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What robots can teach us about intimacy: The reassuring effects of robot responsiveness to human disclosure

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ABSTRACT

Perceiving another person as responsive to one's needs is inherent to the formation of attachment bonds and is the foundation for safe-haven and secure-base processes. Two studies examined whether such processes also apply to interactions with robots. In both studies, participants had one-at-a-time sessions, in which they disclosed a personal event to a non-humanoid robot that responded either responsively or unresponsively across two modalities (gestures, text). Study 1 showed that a robot's responsiveness increased perceptions of its appealing traits, approach behaviors towards the robot, and the willingness to use it as a companion in stressful situations. Study 2 found that in addition to producing similar reactions in a different context, interacting with a responsive robot improved self-perceptions during a subsequent stress-generating task. These findings suggest that humans not only utilize responsiveness cues to ascribe social intentions to robots, but can actually use them as a source of consolation and security.

1. Introduction

Robots are predicted to serve in an increasing number of intimate support roles, such as nursing, childcare, education, and elderly care. In these roles, robots may be required to monitor their human interlocutors and engage in supportive interactions. For example, a robot serving in an elderly care facility might provide support by listening to the experiences of elderly people. The way a robot responds to the human's communication in such scenarios may have a profound effect on various personal and relationship outcomes, including the human's perception of the robot, the human's sense of support and security, the human's willingness to continue to interact with the robot, and the human's overall well-being.

Indeed, in humans, perceiving another person as responsive to one's needs is inherent to the formation of emotional bonds. As such, it plays a key role in intrapersonal and interpersonal processes (e.g., self-regulation, relationship well-being; Reis, 2014) in a variety of contexts, including parent-child relationships, adult close relationships, and therapeutic relationships (Reis & Clark, 2013; Reis, 2014). Unfortunately, the social skills displayed by many caregiving robots are not sufficiently effective in evoking the appropriate sense of responsiveness that is characteristic of human disclosure and well-being (Torta, Oberzaucher, Werner, Cuijpers, & Juola, 2012). In the present research, we sought to explore whether implementing responsiveness cues in a robot would be compelling enough for these keys to human bonding to be also evident when interacting with inanimate objects. Specifically, we examined whether humans would be receptive to responsive support from a robot, using it as a safe haven in times of need and as a secure base for becoming more confident in a subsequent stressful interaction.

1.1. Related work

1.1.1. Socially assistive robots

Robots that assist human users through social interaction, as

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opposed to merely assisting them by their mechanical capabilities (e.g., carrying things), are categorized as socially assistive robots (Feil-Seifer & Mataric, 2005). These robots have already been used successfully in a variety of therapeutic applications (see Rabbitt, Kazdin, & Scassellati, 2015; for a review). In these applications, a robot's multimodal communication channels allow it to communicate verbally and non-verbally with humans, enabling humans to benefit from socially interacting with the robot, engage in personally meaningful relationships, and experience enhanced well-being as a result. For example, the baby seal robot PARO, which was designed to be held and touched, was deployed in a senior center. There, seniors interacting with it displayed increased levels of human-human interaction, as well as decreased levels of stress (Wada & Shibata, 2007). Robots have also been found to improve the social interaction skills of children with autism (Scassellati, Admoni, & Mataric, 2012) and help patients to recover from injury by adhering to activity recommendations (Gadde, Kharrazi, Patel, & MacDorman, 2011; Mataric, Eriksson, Feil-Seifer, & Winstein, 2007).

Research suggests that people tend to perceive robots as social actors and attribute to them human-like traits, including mental states and personality (e.g., Friedman, Kahn, & Hagman, 2003; Lee, Peng, Jin, & Yan, 2006). Studies also suggest that people are willing to play along with the illusion that the robot is a sentient creature appropriate for relational interactions. They are often willing to ignore the mechanical aspects of the robot and to treat it in a manner similar to how they would respond to a fellow human being (Turkle, 2007). For example, preschool children were as likely to share a secret with a robot that listened to them as with a human, given a similar amount of prompting questions, and interacted with the robot using similar social conventions (Bethel, Stevenson, & Scassellati, 2011). Adults who interacted with both a social robot expressing social behaviors, like turn-taking and emotional expressions, and a text-based assistant saw the robot as more empathic and trustworthy than the text-based assistant, and expressed more conversational behavior toward it (Looije, Neerincx, & Cnossen, 2010).

1.2. Robot responsiveness and humans' perceptions of attachment-related behaviors

Building on the literature that indicates that perceived partner responsiveness is the linchpin of human attachment processes, with positive effects on personal and relational well-being (Reis & Clark, 2013), we argue that responsiveness will be a crucial feature for any robot in order to be fully effective in a caregiving role. In particular, such a robot will need to display behavior that is psychologically sensitive to their care-receivers and behave in a manner that is attentive to and supportive of their needs. Furthermore, humans will have to be receptive to receiving responsive support from this robot. We sought to extend the literature on socially interactive robots by examining how human participants would respond to a robot that behaves as if it possessed responsiveness skills and whether humans who interact with such a robot would ascribe human-like traits and social intentions to the robot and benefit from doing so.

We proposed possibilities for designing responsive behaviors in non-anthropomorphic robots and investigated whether a robot's behavior could instill a sense of responsiveness and the effects of a robot's perceived responsiveness on humans' perceptions of the robot's appeal. Increased robot attractiveness could have implications for the robot's perceived value and thus for long-term relationships with a caregiving robot, including humans' willingness to interact with the robot and the amount of time they would want to spend with it. Because responsiveness is known to affect perceptions of attraction and mate value in human relationships (Birnbaum & Reis, 2012; Birnbaum, Ein-Dor, Reis, & Segal, 2014), we expected that similar social mechanisms would come into play between humans and the robot. However, given that the robot was not a potential romantic partner for the disclosers, we were interested in a broader notion of attraction to and impressions of the robot. We therefore evaluated attraction in a more general sense and combined this metric with measures that assessed people's impression of the robot's positive human-like character traits (sociability, competence, and attractiveness).

We also explored whether humans would display attachment-related behaviors while interacting with the robot (e.g., proximity and reassurance seeking) and might actually use the robot as a source of consolation and security in times of need. Such behaviors may indicate that the robot serves safe-haven and secure-base functions similar to those served by a human attachment figure. Indeed, a caregiver who is responsive when an individual experiences distress assists in emotion regulation (i.e., acting as a safe haven) and instills a sense of security (i.e., acting as a secure base), which promotes feelings of competence for coping with future stressful circumstances (Bowlby, 1969/1982). Accordingly, we expected that a responsive robot would be more likely than an unresponsive robot to be approached, to be viewed as a desirable companion in times of distress, and to promote self-perception under stress.

Specifically, in two studies, participants disclosed a personal event to a non-humanoid robot that responded either responsively or unresponsively across two modalities (simple gestures and written text). In Study 1, participants disclosed a negative event to the robot and, after interacting with the robot, rated its responsiveness and appeal as well as their desire for robot companionship in times of need (a manifestation of the safe-haven function in attachment theory terms; Bowlby, 1969/1982). These interactions were videotaped and coded by independent judges for self-disclosure and approach behaviors towards the robot. Study 2 examined whether a robot's responsiveness in a different context, the disclosure of positive events, would produce positive reactions in people interacting with it and improve their self-perception during a subsequent stress-generating task (a manifestation of the secure-base function in attachment theory terms; Bowlby, 1969/1982).

1.3. Hypotheses

Hypothesis 1. A responsive robot (versus an unresponsive one) will be perceived as more responsive and appealing (sociable, competent, and attractive).

Hypothesis 2. A responsive robot (versus an unresponsive one) will elicit more approach behaviors during the interaction.

Hypothesis 3. A responsive robot (versus an unresponsive one) will increase the desire for its companionship when alone or under stressful circumstances.

Hypothesis 4. A responsive robot will improve self-perception during a subsequent stress-generating task.

Hypothesis 5. Perceived robot responsiveness will mediate this effect of the robot responsiveness manipulation on self-perception.

2. Study 1

Study 1 was designed to examine the effects of a robot's responsiveness to human disclosure on perceptions of robot's responsiveness and appeal. In addition, Study 1 sought to demonstrate not only that people feel that a responsive robot is more appealing than an unresponsive robot, but also that they exhibit more approach behaviors towards the robot during interaction and use it as a source of consolation in times of need. Participants had one-at-a-time videotaped sessions, in which they disclosed a recent negative event to a desktop-scale, non-humanoid robot. The robot responded with either responsive or unresponsive behaviors, across two modalities: simple gestures and written text. Following this interaction, participants rated the robot's responsiveness, sociability, competence, and attractiveness, as well as their desire for robot companionship when alone or under stressful circumstances. Independent judges rated each participant's self-disclosure and approach behaviors towards the robot.

2.1. Method

2.1.1. Participants

One hundred and two undergraduate students (49 women, 53 men) from a university in central Israel volunteered for the study without compensation. Sample size was determined a priori via power analysis (targeting 80% power to detect an effect size, *d*, of 0.50 at $p < 0.05$). Participants ranged from 20 to 34 years of age ($M = 24.13$, $SD = 2.62$). No significant differences were found between the experimental conditions for any of the socio-demographic variables (e.g., age, relationship status).

2.1.2. Measures and procedure

Participants who agreed to participate in a study of a new speech-comprehension algorithm were individually scheduled to attend a single half-hour laboratory session, which was adapted from Birnbaum and Reis (2012) to reflect human-robot interactions. Prior to each session, participants were randomly assigned to interact with either a responsive or an unresponsive robot. We used the robot Travis (Hoffman & Vanunu, 2013; Hoffman, 2012), which is a research platform developed to examine human-robot interactions. Travis is a small non-anthropomorphic robot with a vaguely creature-like structure, but without a face (see Fig. 1). It is capable of basic gesturing (e.g., nodding, swaying). Travis stands about 28 cm (11 inches) tall, sized so that, when placed on a desk, its head is roughly in line with a seated person's head in front of it. All the robot's software runs on an Android smartphone, sending motor positions and velocities to an electronics board controlling the motors (see Hoffman, 2012, for a detailed description of the robot's design, hardware, and software modules).

In this experiment, the robot was controlled remotely in a Wizard-of-Oz setup (Riek, 2012). This setup allowed the wizard operator, who was sitting in a control room, to operate the robot, controlling its gestures and the text it produced (its "speech"), without the awareness of the participants. The setup had three main control components networked through a wireless network: A PC, which was located in the control room; a smartphone, which controlled Travis by being directly connected to the robot, and placed in the robot's "hand"; and a tablet, which was leaning against Travis's body and displayed its responses to the participants' disclosure. The wizard operator used the PC to type in these responses. Travis displayed the text on a tablet screen, instead of using audible speech, to eliminate the possibility for estrangement associated with a robotic voice. This screen was completely black, except when Travis presented text. Then, a single sentence appeared on the screen for five seconds before disappearing. The wizard operator also used the PC to send commands to the smartphone, which translated them into timed motor commands. Two cameras were monitoring the experiment room to enable the wizard operator to time Travis's behaviors to the participant's speech acts.

Upon arrival at the laboratory, participants were led to believe that we were testing a new speech-comprehension algorithm developed for robots. Then, they completed a demographic questionnaire and were asked to sit on the couch, facing Travis (see Fig. 2), and to disclose a personally negative event to it. Participants were informed that the robot would try to understand what they say and respond with a relevant response, using artificial intelligence and speech recognition. Participants were given the following instructions:

> "*We would like you to choose some current problem, concern, or stressor you are facing in your life. This may be something that happened before but continues to bother you, something going on now, or something you anticipate will happen in the future. Some examples could be a recent argument with a friend or a family member, a grade in class, work or financial problems, or personal illness. Please pick something that has been on your mind recently, no matter how big or small you may think it is. While you are*

Fig. 1. Travis, the robot used in the experiments.

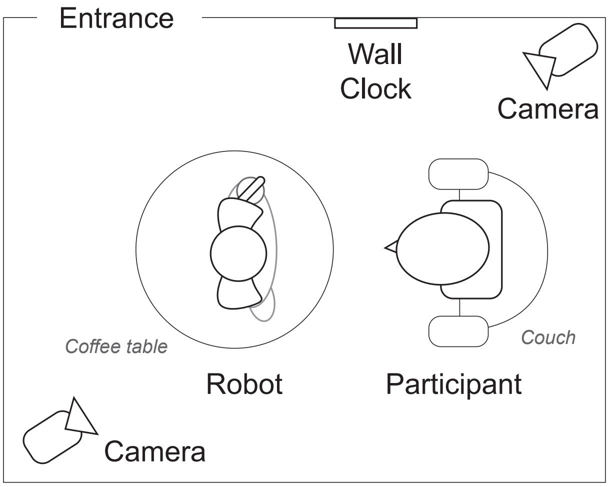

Fig. 2. Experimental room layout diagram. The robot's head height is roughly in line with the seated human's eyes.

> *interacting with the robot, please feel free to talk about anything related to the personal concern by dividing it into three messages. Some suggestions would be to discuss the circumstances surrounding the concern in your first message; how you feel and what you think about the concern in your second message; and any other details or issues that you think are important, such as the implications of this event for your life, in your third message. At the end of each message, please use the statement 'and that's it', which will signal to the robot that the part is done and that speech recognition can begin. The robot will reply to each of your messages with a single line*."

Participants and Travis then discussed the participant's negative event for up to 7 min. These interactions were videotaped by two cameras mounted in the corners of the room (visible to participants), allowing for full frontal recording. We experimentally manipulated Travis's responsiveness across two modalities: simple gestures and written text. On the non-verbal channel, we displayed responsiveness by having Travis maintain a forward focus towards the participants, gently sway back and forth to display animacy, and nod affirmatively in response to human speech. The same behaviors were used consistently and roughly at the same time points in the disclosure. On the verbal channel, we used positively responsive speech acts, following a previously established protocol of human responsiveness to negative event disclosures (Birnbaum & Reis, 2012; Birnbaum et al., 2014). Specifically, at the end of each participants' message, the wizard operator selected a single standardized responsive message from a bank of preset phrases (e.g., "You must have gone through a very difficult time"; "I completely understand what you have been through"). These phrases were slightly adjusted to fit the content of the discloser's story, if necessary.

Travis displayed unresponsiveness by not engaging in any nonverbal behavior and by not commenting verbally, beyond asking the participant to continue to the next of the three segments of the participant's disclosure. This form of unresponsiveness is akin to giving someone "the cold shoulder." Paradoxically, such a neutral form of unresponsiveness might be more effective in displaying unresponsiveness in a robot than the more negative forms of unresponsiveness that humans often display (e.g., occasional distraction behaviors in the form of looking away from the human conversation partner), because some people may perceive any movement of the robot, even a distancing one, as responsive (Birnbaum et al., 2016; Hoffman, Birnbaum, Vanunu, Sass, & Reis, 2014).

After interacting with Travis, participants completed a measure of perceived robot responsiveness, adapted from Birnbaum and Reis (2012) to reflect human-robot interactions. The current version assessed perceptions of how understood, validated, and cared for the discloser felt when interacting with the robot. Participants rated nine statements, such as "The robot was aware of what I am thinking and feeling" or "The robot participant really listened to me." Items were rated on a 5-point scale from 1 (*not at all*) to 5 (*very much*). This scale was factorially unidimensional and internally consistent in our sample (see Appendix B). Participants also rated their impression of the robotic agent on an eight-item measure, indicating positive character traits (e.g., "To what extent do you think that the robot is cooperative?"; Hoffman & Vanunu, 2013). Four items tapped social perceptions of the robot (cooperativeness, sociability, friendliness, and warmth), and four items tapped competence perceptions of the robot (knowledgeability, consciousness, capability, and reliability). In addition, participants completed a six-item measurement of the robot's perceived attractiveness, adapted from Birnbaum, Weisberg, and Simpson (2011) to reflect robot rather than human attractiveness. This scale measured how attractive they perceived the robot to be (e.g., "How attractive is the robot?"; "How hot is the robot?"). These items were rated on a 7-point scale from 1 (*not at all*) to 7 (*very much*).

Finally, participants rated two items assessing their desire for companionship by this robot when alone or under stressful circumstances ("To what extent do you want the robot to keep you company during stressful events, such as a dental treatment and or a difficult test?"; "To what extent do you want the robot to keep you company when you are alone?") on a 5-point scale from 1 (*not at all*) to 5 (*very much*). We conducted a principal components analysis with oblimin rotation of the 10 items of the new measures assessing impression of the robot and desire for its companionship (see Appendix A). As expected, the items measuring perceived sociability, perceived competence, and desire for companionships loaded high on their respective components and relatively low (<0.40) on the other components. Moreover, all subscales had adequate Cronbach's α coefficients (see Appendix B for internal consistency reliabilities, descriptive statistics, and zero-order correlations). Upon completion of these questionnaires, participants were asked to provide demographic information (e.g., sex, age, relationship status, education) and then fully debriefed. We made sure, especially in the unresponsive condition, that they felt good about their participation in the study.

2.1.2.1. Coding approach behaviors and self-disclosure during the interaction with the robot. The video-recorded human-robot interactions were coded by a team of two trained independent judges (psychology students) who were blind to the hypotheses and to participants' condition and self-report data. Each judge watched the interactions and rated each participant's behavioral expressions of approach toward the robot (e.g., physical proximity, leaning toward the robot, smiling, and eye contact maintenance) in a single overall coding of approach behaviors. These behaviors typically signal warmth and immediacy and convey contact readiness (e.g., Andersen, 1985; Eibl-Eibesfeldt, 1989). The judges also coded participants' verbal self-disclosure (the extent to which the participants revealed personal information, feelings, and thoughts to the robot). Ratings were made on a 5-point scale ranging from 1 (*not at all*) to 5 (*very much*). Inter-rater reliability was high: intraclass correlation coefficients (ICC)[1] for approach behaviors and self-disclosure were 0.86 and 0.88, respectively. Hence, judges' ratings were averaged for each participant.

2.2. Results and discussion

2.2.1. Manipulation check

A *t*-test on perceived robot responsiveness yielded the expected effect, such that the robot was perceived as more responsive in the responsive condition than in the unresponsive condition. To determine whether differences existed between the responsive and unresponsive conditions in participants' self-disclosure, an independent-sample *t*-test was performed. Disclosure was not significantly different between the responsive condition and the unresponsive condition, suggesting that Travis's behavior did not interfere with participants' reactions to the experimental instructions, which were to self-disclose (see Table 1 for means, standard deviations, and statistics).

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[1] Notes: The intraclass correlation coefficient (ICC) reflects both degree of consistency and absolute agreement between the two raters about the extent to which approach behaviors and self-disclosure were displayed.

Table 1
Means, Standard Deviations, Statistics, and Effect Sizes of Perceptions of the Robot's Traits, Desire for its Companionship, Self-Disclosure, and Approach Behaviors for the Responsive and Unresponsive Conditions (Study 1).

	Responsive Robot		Unresponsive Robot		$t_{(100)}$	*Cohen's d*	*95% CI for Cohen's d*
	M	*SD*	*M*	*SD*			
Perceived responsiveness	3.23	0.76	1.89	0.75	9.03^{***}	1.79	(1.33, 2.25)
Self-disclosure	3.75	0.71	3.60	0.83	0.97	0.19	(−0.20, 0.58)
Perceived sociability	4.45	0.89	3.10	1.17	6.57^{***}	1.30	(0.87, 1.73)
Perceived competence	4.18	0.84	3.28	0.95	5.06^{***}	1.00	(0.59, 1.41)
Perceived Attractiveness	2.98	0.82	2.81	1.03	0.88	0.17	(−0.21, 0.56)
Desire for companionship	2.20	1.11	1.79	0.88	2.07^{*}	0.41	(0.02, 0.80)
Approach behaviors	3.14	0.59	2.62	0.60	4.28^{***}	0.86	(0.45, 1.27)

Note. $^{*}p < 0.05$, $^{***}p < 0.001$.

2.2.2. Responsiveness, perceptions of robot's traits, desire for its companionship, and approach behaviors

To determine whether differences existed between the responsive and unresponsive conditions in perceived robot sociability, competence, and attractiveness, a one-way multivariate analysis of variance (MANOVA) for responsiveness condition was performed on these three measures. This MANOVA yielded a significant difference between responsiveness conditions, *Hotelling's Trace* = 0.53, $F(3,98) = 17.23$, $p < 0.001$, $\eta_p^2 = 0.35$, *95% CI for* η_p^2 (0.18, 0.46). A series of independent-sample t-tests indicated that this effect was significant for perceived robot sociability and competence, such that a responsive robot was perceived as more social and competent than an unresponsive robot (see Table 1 for means, standard deviations, and statistics). Robot responsiveness did not significantly affect its perceived attractiveness, possibly because people tend to ascribe character traits to non-anthropomorphic robot, but are less likely to think of it in terms of attractiveness per se. These results show that a robot's responsiveness increases perceptions of its appealing traits, except for attractiveness, demonstrating that an experimental manipulation of the identified responsiveness cues of nodding and affirmative texts can instill a sense of responsiveness in human-robot interactions and cause people to evaluate the robot's character traits more favorably than when the robot behaves unresponsively.

To determine whether differences existed between the responsive and unresponsive conditions in participants' desire for robot companionship when alone or under stressful circumstances, an independent-sample *t*-test was performed. This *t*-test yielded the expected effect: Participants were more interested in robot companionship in the responsive condition than in the unresponsive condition (see Table 1 for means, standard deviations, and statistics).

To determine whether differences existed between the responsive and unresponsive conditions in participants' approach behaviors, an independent-sample *t*-test was performed. This *t*-test yielded the expected effect: Participants exhibited more approach behaviors in the responsive condition than in the unresponsive condition (see Table 1 for means, standard deviations, and statistics). The results indicate that a robot's responsiveness increases approach behaviors towards the robot and the desire for its companionship during stressful events, demonstrating that the human mind utilizes responsiveness cues to ascribe social intentions to technological entities, such that people can treat robots as a haven of safety —as a source of consolation in times of need. Overall, these findings show that responsiveness can transfer from human-human to human-robot interactions, using extremely simple cues from an abstract non-anthropomorphic robot.

3. Study 2

Study1 indicated that a robot's responsiveness to participants' negative event disclosure could instill a sense of responsiveness and increase approach behaviors and the desire to use it as a companion when needed. In Study 2, we sought to expand upon these findings by examining whether a robot's responsiveness produces positive reactions in a different context: disclosures of positive events. Given the robot's potentially reassuring function, we also examined whether interacting with a responsive robot (versus an unresponsive one) would improve self-perception during a subsequent stress-generating task. Participants had individual sessions in which they disclosed a recent positive dating event to a robot. The robot responded with either responsive or unresponsive behaviors, and the participants reported their perceptions of the robot. These interactions were videotaped and coded for participants' approach behaviors towards the robot. Participants were then asked to perform a dating-relevant self-presentation task and to rate their performance on this task in terms of mate value.

3.1. Method

3.1.1. Participants

Seventy-four undergraduate students (37 women, 37 men) from a university in central Israel volunteered for the study without compensation. Sample size was determined a priori to detect effects of the magnitude from Study 1. Participants ranged from 19 to 34 years of age ($M = 24.04$, $SD = 2.36$). All participants were heterosexual and not currently involved in a romantic relationship. No significant differences were found between the experimental conditions for any of the socio-demographic variables.

3.1.2. Measures and procedure

Participants followed the same initial procedure as in Study 1, with two exceptions. First, they were led to believe that we were testing a new speech-comprehension algorithm developed specifically for dating sites. Second, participants discussed with the robot a recent personal positive event (rather than a negative one) while being videotaped. Instructions for the positive event discussions were similar to those used in Study 1, except for the introduction, as follows:

> *"We would like you to choose some recent positive dating event from your life, which made you feel very attractive and desirable. This positive dating event continues to arouse positive feelings in you when you think about it now."*

The participants and the robot discussed the participant's positive event for up to 7 min while being videotaped. The robot behaved either responsively or unresponsively across two modalities (simple gestures, written text), as described in Study 1, with the exception that in the responsive condition, we used a set of standardized responses that were appropriate for positive events (e.g., "Wow, that's really great!"; "What a pleasant experience!"). These responses were previously pilot-tested to fit the experimental condition (Reis et al., 2010) and were slightly adjusted to fit the content of the discloser's story, if necessary.

After interacting with the robot, participants completed the following measures of perceptions of the robot: responsiveness, sociability, and competence, which were described in the Study 1, as well as an item assessing attractiveness ("How attractive is the robot?"). Then, participants were instructed to introduce themselves to potential romantic partners for two minutes by talking about their hobbies, positive traits, and future career plans while being videotaped. To lessen the potentially intense stress that might be generated by this task, we told participants that we were just hoping to get their insights about the experience as we pilot tested for future studies.

After introducing themselves to potential partners, participants completed a measure of self-perceived mate value, which assessed their perceptions of how attractive they were to potential partners watching the self-presentation video. Participants rated on a 5-point scale from 1 (*not at all*) to 5 (*very much*) the following statements: "I am presented in the video as an attractive partner"; "Prospective partners watching the video will find me sexually attractive"; and "Prospective partners watching the video will be interested in a long-term relationship with me" (see Appendix C for internal consistency reliabilities, descriptive statistics, and zero-order correlations). Upon completion of the questionnaire, participants were asked to provide demographic information and then fully debriefed. We made sure that they felt good about their participation in the study.

3.1.2.1. Coding approach behaviors during the interaction with the robot. The coding of participants' approach behaviors towards the robot during the interaction with it was similar to the one described in Study 1. Inter-rater reliability was high (ICC = 0.86). Hence, judges' ratings were averaged for each participant.

3.2. Results and discussion

3.2.1. Manipulation check

A *t*-test on perceived robot responsiveness yielded the expected effect: The robot was perceived as more responsive in the responsive condition than in the unresponsive condition (see Table 2 for means, standard deviations, and statistics).

3.2.2. Responsiveness, perceptions of robot's traits, approach behaviors, and self-perceived mate value

To examine whether differences existed between the responsive and unresponsive conditions in perceived robot sociability, competence, and attractiveness, a one-way multivariate analysis of variance (MANOVA) for responsiveness condition was performed. This MANOVA yielded a significant difference between the two responsiveness conditions, *Hotelling's Trace* = 0.61, $F(3,70) = 14.11$, $p < 0.001$, $\eta_p^2 = 0.38$, *95% CI for* η_p^2 (0.18, 0.50). A series of independent-sample t-tests indicated that this effect was significant for perceived robot sociability and competence, but not for attractiveness, such that a responsive robot was perceived as more social and competent than an unresponsive robot (see Table 2 for means, standard deviations, and statistics).

To determine whether differences existed between the responsive and unresponsive conditions in participants' approach behaviors and self-perceived mate value, two independent-sample t-tests were performed. These t-tests yielded the expected effect: Participants exhibited more approach behaviors and reported higher self-perceived mate value in the responsive condition than in the unresponsive condition (see Table 2 for means, standard deviations, and statistics). These findings replicated those of Study 1 in a different context, showing that in addition to producing similar positive reactions, interacting with a responsive robot improved self-perceptions during a subsequent stress-generating task.

To examine whether the effect of the robot responsiveness manipulation on self-perceived mate value was mediated by perceived robot responsiveness, we used PROCESS (Hayes, 2013; model 4), in which the robot responsiveness manipulation was the predictor, self-perceived mate value was the outcome measure, and perceived robot responsiveness was the mediator. Fig. 3 shows the final model. This analysis revealed a significant main effect of the robot responsiveness manipulation on perceived robot responsiveness, $b = 1.33$, $SE = 0.19$, $t = 6.96$, $p < 0.001$, $\beta = 0.63$, the 95% CI for β [0.45, 0.81]. The analysis further revealed a significant main effect of perceived robot responsiveness on self-perceived mate value, $b = 0.28$, $SE = 0.08$, $t = 3.52$, $p < 0.001$, $\beta = 0.38$, the 95% CI for β [0.16, 0.60], such that participants who perceived the robot as more responsive also perceived themselves as more valuable partners. In addition, when robot perceived responsiveness was included in the regression predicting self-perceived mate value as a function of the robot responsiveness manipulation, this manipulation no longer significantly predicted self-perceived mate value, $b = 0.11$, $SE = 0.22$, $t = 0.51$, $p = 0.61$, $\beta = 0.07$, the 95% CI for β [−0.21, 0.35], whereas robot perceived responsiveness still significantly predicted self-perceived mate value, $b = 0.25$, $SE = 0.11$, $t = 2.38$, $p = 0.02$, $\beta = 0.34$, the 95% CI for β [0.04, 0.61].

Finally, results indicated that the 95% CI of the indirect effects for robot responsiveness manipulation as a predictor of self-perceived mate value through perceived robot responsiveness did not include zero and thus is considered significant, $b = 0.33$, $SE = 0.15$, $t = 2.23$, $p = 0.02$, $\beta = 0.24$, *95%CI* = [0.06, 0.65]. Hence, the analyses showed

Table 2

Means, standard deviations, statistics, and effect sizes of perceptions of the robot's traits, approach behaviors, and perceived mate value for the responsive and unresponsive conditions (Study 2).

	Responsive Partner		Unresponsive Partner		$t_{(72)}$	*Cohen's d*	*95% CI for Cohen's d*
	M	*SD*	*M*	*SD*			
Perceived responsiveness	3.50	0.89	2.16	0.76	6.96^{***}	1.62	(1.09, 2.14)
Perceived sociability	4.26	0.81	3.06	0.98	5.68^{***}	1.32	(0.81, 1.82)
Perceived competence	3.72	0.72	2.60	0.94	5.67^{***}	1.31	(0.81, 1.81)
Perceived attractiveness	2.38	1.16	1.97	1.09	1.55	0.36	(−0.10, 0.82)
Approach behavior	2.81	0.86	2.01	0.90	3.89^{***}	0.90	(0.42, 1.38)
Perceived mate value	3.50	0.70	3.06	0.80	2.53^{*}	0.59	(0.12, 1.05)

Note. $^{*}p < 0.05$, $^{***}p < 0.001$.

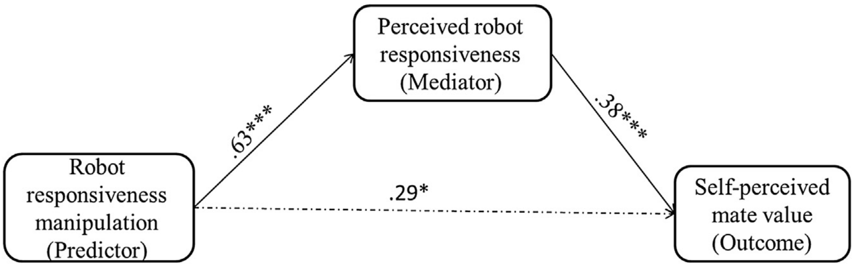

Fig. 3. Mediation model showing that perceived robot responsiveness mediated the effect of robot responsiveness manipulation on self-perception of mate value in Study 2. The 95% CI of the indirect effect for robot responsiveness manipulation as a predictor of self-perceived mate value through perceived robot responsiveness did not include zero [0.06, 0.65] and thus the indirect effect is considered significant. *Note*. Path coefficients are standardized; $^{***}p < 0.001$.

that the effect of robot responsiveness manipulation on participants' perceptions of their mate value was mediated by perceived robot responsiveness. These findings indicate that the sense of responsiveness instilled by the robot affects not only humans' social impressions of the robot and their willingness to use it as a source of consolation in times of need, but also has beneficial effects on their self-perceptions and courage in romantic pursuit.

4. General discussion

Responsiveness to one's bids for proximity in times of need is a linchpin of the human attachment-bonding process (Bowlby, 1969/1982). The ability to be perceived as responsive may therefore have design implications for socially assistive robotics. In this work, we examined whether and how a robot's behavior could induce perceptions of responsiveness, and whether the documented beneficial effects of responsiveness in human-human interactions (Reis & Clark, 2013) could transfer to human-robot interactions. The findings showed that a robot's responsiveness increased humans' perceptions of its appealing traits and the desire to use it during stressful events. Moreover, a robot's responsiveness improved self-perceptions during a subsequent dating-relevant self-presentation task, indicating that people can leverage responsive social interactions with a robot to become more confident and appealing romantic partners.

The findings also revealed that a robot's responsiveness facilitated behaviors that signal contact-readiness (i.e., seeking the robot's psychological proximity through approach behaviors), implying that people find the robot real and compelling and respond to it in ways in which they typically respond to social partners. Viewed together, these findings suggest that humans not only utilize responsiveness cues to ascribe social intentions to robots, but they actually adjust their behavior towards responsive robots; want to use such robots as a source of consolation; and feel better about themselves while coping with challenges after interacting with these robots. In doing so, the findings demonstrate that a responsive robot can be reassuring, indicating that it is compelling enough to serve as a haven of safety and to build a sense of security that generalizes later to enhanced functioning under threatening circumstances. In this sense, a robot may serve a secure-base function similar to the one served by a human caregiver (Bowlby, 1969/1982), facilitating a sense of security from being in proximity to a responsive entity and an enhanced sense of competence while navigating future challenging events.

Overall, this work is a step toward understanding how responsiveness plays into human-robot relationships, indicating that a human can be receptive to, and benefit from, responsiveness that comes from a robot. By doing so, our findings underscore the importance of designing assistive robots that display appropriately responsive behavior to support humans' psychological needs. Designing such responsive robots may have implications beyond assistive care. For example, these robots can interview people and take testimony after traumatic events (e.g., natural disasters, violence). In such cases, a robot's responsive behavior could provide humans with some of the psychological support they need, without being judgmental. Still, given that we used a Wizard-of-Oz setup and that our studies only covered two disclosure types, more research is needed to explore the possibility of designing autonomously acting robots that behave responsively, the effects of responsiveness in long-term human-robot relations, and the resulting implications for people's confidence and functioning in a variety of areas of their lives.

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Appendix A. Principal Component Structure of the New Scales Used in Study 1.

Item	Sociability	Competence	Desire for companionship
Perceived Sociability			
Cooperativeness	0.86		
Sociability	0.85		
Friendliness	0.84		
Warmth	0.81		
Perceived Competence			
Knowledgeability		0.80	
Consciousness		0.77	
Capability		0.67	
Reliability		0.66	
Desire for Companionship			
During stressful event			0.85
While being alone			0.83
% of Explained variance	40.85	14.76	10.60

Appendix B. Internal Consistency Reliabilities, Descriptive Statistics, and Zero-Order Correlations of the Measures Used in Study 1.

	1	2	3	4	5	6	7
1 Perceived responsiveness	–	0.13	0.77***	0.64***	0.41***	0.43***	0.29**
2 Self-disclosure		–	0.07	0.05	−0.01	−0.10	0.20*
3 Perceived sociability			–	0.63***	0.34***	0.29**	0.33***
4 Perceived competence				–	0.44***	0.27**	0.22*
5 Perceived attractiveness					–	0.38***	0.09
6 Desire for companionship						–	0.09
7 Approach behavior							–
Cronbach's alpha/ICC	0.94	0.88	0.77	0.64	0.80	0.79	0.86
Mean	2.58	3.68	3.79	3.74	2.90	2.00	2.89
SD	1.01	0.77	1.23	0.99	0.92	1.02	0.65

Note. Perceived sociability, perceived competence, and perceived attractiveness were rated on 7-point Likert scales; perceived responsiveness, self-disclosure, desire for companionship, and approach behavior were rated on 5-point Likert scales.
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$; $n = 102$.

Appendix C. Internal Consistency Reliabilities, Descriptive Statistics, and Zero-Order Correlations of the Measures Used in Study 2

	1	2	3	4	5	6
1 Perceived responsiveness	–	0.70***	0.83***	0.44***	0.20	0.38***
2 Perceived sociability		–	0.69***	0.46***	0.17	0.29*
3 Perceived competence			–	0.37***	0.19	0.37***
4 Perceived attractiveness				–	−0.01	0.07
5 Approach behavior					–	0.14
6 Perceived mate value						–
Cronbach's alpha/ICC	0.89	0.71	0.68	–	0.86	0.82
Mean	2.83	3.66	3.16	2.18	2.41	3.28
SD	1.06	1.08	1.00	1.14	0.96	0.77

Note. Perceived sociability, perceived competence, and perceived attractiveness were rated on 7-point Likert scales; perceived responsiveness, approach behavior, and perceived mate value were rated on 5-point Likert scales.
$^{*}p < 0.05$; $^{***}p < 0.001$; $n = 74$.

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