01$).
This suggests that for cognitive tasks, dispositional attributions are affected by the age of
the robot and the reliability of the task performance. However, when the task domain is
physical, dispositional attributions depend on the reliability only when the robot appears
older.

Error Bars: +/− 1 SE
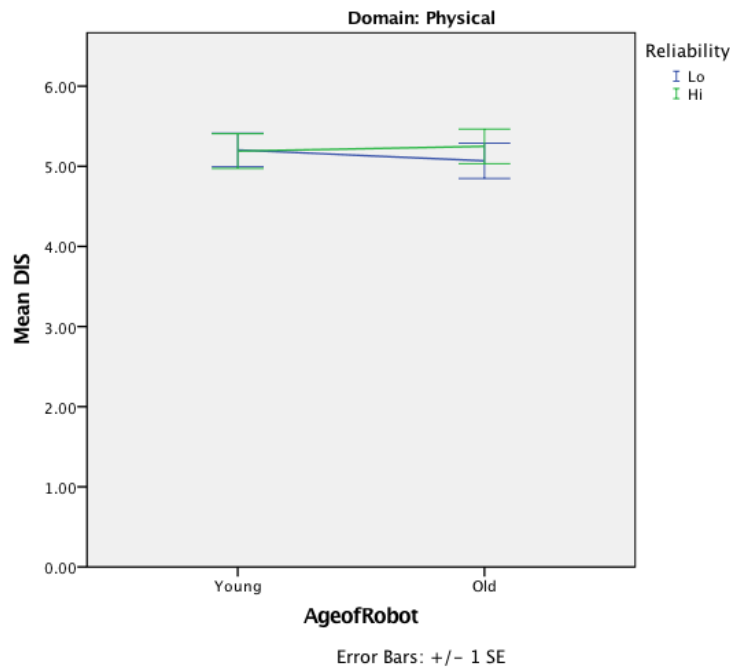
Figure 8. Robot age x reliability x task domain on dispositional attributions.

Situational Attributions. Situational attribution ratings indicate the likelihood of attributing robot task performance to the situation rather than inherent robot characteristics. The ANOVA for situational attributions revealed a significant main effect of robot age (F (1, 83) = 10.900, p = .001, η_p^2 = .116). Participants made significantly more situational attributions about the robot's behavior when the robot appeared younger (M = 4.18, SD = 1.94) than when the robot appeared older (M = 4.01, SD = 1.79). There was a significant interaction between reliability and task domain (F (1, 83) = 4.097, p = .046, η_p^2 = .047; Figure 9). Pairwise comparisons revealed that there were no differences in situational attributions between cognitive (M = 4.06, SD = 1.94) and physical task domains (M = 3.89, SD = 1.75) when reliability was low. When reliability was high, participants made significantly more situational attributions for cognitive tasks

($M = 4.44$, $SD = 2.42$) than for physical tasks ($M = 3.98$, $SD = 1.64$). Situational

attributions were also significantly higher for cognitive tasks in the high reliability

condition than in the low reliability condition.
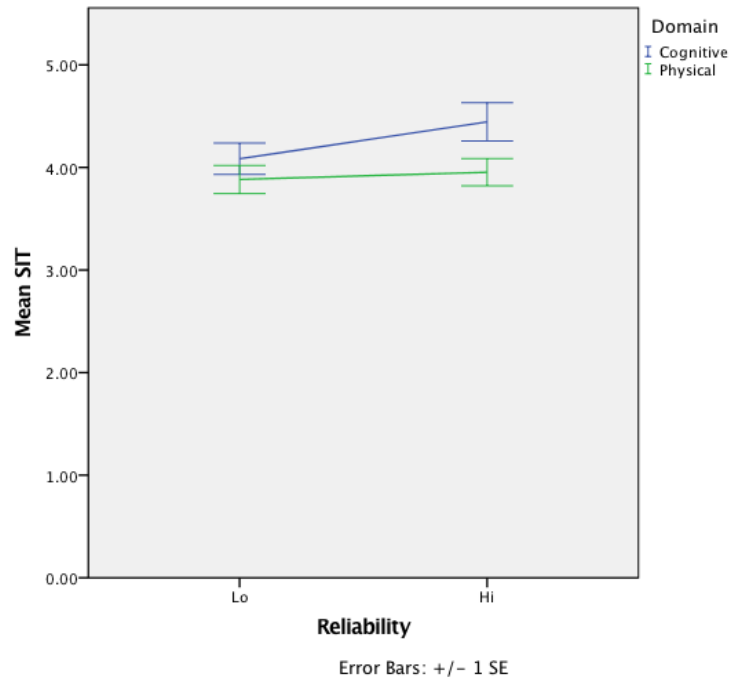
Figure 9. Reliability x task domain on situational attributions.

4. DISCUSSION

This study examined how pre-existing age stereotypes affected older and younger

adults' perceptions of robots. Previous research has shown that stereotypes can affect

performance and interactions with anthropomorphized technological aids. This study

attempted to extend these findings to the HRI domain. It was hypothesized that trust in

the robot would be highest when the task was stereotypically congruent with the robot's

appearance and its performance was reliable. Our results showed that trust was

influenced by the age appearance of the robot and by task domain. However, participant

age group moderated this effect. Younger participants' trust ratings did not differ based on age appearance of the robot or by task domain. However, older adults' trust ratings were influenced by the age of the robot such that when the robot appeared older, participants trusted a robot that performed a physical task more than a cognitive task. Although task domain was treated as an exploratory variable in our study, this finding is consistent with the literature that trust in adults' cognitive abilities tends to decrease with advancing age (Lineweaver & Hertzog, 1998). It is surprising, however, that the effect of aging stereotypes did not affect younger adults' trust ratings. The aging literature suggests that the presence of aging stereotypes is predicted more by level of contact with aging individuals rather than by a persons' age (Hale, 1998). This idea could also relate to level of contact with automation. It is documented that younger adults are more likely to own and interact with technology (Pew Research Center, 2011) and in-home robots (Sung, Grinter, Christensen, & Guo, 2008). Therefore, younger adults' levels of trust might be more influenced by their level of contact and familiarity with technology in general rather than the appearance of the robot.

Participants trusted the robot significantly more when performance was reliable, partially supporting the first hypothesis. Again, however, this effect was moderated by participant age and task domain. Although younger adults' trust ratings were resistant to changes in task domain and reliability, older adults are affected by these changes. When reliability was low, older adults trusted robots that performed physical tasks more than cognitive tasks. Conversely, when reliability was high, older adults trusted robots that performed cognitive tasks significantly more than those that performed physical tasks.

This suggests that although all participants' trust ratings are sensitive to reliability in the expected direction, older adults' trust in robots is sensitive to reliability as a function of task domain. This supports the idea that trust in automation might depend on the domain in which it is placed (e.g., industry, entertainment, social; Schaefer, Sanders, Yordon, Billings, & Hancock, 2012; Pak, Rovira, McLaughlin, & Baldwin, in press). These findings are interesting for a number of reasons. By applying aging stereotypes to robots, older adult participants may be attributing age-related qualities to the robot similarly to the way they would attribute these qualities to themselves or to their peers. In the aging stereotype literature, aging-related cognitive failures are perceived to indicate an inherent lack of ability that is difficult or impossible to mitigate (Bieman-Copland, & Ryan, 1998; Cuddy, Norton, & Fiske, 2005). Conversely, the extent of age-based stereotype threat within physical domains is unclear (Lamont, Swift, & Abrams, 2015), indicating that aging stereotypes are indeed multidimensional such that physical decline might not be perceived as negatively as a cognitive failure. This supports our finding that unreliable performance on a physical task is not catastrophic to older adults' trust in the robot.

From a design perspective, when it is important for users to maintain high levels of trust in imperfect automation, a younger appearing robot that performs more physical tasks would be optimal because it is less susceptible to large fluctuations in perceptions of trust as a function of stereotypic thinking. However, these findings are more applicable to older adult users who experienced fluctuations in trust as a function of reliability, appearance, and task domain. Although young adults' trust ratings were not sensitive to the manipulations, stereotype research shows that people of all ages are susceptible to

stereotypic thinking (Kite, Stockdale, Whitley, & Johnson, 2005) therefore, a reasonable option would be to design to avoid activating age stereotypes, especially in the face of imperfect automation.

It was expected that perceived capability ratings would be higher when the robot performed reliably and appeared young. Supporting our hypothesis, participants rated reliable performing robots as having higher capabilities than those that performed a task unreliably. Further, participants rated younger appearing robots as having more capabilities than older appearing robots. We also expected that participants would have higher ratings of perceived capabilities when the robot performed physical tasks. This hypothesis was not supported. Robots had the highest amount of perceived capabilities when they appeared young and completed cognitive tasks. However, age stereotypes did influence capability ratings such that, compared to younger adult robots, perceived capabilities were significantly lower when the robot appeared older and performed cognitive tasks.

Predictions of causal attributions were based on previous social cognition literature (Blanchard-Fields, 1996). Therefore, we expected that dispositional attributions would be highest for older adult participants when the robot appeared older and performed tasks unreliably. However, this hypothesis was not supported. Contrary to our predictions, younger adults made significantly higher dispositional attributions than older adults. Overall, dispositional ratings were highest when a young appearing robot reliably performed a cognitive task.

Because people attribute human-like qualities to technology, it is often the case that social constructs such as trust or stereotyping affect human-automation interaction similarly to the ways in which they affect human-human interaction. However, this finding suggests a major caveat in applying human theories of social cognition to technology. Specifically, individuals are more likely to "give credit" to a robot for reliable performance as opposed to blaming it for unreliable performance. In particular, participants were most likely to give credit to the robot when it appeared young and reliably performed a cognitive task.

Situational attribution ratings indicate the likelihood of attributing robot task performance to the situation rather than inherent robot characteristics. It is important to note that dispositional and situational causal attributions are not mutually exclusive. Optimal causal reasoning involves consideration of both the dispositional characteristics of the actor and the external, situational influences (Fiske, 1993). In our study, situational attributions followed a similar pattern as dispositional attributions such that participants made more situational attributions when the robot appeared young. Participants were also more likely to attribute task performance to situational factors when a cognitive task was performed reliably. Therefore, our results suggest that situational factors also influence adults' perceptions of causal reasoning. The fact that our dispositional and situational attribution patterns are similar suggests that adults are able to attribute cause in a multidimensional way that is considered to be more ideal and accurate (Fiske) within the HRI context.

It is well established that individuals are more likely to place overdue emphasis on dispositional factors when a situation is ambiguous (i.e., the relative contributions of the actor and the contributions of the situation on a final outcome are unclear; Blanchard-Fields, 1994; Trope, 1986). In our slideshow vignettes, although we presented photographs of the final outcome in each scenario, the stimuli were ambiguous regarding the human collaborator's (a situational factor) influence over the final outcome. We also did not include any internal information about the robot's programming or instructions. Therefore, we believe our stimuli were ambiguous enough to allow participants to place overdue influence on the robot's internal qualities in the predicted direction. However, because results were contrary to our hypothesis, perhaps individuals attribute causal attributions differently within the HRI context. From a design perspective, robots that appear younger and reliably perform cognitive tasks are more likely to yield more optimal attribution patterns that consider both the dispositional qualities of the robot as well as external influences of the situation.

One limitation is that we did not assess pre-existing stereotypes held by our participants because a stereotype assessment could have biased participant ratings during the survey. However, the social cognition literature consistently finds pervasive expectations of cognitive and physical decline with increasing age (Davis & Friedrich, 2010). Another caveat is the use of slideshow vignettes using stop-motion progression as opposed to continuous video of the robot performing the task. A slideshow presentation was selected for both practical and theoretical reasons. First, the Baxter robot must undergo significant programing in order to perform the simplest of tasks, such as gripping

a block at a specific location on a flat surface. Therefore, programming the robot to complete full circuit tasks would have required extensive time. Theoretically, our purpose was to apply a well-researched area, social cognition and aging stereotypes, to a novel field, HRI. Therefore, we tried to replicate experimental paradigms that require situational ambiguity within the stimuli. The slideshow format provided a means to present sequences of the robot's behavior while still allowing for ambiguity.

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