Emotionally Supporting Humans Through Robot Hugs

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ABSTRACT
Hugs are one of the first forms of contact and affection humans experience. Due to their prevalence and health benefits, we want to enable robots to safely hug humans. This research strives to create and study a high fidelity robotic system that provides emotional support to people through hugs. This paper outlines our previous work evaluating human responses to a prototype's physical and behavioral characteristics, and then it lays out our ongoing and future work.

KEYWORDS
Social-physical human-robot interaction, system evaluation

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1 INTRODUCTION
Hugging gives an individual social support, relieves stress, lowers blood pressure, and increases oxytocin levels [2]. Because of hugging's health benefits, roboticists have tried to artificially create this gesture. DiSalvo et al.'s The Hug is a plush comfort object, whose shape mimics a child's; it works in pairs to provide users "tele-hugs" [3]. While its stomach glows, vibrates, and plays a melody when receiving a hug, it lacks the ability to wrap its arms tighter around the human, and it requires an additional human partner. Stiehl et al.'s teddy bear robot, the Huggable, uses sensors under a layer of silicone and fur to detect where and how it is being touched [9]. It provides companionship to and monitors children in the hospital. While it can move its head and arms, because of its small size, it can be hugged but cannot actively hug back.

Shiomi et al. ran two experiments with a large teddy bear robot, finding that users who hugged the robot interacted with it longer, provided more self-disclosure, and afterwards were more inclined toward prosocial behavior [8] [7]. Miyashita and Ishiguro used an autonomous wheeled inverted pendulum humanoid robot to hug in a three-step process, while maintaining its balance [5]. Determining the hug duration was not described. It appears the robot uses the human to balance itself, which is a potentially uncomfortable tactile experience for humans, as it is made of metal.

Physical properties affect how contact interactions are perceived. Harlow and Zimmermann showed the correlation between softness

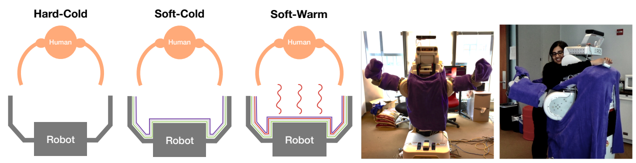

Figure 1: The three physical robot configurations tested, the soft robot outfit, and a hug taking place.

and comfort: when infant monkeys were given the choice of which surrogate mother they preferred, a wire mother who fed them or a cloth one who did not, the majority chose the cloth mother [4]. Williams and Bargh showed that humans associate positive/warm personality traits with warm physical contact, and vice versa; here subjects briefly held a cup of warm or iced coffee and were then asked to judge a target person's personality [10]. This result was replicated when Park and Lee altered the skin temperature of a dinosaur robot [6]. They found user perceptions of the sociability of the robot increased with warmth.

2 COMPLETED WORK
My initial work on this topic addressed the research question, "How should robots hug?" We hypothesized that a soft, warm, touch-sensitive humanoid robot would provide satisfying hugs to humans by matching their hugging pressure and duration. I conducted a 30-participant study where users experienced 12 hugs from Willow Garage's Personal Robot 2 (PR2): the first group of 3 hugs varied the physical conditions, and the second group of 9 hugs varied the behavioral conditions. The presentation order of the hugs was varied within each group, and the user completed a survey after each hug.

Three different physical conditions were tested, as shown in Fig. 1: a hard-cold, a soft-cold, and a soft-warm robot. A hard-warm robot was not tested because the heating elements somewhat soften the robot and divulge the thermal experimental variable to users. **Hard-cold:** The robot has no additional padding layers. **Soft-cold:** The robot wears a layer of foam, a layer of cotton, then a layer of purple fluffy polyester. **Soft-warm:** The robot wears the same as the soft-cold condition with added heating elements: the wires from an electric blanket cover the robot's chest and back. A heating pad is placed on the chest. Chemical warming packs are placed on the robot's upper arms and forearms. The robot outfit was designed to be gender neutral to be more universally accepted and to limit the number of experimental variables.

Nine different behavioral conditions were tested, varying the pressure and the duration of the hug. We customized three distinct pressure levels for the robot to hug each user: "too loose," "just right," and "too tight". Using flexible sensors [1] to detect user contact on the robot's back, we programmed the robot to terminate the hug "too soon" (not using user input, releasing 1 second after the arms close), "just right" (immediately upon human release), and "too late" (releasing 5 seconds after the human released).

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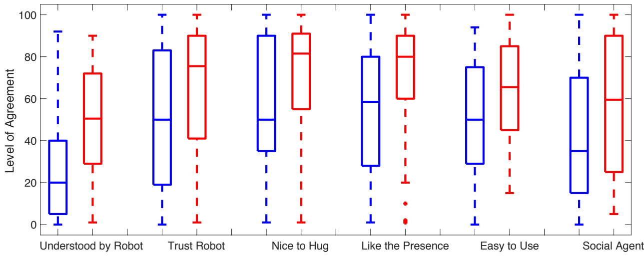

Figure 2: The results of the opening (blue) and closing (red) survey responses with significant differences. The top and bottom of the box represent the 25th and 75th percentile responses, respectively, while the line in the center of the box represents the median. The lines extending past the boxes show the farthest data point not considered outliers. The dots indicate outliers.

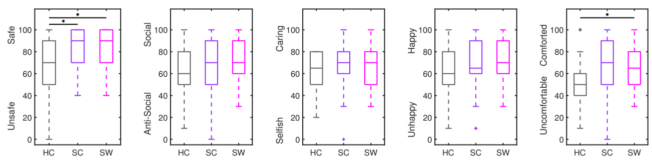

Figure 3: A comparison of the responses to the survey questions after the first three hugs, changing physical conditions. The grey represents the hard-cold condition (HC), the purple color represents the soft-cold condition (SC), and the pink color represents the soft-warm condition (SW). Black lines with stars at the top of the graph indicate where there was a statistically significant difference found.

Subjects completed a 15-question opening survey based on their initial impressions of the robot, and they answered the same questions at the end of the experiment. These subjective measures were used for evaluation because we were interested in user preference, attitude, and opinion. We plan to include objective measures such as heart rate and facial expression in future experiments. These results were analyzed using a paired t-test comparison, and we found that users felt understood by, trusted, and liked the presence of the robot significantly more after the experiment ($p < 0.05$). As shown in Fig. 2, people also found robots to be nicer to hug, easier to use, and more of a social agent than they initially anticipated, after the experiment.

All post-trial survey responses were analyzed in MATLAB 2017a using a repeated measures analysis of variance with a Tukey's posthoc multiple comparison test to determine which conditions differed significantly. As can be seen in Fig. 3, the perceived safety of the robot increased in both soft conditions, while only the soft-warm condition improved the users' comfort.

While significant differences were not noticed in the surveys between the three tightness factors, written and verbal comments made to the experimenter indicated user preferences for "very tight hugs". As can be seen in Fig. 4, users thought the robot was more social, more caring, and made them feel happier and more comforted when it released them immediately or held on to them too long. Written and verbal comments indicated a preference for an immediate release from the hug, though a significant different was not noticed between these two levels in the surveys.

3 ONGOING WORK

I plan to expand and refine this project over the course of my doctorate. First, we will create a new robotic platform, customized for

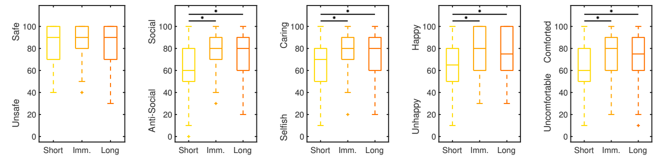

Figure 4: A comparison of the responses to the survey questions after the last nine hugs, changing behavioral conditions. This row represents the three levels of the duration factor. Shading indicates the level, from shortest (light) to longest (dark).

social-physical interactions with humans. After an extensive search, we have chosen to use two Kinova JACO arms because of their slender design, quietness, fluid movement, and their built-in safety features. We will cover the arms and chest in a layer of foam, thermally conductive fabric, and electrically conductive fur for softness, heating, and touch sensing, respectively. This new robot will match the hugging pressure of the human user, and it will use torque and/or tactile sensors to determine when the subject wants to be released.

Next, we aim to enable people to send customized hugs to each other through this new platform, to discover the extent to which personal connections can be reinforced at a distance. We plan to create an online forum for people to customize the hug they would like to send, including setting a duration, uploading a voice recording, and adding a rub or pat on the receiver's back.

A final area we are interested in investigating is equipping this robot with emotional intelligence. Using machine learning, we will enable the robot to sense a person's mood based on facial expressions measured using a camera-based emotion tracking tool, and the way a person hugs the robot, which is a form of haptic intelligence only people currently possess.

Applications for this research range from helping alleviate student stress on college campuses to bringing happiness to residents of nursing homes. As research progresses, it could also be adapted for use by people undergoing rehabilitation or children with autism.

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