An Exploration of Robot Builders' Attachment to Their LEGO Robots

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This research explored the emotional attachment that students might develop towards robots that they built in a 2-month period, as well as the factors that contributed to their emotions towards the robots. The research studied 16 students enrolled in the robotics class in the fall 2012 semester who completed a specially-designed questionnaire. The results showed that students had strong positive emotions towards their robots. However, the students differed from typical attachment in that they had low avoidance or anxiety related to loss of the robot. In open-ended responses on the questionnaire students indicated that they would feel sad dismantling their robots, but they rationally reported the robots could be rebuilt. Reflective journal data showed that they enjoyed the building process greatly, especially when they solved challenging problems. The data suggested that students' affection for their robots was not attachment as is typically defined in human-human or human-pet relations. Limitations and further research directions were included.

INTRODUCTION

The first half of the 21st century has been predicted to be the age of robots (Norman, 2004). Accordingly, understanding the complexities of human emotional responses to advanced technological artifacts, such as robots, has become important for understanding human-robot interactions (Kahn, Severson, & Ruckert, 2009). In addition, an increasing number of social robots and service robots have come into people's lives, such as robotic dogs, "AIBO," and robotic cleaners, "Roomba." Robot users reported happiness from being with the robots, and gave their robots names as if they were human beings, friends, or even family members (Kahn, Severson, & Ruckert, 2009).

Both AIBO and Roomba are products that people purchase ready to use. Might people who build their own robots have an even stronger emotional bond with their robots? An anecdotal observation that college students in a robotics education class showed sadness when they were asked to dismantle the robots that they had built over a semester provides a great opportunity to investigate robots builders' emotional and cognitive responses to their work.

The purpose of the present research was to examine whether students would become emotionally attached to robots that they built during a 2-month period of a class. As part of this investigation, we also examined associated factors related to the student builders' emotions. For this research, we began by examining existing attachment research in human-human, human-pet, human-robot relations, as well as the mechanisms of attachment. We then collected data related to attachment and other emotional responses by students during LEGO® robot building.

LITERATURE REVIEW

Originally, the term attachment was applied to infants' affection to their care-givers. Gradually people have begun to research human attachment to pets (e.g., Zilcha-Mano, Mikulincer, & Shaver, 2011), robots (e.g., Sung, Guo, Grinter, & Christensen, 2007; Weiss, Wurhofer, Tscheligi, 2009), and even broadly, possessions (Belk, 1988). The emotional connection that people have with non-human entities seems similar to attachment in some ways, but differs from attachment in others (Zilcha-Mano et al, 2011).

Human-Human Attachment

Much of the research on parent-child attachment has examined the feelings of attachment that a child has towards the parent (for a review, see Bowlby, 1988). Recently, Zilcha-Mano, Mikulincer, and Shaver (2011) have identified four features of adolescent and adult relationships to fit attachment theory: 1) physical closeness to the attachment figure, especially in need or stress; 2) sense of removing distress and receiving comfort, encouragement, and support from the attachment figure; 3) sense of safety from the attachment figure which incur exploration, risk taking, and self-development; 4) sense of separation distress when the attachment figure becomes temporarily or permanently unavailable. Thus, attachment is characterized by positive affect when the attachment figure is present and negative affect in the absence of the attachment figure.

Attachment theory has also been applied to relationships among adults, particularly romantic relationships. Secure attachment in a romantic relationship centers on positive affect, with both intimacy and independence as critical factors, whereas insecure attachment involves a strong component of negative affect, such as anxiety and avoidance (e.g., Bartholomew & Horowitz, 1991). However, neither child-to-parent attachment nor adult-to-adult romantic attachments seem to be good analogues for human-to-robot attachment.

Human – Pet Relationship

Human-robot relations might more closely resemble the relation that a human has with a pet or animal companion. Archer and Ireland (2011) identified four factors in measuring human attachment to pet dogs: a general sense of closeness of having the pet as a family member, a perception of companionship and care-giving desire, a desire to keep close relationship, loss and separation-related items. Zilcha-Mano, Mikulincer, and Shaver (2011) compared the similarity and differences between human-human relationship and human-pet relationship in terms of the four criteria characterizing adult attachment, but they mainly looked into anxiety and avoidance as two perspectives of attachment orientation, and found that individual differences existed in these dimensions, which could predict their emotional and behavioral response to a pet's death. Zilcha et al. (2009) found that pet owners felt unconditionally accepted and loved. Their relationships were characterized by stability, consistency, tenderness, warmth, loyalty, authenticity, and lack of judgment or competition, which lead to an attachment to a particular pet. Robots could do many things living pets can, yet robots are still different from living pets (Melson et al, 2009). Empirical research on the human – robot relationship is needed.

Human-Robot Relationship

With the recent advent of service robots, such as the Roomba, in the home, researchers have begun to examine attachment of humans to those service robots (e.g., Forlizzi & DiSalvo, 2006; Sung, Guo, Grinter, & Christensen, 2007). Sung et al. (2007) observed that the majority of their participants had named or nicknamed their robot and thought about their robot in gendered terms. Findings such as this suggested that people sometimes treat robots like they treat other people or animals (Jones & Schmidlin, 2011).

Weiss, Wurhofer, and Tscheligi (2009) studied children and adults' first impression of robotic AIBO dog. They used Norman (2004)'s three dimensions of user experience to explore people's emotional attachment to the robotic dog: visceral, emotional, and reflective. The results indicated that both children and adults showed positive feelings toward the robotic dog at the visceral level. Reflective level results indicated that children developed emotional attachment to AIBO, while adults showed indifference to some extent when asked whether AIBO is an adequate playfellow for their children.

Holle, Bard, and Canamero (2009) designed sensors for robots that required participants to give attention, and compared them to robots that need less attention. They found that the needy robot setting was sufficient to elicit care-giving like behaviors from the participants, as well as positive experience in terms of enjoyment, reactivity, predictability, willingness to assist, and ease to interact.

The prior research on attachment of humans to robots has focused on robots that simply interact with the humans, not robots that have been built by humans. The creation process might be expected to lead to a stronger sense of attachment. In the robot building scenario that we studied, the robot builders' relationship to their robots might resemble this care-giving role, which could lead to attachment. If the robot builders form bonds of attachment towards their robots, they might have strong negative affect at the end of the semester when they have to dismantle their robots.

METHODS

Participants

This study involved 12 male and four female undergraduate students from a robotics education class in a southeastern university in the United States, with an age range from 20 to 29 years (*mean* =21.44, *SD* = 2.16). Fourteen (87.5%) had no robot-building experience prior to the class, one participant had taken this class before, and one participant used LEGO® MINDSTORMS® about 5 years prior to the class. Twelve (75%) reported not owning any robots, three (18.8%) owned one robot, and one (6.3%) owned 10 robots.

Measures

Essay questions. The essay questions explored participants' attitudes and background. The main questions included: 1) What experience did you have with any robots before you took the class? 2) Describe your experience with the robot you built, including playing, learning, problem solving, recording, and other interactions you had with the robot. 3) What role do you treat your robot? – Friend, assistant, toy, or other? 4) Why do you think about the robot this way? 5) On a scale from 1 to 10, how do you like the robot you built? 6) Has this feeling changed over the semester? Why? 7) How would you feel about dismantling your robot?

Attachment questionnaire. This questionnaire was a revised version of a human-pet attachment questionnaire (Zilcha-Mano, Mikulincer, & Shaver, 2011), using a seven-point category scale (1=strongly disagree, 7=strongly agree). Example items were: Being close to my robot is pleasant for me; I am worried that something bad could happen to my robot. Six items were reverse scored, and the overall Cronbach's Alpha was .67.

Features of the robots. The researchers created this questionnaire using items from the literature review (e.g., Jones & Schmidlin, 2004) about usability and features that are most attractive to people. For example, playfulness, easy to use, exceeding my expectations, great learning experience, good companion, easy to learn to use, low rate of malfunction, continuous improvement, my capability to advance it, and other (for which participants were asked to specify).

Demographic questionnaire. This questionnaire inquired about participants' personal details (age, gender), and prior experience with robots.

Reflective journal. The students were required to write a reflective journal at the end of each class session, the form of which could be text, videos, and/or photos. The guiding questions for the reflective journal included: 1) What did I do? 2) How did I do it? 3) What did I like/dislike? 4) What did I learn? The students were asked to respond to the guiding questions in narrative format, without bulleted lists, at length of one to two paragraphs. This study only included the reflective journal text, not the other format data.

Procedure

For the first two months of the semester, robotics education students, using hands-on active learning strategies, built and programmed a robot using the LEGO® MINDSTORMS® Education *NXT* base set. For the last eight weeks of the semester, students, in teams of four, created a robot of their own design using only components of the basic kit. On the last day of class, students demonstrated their robots and interacted with the public, discussing the processes they used to complete this project. During this exhibition, students reported to the robotics lab, signed the required consent form, and completed the online survey.

RESULTS

Affection for Robots

To determine whether participants developed strong attachment to their robots after the robot building process, the extent of their affection for robots in general and for the particular robot that they built, the amount of emotion change during the semester, and the extent of attachment were investigated. The results showed that participants had a mean score of 8.44 (*SD* =1.03) on the 10-point scale of affection for robots in general, and 8.81 (*SD* =1.28) for the robot that they built.

Eleven participants (69%) reported that their affection for their robot increased over time. Participants replied with reasons for their increased affection such as being more satisfied with the second design; it was frustrating at the beginning to operate and program but later it became easier; the original plan did not work out, but the optional plan was cool; the more time spent with the robot, the more eager to make the robot succeed; building the robot changed from fulfilling a duty to something creative and would like to work on it more; being doubtful about the capability to solve the problems at the beginning but when the issues did get solved they became more interested in working with the robot. Four participants (25%) reported that their affection for the robot had not changed over the semester. However, their average rating was 9.5 out of 10, so they may have not changed due to a ceiling effect. Only one (6.25%) participant reported that affection for the robot decreased over the semester because some plans on the robot turned out to be impossible to carry out -- this participant rated affection as a 6. Therefore, it appears that most students either maintained a high level or increased their affection for robots over time.

Table 1 The Roles of the Robot

Role	Explanation
Assistant/ Tool/Aid (n=11)	“no feelings…a technological tool used to make life easier”; “more of a worker…lacking human characteristics”; “assist solve a problem…an aid, help, assist”; “made for work”; “aids me by getting me to work my mind in new creative ways that I didn't know I could do”; made for work and they can be more efficient than people and cause you less troubles”
Toy (n=5)	“a powerful toy”; “enjoy playing with it”; “feel like playing with a toy”; “fun to make it function without any limitations other than our imaginations, our materials, and programming options”
Project/ Assignment (n=5)	“assigned as my final project for the class”; “an assignment for my class”
Pet (n=1)	“a pet that you are trying to train”

The roles of the robot. Investigating the perceived roles of the robot was another approach that we used to determine subjects’ attitude toward them. Some participants treated the robot with more than one role (see Table 1).

Dismantling the robot. As part of measuring attachment, the students were asked how they would feel if they were asked to dismantle the robot. Ten students (67%) reported negative feelings -- sad, hard, disappointing, or ambivalent -- if they had to dismantle the robot they built. Among them, six (38%) expressed mixed feelings in the form of “sad, but…” The complement to sadness were some positive perspectives, including the satisfaction of successfully completing the robot, possibility to build a new and better robot, learning from dismantling. Six (38%) did not report any negative feelings over dismantling the robots. The reasons for the different feelings are listed below (see Table 2).

Table 2 Feelings of Dismantling the Robots

Feeling	Reasons for the feeling
Sad (n=4)	“it works”; “a lot of time and effort into making it”; “a lot of hard work went into building and programming the robot”; “our idea was innovative and great”; “it is part of the process, so I feel ambivalent.”
Sad but (n=6)	“we had created something that professionals may really use”; “it will be satisfying to know that I successfully completed the course”; “I see the potential in disassembling it because we could build a new and possibly better robot”; “will be fun to compare the final result to what our original plans”; “I might spot some more improvements while dismantling”; “we glad it worked really well so at least we know our robot was a success.”
No problem (n=6)	“it would have to be done eventually - they are just Legos”; “it performed its job well, and must be put to rest as human beings do”; “would not care; the important part of the robot is the programming of the body can be broken down and rebuilt at any time in a new and more efficient form.”

Analysis of the Attachment

The attachment scale. The 12-item scale was particularly created for this study based on items from human-pet attachment orientation scales (Zilcha-Mano et al., 2011). Though the scale had a .67 Cronbach’s Alpha, there were no significant correlations among overall affection for the robot and the attachment items. Additionally, the overall affection for the robot had no significant correlation with students’ avoidance and anxiety toward the robots. Correlation coefficients were less than .38. The ones that had negative correlations with their positive affection for robots indicated that they were not worried bad things happening to their robots, they did not wish the robots show emotional commitment, they were not attached to the robot, they had no difficulties giving their robots away, they had no problem keeping away from the robots, and they did not feel frustrated when the robots were not available.

Table 3 Feelings Coding

Coding	Definition	Examples
Learning (n=24)	Learned something new	"It was interesting to see how complex machines that are seen all over the place[s] were simplified into an easy to build set that mimics what the machines do." "I think that this is a great project for discovering how pressurized mechanisms work, especially for someone with little to no previous experience with machines."
Doing (n=19)	Participated in designing and building the robots	"This was a fun process because we actually go to design and constructed the devices."
Accomplish-ment (n=23)	Finished the robots and saw them work, including both smooth process and problem solving.	"After we figured it out everything went smoothly and we had a great time doing the project. We had one problem, but we solved it!!!! We used the kits and their contents to build the simple machines. The recliner was definitely the most challenging, but the most rewarding when it worked."
Function (n=7)	The robot itself is useful, powerful, and interesting to watch.	"This simulation was the coolest we have done so far. This had an arm that extended using a hydraulic system after pushing the button. This reminded me of a crane in some sort of fashion since it uses both extending arms and hyd+B13raulics."
Multi-coding (n=27)	Contain more than one coding: the example here used learning, accomplish ment, and doing.	"Simple Machines Activities... This press was one of the coolest things I had done in college to this point…The lift was even more fun than the press. Although we had a few slow downs we finished and it worked perfectly… The sliding door again was more fun. This one also gave some insight into how a sliding door works… Last but not least was the dentist chair. By far the most fun and it was amazing when we got it working. It was the most complicated but offered the most challenge[s] which came with a great reward. The simple machines gave me a good understanding of pneumatics work. It was by far the best class that I have ever had, and I hope that the rest of this semester is just as fun."

Reflective journal text. The number of each student's reflective journal text entries ranged from 1 to 10 (mean = 5.8) for the first two months when they were learning all the basics, not including videos and pictures with technical explanations. The total journal text entries included in this study were 93. In the text, four students (25%) did not use any emotion words to describe how they felt but just what they did for that day, whereas the remaining students reported explicit positive feelings toward the class and the robots. The criteria to judge positive feeling include the following cues: like/liked, fun, great, love/loved, enjoy/enjoyed/enjoyable, interesting, excited/exciting, cool/coolest, nice, glad, good, and reward/rewarding. Forty-nine statements were extracted by this criterion. In these statements, like was used 19 times, interesting 12 times, fun 11 times, enjoy 10 times, great 8 times, and love 6 times. The coding for their feelings included learning, function, accomplishment, doing. Some statements contain more than one coding (see Table 3).

Features of Robots

The second research question focused on the factors that contributed to students' attachment to the robots, but given that the attachment scale was not well received, then the overall affection for the robots was used as a criterion. However, only one item of the features had a significant correlation with the overall affection for the robot, i.e., I found my robot exciting because it evolved over time ($r = .52$, $p < .05$). Two items had negative correlations with the overall affection: I found my robot playful ($r = -.05$, $p > .05$); it seemed sometimes that my robot appeared to show emotions (e.g., happiness or sadness) ($r = -.41$, $p > .05$).

Ranking of features. Given the low correlations among the overall affection for the robots and robots' features, the participants rated their preferences of 10 features, with the most preferred feature as 10, and the least as 1. Each feature got a weighted value = (Σ frequency ∗ value)/N. The results of the ranking were listed below (see Table 4).

Table 4 Ranking of Contributing Features

Ranking (value)	Features
1 (7.56)	great learning experience
2 (6.94)	continuous improvement
3 (6.94)	easy to learn to use
4 (6.78)	my capability to advance it
5 (6.17)	easy to use
6 (5.89)	exceeding my expectation
7 (3.72)	low rate of malfunction
8 (3.56)	playfulness
9 (1.44)	good companion

DISCUSSION

Affection for Robots

The overall mean rating of how participants liked their own robot was 8.81 out of 10. However, the attachment scale showed no statistically significant correlations among any survey items and subjects' affection toward their robot. Affection in this case may differ from the emotional attachment studied in human-human and human-pet relations (which focused on avoidance of parting and anxiety related to parting). It is also different from the relationship between human and robots that are purchased ready to use (Sung et al., 2007). Results indicated that the majority of subjects took the role of robots as assistant/tool/aid lacking feelings, which agrees with previous research (Dautenhahn et al., 2005). Although the instructor told the students at the beginning of and during the semester that they would have to dismantle the robots and therefore they should have prepared for this moment, most of them still reported being sad. In other words, they did develop positive affection for the robots after a semester (15 weeks), but the sadness might be ameliorated by the warning.

However, the absence of significant correlations between positive affection for robots and the attachment scale item related to avoidance or anxiety in parting from the robots indicated this affection was different from the previously-studied attachment on the avoidance and anxiety dimension. Their affection seemed less than human attachment to another human or a pet, but might be closer to what Belk (1988) described as affection for possessions. LEGO® robots can be rebuilt, which makes them unique.

Anthropomorphism and personification are the terms used to describe the phenomenon that the creators project their own egos to the objects. People regard possessions as one's extended self, and therefore attach to their possessions (Belk, 1988). In some research, people regard automobiles as part of their extended selves and ego ideals. They customize their cars and maintain them. When the cars are damaged, they react as if their own bodies are damaged (Belk, 1988). Robots could be this type of possession. When the college student built the robots, they embodied the robots in a direction that confirms their will, preference, and interest.

Two students mentioned that their expectations for the class influenced their feeling about robots over the semester. One of them was satisfied by an optional design when the original plan failed, and the other decreased the extent of affection for the robot when they found that the class could not fulfill his expectation on robots. In other words, the extent to which the class met their expectation may relate to higher emotions, and if the expectation is unfulfilled, they might have negative emotions toward the robots.

Robotics in Learning Scenario

Because participants in this study were students in an actual class who cared about their grades while building the robots, learning and accomplishment were undoubtedly high priorities for the students. In the meantime, building one's own innovative robots using basic knowledge and skills is quite challenging, which also may have reduced some of the entertainment value of the robot-building task. This was supported by the feature ranking results, in which playfulness and company were rated at the bottom three while the top feature was great learning experience.

The reflective journal text data indicated a few patterns of students' enjoyment. They enjoyed the robot building process and the robots when they physically interacted with the robots, learned something new, solved challenging problems, and made good progress. The majority of the statements showed strong association between the enjoyment and accomplishment. As long as they finished the projects and saw them work, the students were happy. If the problems remained unsolved and the robots did not work, they would not be happy. This pattern was consistent with the essay response that problems made them feel frustrated, but successfully solving the problems made the process especially rewarding and pleasant.

Limitation and Future Research Direction

This study explored students' emotion toward the robots they built. It was surprising to see no anxiety-avoidance type of attachment existing in the robot builders towards their robots. The scale used was created based on the literature review, although the literature on emotional attachment to LEGO® robots was quite rare. In order to verify the unique affection for robots in this special scenario, a unique instrument for measuring emotional response to robots may need to be developed.

The present study was conducted at the end of a semester; in contrast, future research should compare students' affection at the beginning and the end to see whether building process contributes to their attitude toward the robots. Self-efficacy could be investigated as well since it seemed a salient variable from current informal observation.

The current reflective journal text data is in a free style, focusing on what the students did and what they learned. Future research should encourage recording more about what they feel towards the tasks and robots during and after the building process.

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