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An Exploration of Robot Builders' Emotional Responses to Their Tournament Robots

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Our exploratory study about robot builders' attachment to their LEGO robots found that college level participants showed strong affection for their robots, but the relationship was different from human-human or human-pet attachment in terms of lack of separation related anxiety and enjoyment of companion. Whether the relationship should be named attachment is now pending. The present research investigated further in three aspects: 1) revised the emotion questionnaire based on a newly developed emotional response model; 2) expanded the participants to middle school and high school students who participate in robotics competition tournaments; 3) examined additional factors that might influence their emotional responses to the robot, including: participation in tournaments, team dependency, time/effect input, performance expectation, and features of the robot. The revised emotion response questionnaire showed high reliability and significantly positive correlations with the overall affection for robot. Time/effort input and features of the robot were found significantly contribute to their emotional responses to the robot. This study will help robotics educators better understand students' emotions, and adjust accordingly to increase students' learning effectiveness and well-being.

INTRODUCTION

Robots growingly play important functional roles in the lives of humans, for example, in industry, home, and entertainment. As a consequence, educators are paying increasing attention to robotics. For example, various robotics competition events have been developed to facilitate robotics education. For FIRST robotics alone, more than 350,000 students organized in 32,600 teams got involved worldwide for the 2013 – '14 season (FIRST, 2014).

As human interact more with robots, the possibility that they will form emotional bonds of some kind towards the robot may increase. For example, Carpenter (2013) suggested that soldiers who were heavily involved in working with field robots developed certain types of emotional attachment to their robots. In contrast, our previous study (Huang, Varnado, & Gillan, 2013) examined human emotional attachment to robots in a robotics education course at the college level and found that the students had a high affection for the robot that they had built, but that emotional response was not like the human-human attachment, or human-pet attachment. Accordingly, further investigation into the topic of emotional responses of humans to robots is necessary, especially to improve the research instrument and increase the sample size.

Extracurricular competitions by students seem to be an excellent source of participants to study human-robot emotional responses for two primary reasons. First, the number of middle school and high school participants in nationwide robotics competition tournaments mentioned above provide the possibility of a large sample size. And students volunteer to participate in these competitions, so they are likely to have high levels of motivation.

The purpose of the current research was twofold: (1) to evaluate middle/high school robot builders' emotional responses to their robots using improved research instruments and (2) to examine factors influencing their emotion responses.

Emotional Responses to Robots

A number of research studies have investigated the interaction between humans and various types of robots (for a brief review see Huang et al., 2013; Jones & Schmidlin, 2011; Sung et al., 2007). In one study researchers proposed that children developed emotional attachment to AIBO, a robotic dog (Weiss, Wurhofer, & Tscheligi, 2009). Another study (Carpenter, 2013) found that soldiers became emotionally attached to their field robot and were reluctant to send it to a dangerous situation. When their robot was destroyed or became nonfunctional, some soldiers held funerals for their robot. Other research (Forlizzi & DiSalvo, 2006; Jones & Schmidlin, 2011) found that people treated their Roomba, a robotic vacuum machine, as a family member with a nickname and thought about their robot in gendered terms. And robots with attention-requiring sensors elicited more care-giving behaviors from participants, as well as positive experience in terms of enjoyment, reactivity, predictability, willingness to assist, and ease to interact (Hiolle, Bard, & Canamero, 2009).

The above researchers used the term "attachment" to describe the relationship between human and robots. However, they did not give a clear definition of attachment in their research, and the research all used small samples and descriptive text to describe human and robot relationship.

Inspired by an anecdotal observation of a student crying over dismantling his robot in a college robotics education class, Huang et al. (2013) investigated human-to-robot "attachment" using both qualitative and quantitative research method. Attachment in that study was defined as showing positive feeling when the object is present and negative feeling in the absence of the object, similar to definitions of attachment of a human to another human (consistent with definitions in the literature, e.g., Bowlby, 1969). The research modified a survey designed to study human attachment to pets to make it fit the human-robot scenario. In addition, the survey asked students to rate their affection level for the robot on a 10 point Likert scale. However, the results of the attachment survey showed no significant correlations with students' high affection for robots. Therefore, further research was suggested to revise the instrument and better measure human and robot relationship.

Huang, et al (2013)'s research raised new issues concerning (1) whether college students using robots in an educational scenario focused their emotional responses on the learning experience; (2) whether the human-robot relationship meets a strict technical definition of attachment; and (3) whether human-robot relationships require a different definition of human attachment to robots?

In order to answer these questions, the present research explored more about the relationship between human and robots. Figure 1 presents a model of emotional responses to a robot. The model, has two dimensions -- positive emotion when the robot is present, and negative emotion when the robot is absent or damaged. Each dimension has some indicators to measure its extent:

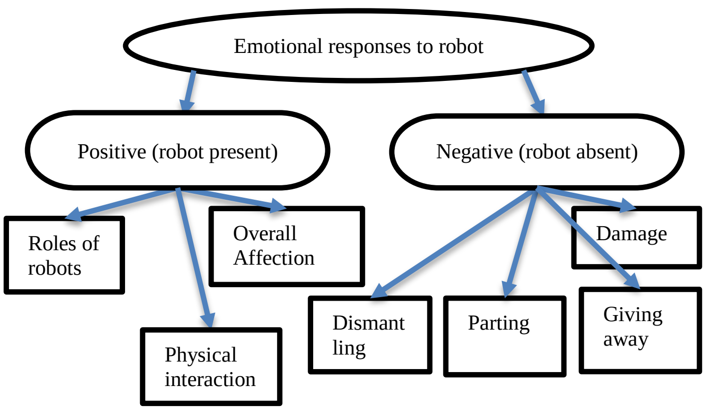

Figure 1. Model of Human Emotional Responses to Robot

Factors that Influence Emotion

Involvement. A conversation with a previous high school robotics team manager suggested the nature of a robotics team (i.e., whether the students independently work on the robot without direct help from mentors) might influence the relationship between students and robots. In some teams, the mentors and coaches are so heavily involved that the students only get to drive the robot using remote controllers without actually touching any parts of the robot. It is reasonable to assume that involvement is an important factor influencing emotion toward an object. A possible way of investigating involvement is to measure students and mentors' responsibilities respectively to determine if the students actually get involved in various aspects of a robot construction.

H1: Independent student teams will have stronger positive affect toward the robot.

Another way to measure involvement is by the time spent working on and with the robot. Normally, robotics teams spend six weeks building the robot from scratch after they get the problem kit.

H2: The more time spent building the robot, the stronger the emotional bond.

Participation in tournaments. Different from working on a class project, participating in tournaments is more intense and fast paced. In order to compete and win, students who participate in tournaments tend to be more motivated to work on the robots.

H3: The students participating in a robotics tournament will display stronger positive emotion toward the robot than will non-tournament students.

Performance. The team robot performance at tournaments included two aspects: actual place at the tournaments, and their expectation of their performance.

H4: The students in a team with actual performance higher than their expectation will display stronger positive emotion toward the robot.

Features of the robot. Previous research (Huang et al., 2013; Jones & Schmidlin, 2004) suggests that several features might influence people's emotional response to objects, including: playfulness, ease of use, exceeding my expectations, great learning experience, good companion, easy to learn to use, low rate of malfunction, continuous improvement, my capability to improve it.

H5: Specific features of the robot itself will increase positive emotion toward the robot.

A hypothesized model for factors influencing emotional responses to robot is developed as below (see Figure 2)

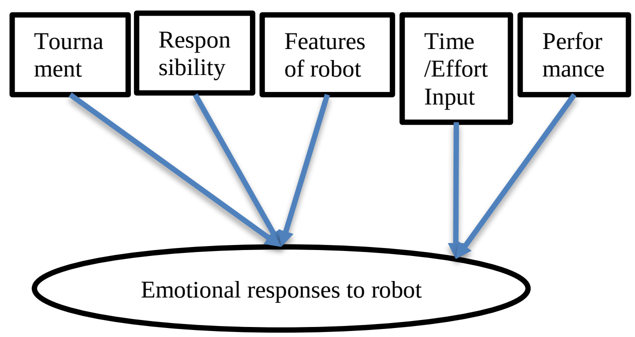

Figure 2. Model of Factors Influencing Human Emotional Responses to Robot

METHODS

Participants

From February 28 to April 30, 2014, an online survey recorded 337 entries. Removing incomplete surveys and surveys filled by non-middle/high school students, resulted in 54 subjects who participated in tournament this year (38 male, 16 female; age ranged from 10 to 18, *mean* = 15; education from 6^{th} grade to 13^{th} grade, *mean* = 10.70), and 67 subjects who had only classroom robotics experiences (42 male and 25 female; age ranged from 12 to 15, *mean* =13; education from 8^{th} to 9^{th} grade, *mean* = 8.36). Classroom robotics experiences included classes and activities: robotics REC 1, robotics REC 2, LEGO® MINDSTORMS®, Project lead the way (PLTW) automation and robotics, robotics camp, and various robotics projects. Tournaments included FIRST Tech Challenge (FTC), FIRST Lego League (FLL), FIRST robotics Competition (FRC), and VEX robotics.

Measures

Essay questions. The essay questions explored participants' attitudes and background, including but not limited to:

- Their responsibilities in the team and their coaches and mentors' responsibilities in the team
- The meaning/role of the robot and reasons for their choice
- The affection for the robot. The extent of liking the robot on a 0 to 100 scale, and reasons for the choice
- Feeling about dismantling the robot

Emotion responses questionnaire. This was a revised version of a previous human-robot relationship survey (Huang et al., 2013), using a 0 to 100 bar scale (0 = not at all, 100 = extremely). Example items were: I am passionate about the robot; I would feel hurt if the robot gets scratched or broken. The emotional response questionnaire had very high internal reliability (*Cronbach's Alpha* = .96).

Features of the robots questionnaire. This questionnaire was developed in the exploratory study (Huang et al., 2013), but the scales changed from seven-point Likert scale to a 0 to 100 bar scale. Features of the robots included: 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). The features of robots questionnaire also had high reliability (*Cronbach's Alpha* = .89).

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

Procedure

In order to recruit participants, the first author visited various robotic competition tournaments in North Carolina during the first three months of 2014 to introduce the research and survey to robotics team coaches/mentors in person, and also contacted event coordinators who knows more coaches/mentors. Then the coaches/mentors helped distribute the survey to their students who participated in tournaments, or just in their class. This online survey research was voluntary and designed to maintain participants' anonymity.

RESULTS

Affection for the Robot

Among 121 subjects, ratings of degree of liking the robot ranged from 0 to 100 (*mean* = 74.35, *SD* = 24.66). Seventy four (61.16%) students reported 80 or higher, including 20 (16.5%) students who rated liking of 100. There was a statistically significant difference between students with tournament experience (*mean* = 82.61, *SD* = 21.03) and students without tournament experiences (*mean* = 67.69, *SD* = 28.92). Therefore, the data supported hypothesis 3 that participation in tournaments resulted in higher affection for robots. As can be seen in Table 1, students who gave ratings of affection of 80 and higher listed different reasons for their ratings than those who gave ratings of 50 and lower.

Feeling about Dismantling the Robot

The reported emotions about dismantling their robots fell under three categories, including: 1) Negative (n=61): sad, annoyed, angry, depressed, mad, offended, anxious, upset, devastated, hurt, disappointed, horrible, emotional turmoil, feel like cussing, bad; 2) Neutral (n=49): fine, all right, ok, not care, indifferent, unaffected, bittersweet, not that bad; 3) Positive (n=11): fun, glad, great, happy, relieved. If negative responses were coded -1, neutral 0, and positive ones 1, then overall attitudes were negative (*mean* =-.41, *SD* =.65). The tournament group (*mean* = -.67, *SD* =.58) had significantly stronger negative emotion (F (1,121) =16.53, p <.01) than classroom group (*mean* = -.21, *SD* = .64).

Table 1 Reasons for the Affection Levels

Rating	Reasons (examples)
80-100	• **Uniqueness:** "its unique design" • **Team work: "**Dedication of the team members", "It has shown the improvement in my skills as well as the teams growth over the 3 years we have been a team" • **Increase grades:** "It brings my grade up" • **My Input and effort**: "I felt proud that I made the robot do that", "We put a lot of time and effort into this robot, and it's grown on me." • **Functioning**: "I love it when after hours of troubleshooting and programming, your robot finally comes together", "it was working as intended, clean, serviceable, and well-built", "easy to repair during competition" "It can also complete every task in the game." • **Cool sensors:** "The robot uses a lot of sensors to help it maneuver during the autonomous section of the game which is really cool" • **Personality:** "I like challenge"
0-50	• **Difficulty**: "Too much complicated processes instead of keeping it simple", "i don't understand how to do it" • **Malfunctioning**: "Sensors not working", "The robot always breaks and never works how it is supposed to" • **Time consuming**: "its a waste of time to make" • **Grade concerned**: "its just some grade i have to make" • **Esthetic**: "not pretty", "the design is not too great" • **No interest**: "I do not care", "not for me"

The subjects' responses indicated that knowing this would eventually happen, past experience of dismantling robots, and building new tasks made the act more acceptable, but no students who rated 100 on liking the robot reported positive emotion (see *Table 2*).

Table 2 Feeling about Dismantling the Robot

	Statements of people who rated 100 on liking the robot (examples)
Neg.	• That would be horrible. I am greatly hoping that since we won this year that she will not have to die. Although if I had to kill her, I would be very sad but I could maybe do it but not without going through emotional turmoil • I would be adamant in saying no. it would be like destroying the mona lisa to myself • I would be rather mad, but I would only do it with a completely valid reason. I would need to be 100% sure that it was for the greater good.
Neutral	• I had to dismantle it anyways so I had no remorse because I know I could build it again if needed. • Ok because The robot served its purpose

Meaning/Role of the Robot

The majority of classroom group treated the robot like an assignment, whereas the tournament group had more positive emotion towards the robot (see *Table 3*).

Table 3 Meaning of the Robot among Tournament Subjects

Role	N	%	Explanation Examples
Baby	12	22	• "I care for her, and we raised her as a family." • "I helped make it, and I care about it a lot." • "I made him; I worked hard for him; and I helped name him. His accomplishments are based on my own and I am extremely proud of him." • "I love my robot so very much"
Friend	1	2	• "i spend a lot of time on it" • "I felt sad when it was unsuccessful or damaged and happy when it was successful at what it did."
Tool	11	20	• i can modify it and use it to help me in everyday life. • In a way, it could be the child of the whole team. I think it is a tool most importantly because we use it for competition and robots are meant to be used for the benefits of humans.
Pet	5	9	• "at time the robot was comparable to a pet. for example getting the robot to accomplish a task after hours of work had a similar feel to the feeling one gets after teaching a dog a new trick. but my inability to communicate with the robot through normal speech was similar to the communication breakdown between human and animal."
Assist	5	9	• "It helps us complete the tasks we cant do on our own."
Toy	6	11	• working with the robot feels a lot like playing with a toy because I get to have fun testing out new things with it
Others	14	26	• "My means to express my inner strengths…" • "My assignment and creation…" • "i believe the best description would be my hero!" • "TEAM MATE: …we work together as a team to compete in the competition" • "My precious!!!!!" • "It is my problem, because I need to worry about it 24/7 and somebody messing it up"
Total	54	100	

Emotional Response Questionnaire

Correlation with overall affection for robot. The average score of the emotion response had a significantly positive correlation with overall liking of the robot in all students (r=.50, p <.01) and both the classroom and tournament groups (r=.33 and .60, respectively both ps<.01).

Factor analysis. The exploratory factor analysis revealed two factors accounting for 67% of the variance. The specific factors were consistent with the hypothesized emotion model. Items that loaded on the expected positive when present component were (1) liking the robot, (2) playing with the robot, (3) caring about the robot, (4) being passionate about the robot, and (5) feeling a strong responsibility for the robot. In contrast, items that loaded on the expected negative when absent component were (1) I would feel bad if I can no longer see the robot, (2) I would feel hurt if the robot gets scratched or broken, (3) If I have to dismantle the robot, I would feel sad. However, the following items also unexpectedly loaded on the negative emotion when absent factor: (1) willing to spend a lot of time with the robot, (2) feeling close to the robot, (3) feeling pleasant being with the robot, (4) feeling attached to the robot.

Students' Responsibilities

Hypothesis 1 tested whether independent teams in which students are fully involved in building a robot will have stronger positive affect toward their robot than will dependent teams in which coaches and mentors do all the work and students only watch and control the robot remotely. Some big teams have separate coaches and mentors, while some small teams have a single person serve as coach and mentor. In a few cases, students were involved so much in the team that they served as the team coaches.

The students listed the following responsibilities, including: 1) *Technical aspect:* computer engineer (programming), mechanical designer, repairs, mechanical engineer (building robot), design and construct mechanical components, electrical engineer (wiring), engineering, computer engineer, mechanical engineer, driving robots during some competitions; 2) *Other aspects:* writes down everything, moral support, cheerleader.

According to the data, the students had a clear understanding that they were the ones to build the robots not the coaches and mentors. Here are some examples:

- "The Mentor/Coach only supervises us and gives us feedback or ideas when we need them. The Robot competition is for us and not him"
- "There is rarely direct guidance"
- "Our teacher helps us with our scenarios and grades the robots, but we build everything on our own"
- "To keep everyone in line, but other than that we have a president and vice-president to run 'the show'"

No data indicated a student being on a dependent team. Therefore, the hypothesis 1 about the dependence of the teams could not be tested without comparison.

Time/effort Input

The question about time input was included in the emotional responses questionnaire: I feel I put a lot of effort into the robot. The time/effort input and overall affection had a significantly positive correlation (r =.35, p <.01). This finding provides support for hypothesis 2 about the relation between positive emotions and time and effort.

Performance Expectation

Correlation with overall affection. Explicit performance rankings were not directly comparable across different tournaments. However, students' expectation of performance could be examined (3=performance was higher than expected, 2=equal, 1=lower than expected). The results indicated significantly positive correlation between a robot's performance expectation and their overall affection for the robot (r = .26, p<.01). In other words, the better the robots perform beyond expectation, the stronger the builders' affection for them. Hypothesis 4 was supported.

Features of Robots

The survey showed the top three features of robots that contribute to their emotion responses were: helpful in learning science and technology, easy to learn to use the robot, robot evolved over time (see Table 4).

Correlation with emotion questionnaire. All the items in the features of robots questionnaire had significantly positive correlations with the emotion questionnaire average score, with r ranging from .49 to .83, all p <.01. All items also had significantly positive correlations with overall affection, with r ranging from .33 to .50, all p <.01. Therefore, the hypothesis 5 was fully supported.

Table 4 Ranking of Robot Features (N=54)

Feature	Mean	SD
3. I found the robot very helpful in learning science and technology.	84.06	27.93
4. I found it is easy to learn to use the robot.	78.70	25.70
7. I found the robot exciting because it evolved over time.	72.70	32.71
8. The robot evolved the way I wanted because I was able to add functions to it.	58.80	34.81
5. I found the robot exceeds my expectation of what a robot can do.	52.20	36.07
2. Sometimes it seemed that the robot appeared to show personality.	51.11	38.55
1. I found the robot playful.	48.81	36.81
6. I found the robot worked effectively without malfunction.	45.93	32.02

DISCUSSION

Emotional Responses to the Robots

This study used multiple approaches to explore middle school and high school students' emotional responses to their tournament robots. Those approaches included single questions about the overall affection for the robot, feeling about dismantling the robot, the meaning/role of the robot, and a comprehensive emotional response questionnaire.

The qualitative and quantitative data revealed a variety of emotional responses students had toward the robots they built. Two dimensions were created to describe the emotions -- positive emotions when they are with the robot, or negative emotions when they are without the robot.

The rating scales and rationales for their rating indicated that the tournament group had a significantly stronger emotional responses towards their robots than did the classroom group. The former also tended to treat the robots more anthropomorphically than the latter did.

Interestingly, a subject described his negative feeling about dismantling the robot being similar to destroying other things that are personally significant to him. In another sense, this emotional responses could be generated to other objects, not just robots.

The reliability of the questionnaire was quite high, and it had significant correlation with overall affection for robot. The data indicated that the emotional responses questionnaire did capture the students' emotional dimensions toward the robot and it is more reliable than the previous attachment scale.

Influencing Factors

Responsibility. Asking them actual responsibilities turned out not the best way to measure the extent of involvement. A better measure might be a rating scale of perceived responsibility: what percentage did the students and mentors at the team contribute to the robot assuming the robot is a 100% project.

Time and effort. The results supported the hypothesis that the perceived time/effort input was positively related to the affection for the robot, which could be reasonably explained by the Festinger effect.

Participation in tournaments. Participation in tournament definitely was associated with students' specific emotional responses. Future research should examine whether this association is due to the differential experience or to selection bias during group formation.

Features of the robots. All items on the features of robots questionnaire were found to contribute to emotional responses to the robot. In addition, Table 1 under reasons of affection for robot question also provide information: Uniqueness, good teamwork, cool sensors, functioning, and bonus "feature" – good grades. These factors could be incorporated in the future research in terms of extrinsic and intrinsic motivation as well.

Limitation and Future Research Direction

Unfortunately, the present study had many incomplete surveys, the future survey might add validation setting to encourage completion of the surveys and increase the data to more than 150 valid data entries, for more powerful analysis.

More indicators for each emotion dimensions could be added to the emotional response model and survey, such as frustration level, since many student mentioned it was pretty frustrating in the trouble shooting process, yet why they still had strong affection for the robot. In addition, the questionnaire could be further validated.

As one student mentioned, significance of an object influences emotional responses to the object. It is worth exploring what make things personally significant, and then we may understand emotional responses better not only to robots but also to other objects like general technology.

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