Robot Responsiveness to Human Disclosure Affects Social Impression and Appeal

Guy Hoffman*, Gurit E. Birnbaum†,
Keinan Vanunu*†, Omri Sass†
*Media Innovation Lab / School of Communication, †School of Psychology
IDC Herzliya
P.O.B 167, Herzliya 46150, Israel
{hoffman,birnbag,kvanunu,osass}@idc.ac.il

Harry T. Reis
Department of Clinical and Social Sciences in Psychology
University of Rochester
P.O.B 270266, Rochester, NY 14627, USA
reis@psych.rochester.edu

ABSTRACT

In human relationships, *responsiveness*—behaving in a sensitive manner that is supportive of another person's needs—plays a major role in any interaction that involves effective communication, caregiving, and social support. Perceiving one's partner as responsive has been tied to both personal and relationship well-being. In this work, we examine whether and how a robot's behavior can instill a sense of responsiveness, and the effects of a robot's perceived responsiveness on the human's perception of the robot. In an experimental between-subject study (n=34), a desktop non-anthropomorphic robot performed either positive or negative responsiveness behaviors across two modalities (simple gestures and written text) in response to participants' negative event disclosure. We found that perceived partner responsiveness, positive human-like traits, and robot attractiveness were higher in the positively responsive condition. This has design implications for interactive robots, in particular for robots in caregiving roles.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems; J.4 [**Computer Applications**]: Social and Behavioral Sciences—*psychology*

General Terms

Human-robot interaction; responsiveness; agent impression; affective & emotional responses; Wizard-of-Oz; care robots; socially assistive robotics; modeling social situations.

1. INTRODUCTION

Robots are predicted to serve in a variety of caregiving roles, such as nursing, childcare, education, and elderly care. There, they would operate in personally meaningful relationships vis-a-vis a wide variety of age and social groups, from children, through teenagers, to adults and the elderly. In addition to their functional operation, robots may be required to monitor their human interlocutors, listen to their experiences, and engage in supportive conversation. For example, a robot serving in an elderly care facility might provide support by listening to life experiences of the caretaker.

In such scenarios, the way a robot responds to the human's communication can have a profound effect on a number of personal and interpersonal outcomes, including the human's perception of the robot, the human's sense of support, the human's mental health, the bond between the human and the robot, the human's willingness to continue to confide in the robot, and the human's overall well-being.

A large body of research in the social psychology literature has investigated the relationship outcomes of human responsiveness—behaving in a sensitive manner that is supportive of another person's needs. Responsiveness has been studied in the context of parent-child relationships, adult close relationships, and therapeutic relationships, as well as in educational, organizational, and healthcare settings. Responsiveness has been shown to play a key role in the provision of caregiving and social support and to be associated with personal and relational well-being [4, 17, 20, 21].

We were interested how some of these findings might carry over to a robot behaving, or not behaving, in a responsive manner to a human's personal event disclosure. We focused on negative event disclosure, because it constitutes a prototypical responsiveness scenario that calls for distress regulation and elicits proximity seeking.

To approach this question, we evaluated whether and how a desktop-scale non-anthropomorphic robot could appear responsive, using simple gestures such as nodding or looking away, in combination with written text associated with the robot, and how this affects the human interlocutor's sense of the robot's character traits and attractiveness.

1.1 Robots in Caregiving Roles

One of the main drivers of personal robotics research is the prospect of using robots in caregiving roles, such as elderly care, health and nursing care, and childcare. A specific class of care robots is denoted as "socially assistive" [6], when in addition to the functional requirements, the robotic agent includes a socially communicative aspect.

Socially assistive robots have been widely researched in the elderly care sub-field of HRI [7]. One example is Paro, a robotic seal designed to be held and touched, which has been

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shown to have positive effects on patients with dementia [30]. Another is USC's humanoid, which showed promising results in therapy for elderly with cognitive impairments, through a musical game [28].

In the healthcare field, a humanoid robot was used in a longitudinal study of children with autism [24]; robotic dogs have been explored in the field of animal-assisted therapy to treat loneliness and depression [1]; and socially assistive robots were used to treat stroke survivors [5].

Robots are also developed for childcare roles, as teachers, learners, and companions. For example, Tanaka studied robots in classrooms as learners, with the intent that students would learn better by teaching the robot [27]. Kanda's work shows that a robot could foster social interaction among elementary school children [14].

We argue that in all of these care roles, robots will need to be psychologically sensitive to their care-receivers and behave in a manner that is supportive of their needs.

1.2 Responsiveness in Human Relationships

Social psychology has long acknowledged the importance of "Perceived Partner Responsiveness" (PPR) for individual well-being and for relationship intimacy. PPR is conceptualized as the "belief that a relationship partner understands, values, and supports important aspects of the self" [3]. Often, PPR is evaluated in the context of disclosure, where one of the conversation partners recounts an event that is important to him or her, and the listening partner responds to this self-disclosure.

PPR has important outcomes for dyadic relationships. It is the linchpin of the development of intimate relationships, and as such, it promotes personal and interpersonal well-being in close relationships. Moreover, PPR has been tied to a large number of other positive outcomes, including mortality, morbidity, happiness, emotional distress, psychological development, and economic success [20].

PPR also plays a crucial role in many relational processes outside of the realm of romantic or couple relationships. For example, perceived parental responsiveness encourages cooperative and exploratory behaviors and is associated with social skills, parent-child relationship quality, and levels of motivation and academic achievement [17]. PPR of physicians towards their patients has been found to positively affect subjective health status in the patient [20]. These findings are particularly interesting to designers of companion robots in the educational, health, and elderly care areas.

Furthermore, PPR has beneficial effects on emotional expression and other emotional outcomes. For example, it has been shown to positively affect self-regulation, which is an important executive function, and has been related to the setting of goals and pursuing them [20].

1.2.1 Responsiveness to Negative Event Disclosures

An established way to study PPR in a lab environment is by using a responsiveness to disclosure protocol. Maisel *et al.* studied responsiveness by asking established romantic couples to discuss personal positive and negative events. Then, they developed a coding guide that assessed responsive behaviors in various interpersonal situations and related PPR to behavioral measures (e.g., expressing empathy, reassurance, providing support) and subjective sense of self-esteem [19].

In another series of three studies, Birnbaum and Reis had couples of opposite-sex strangers interact, and then they related reported PPR to sexual attraction [3]. In the first study, they examined the association between perceived partner responsiveness and sexual attraction in randomly paired strangers. Then, in the second study, the researchers set up an experimental procedure, where they had participants believe that they interacted via textual chat with conversation partners in a different room, whereas they really were chatting with a confederate, in either a positive or a negative responsiveness condition. In this case, they used only negative event disclosure. Given that the second study did not include any nonverbal behavior, a third study replicated the above procedure, but instead of text chat, it employed a face-to-face interview methodology. Results indicated that perceiving a partner as responsive was associated with heightened sexual attraction toward this partner, primarily among men and among less avoidant participants.

The current study is based on the above studies, using the same protocol for negative event disclosure. However, because this is a human-robot conversation, we expand the scope of the previously investigated scenarios by combining face-to-face (the human and the robot are in the same room) with nonverbal behavior (the robot gestures and moves), with mediated communication (a robot is by definition a medium), with textual chat (the robot's response is conveyed not through speech, but through textual chat).

1.2.2 Perceived Responsiveness and Attraction

The studies reported above primarily evaluate the impact of PPR on sexual attraction. In the robot case, however, we were interested in a more general notion of attraction and impression of the agent, especially because the robot was not a potential romantic partner for the disclosers. 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 character traits.

2. HOW CAN A ROBOT BE RESPONSIVE?

Human responsiveness research has extensively investigated what behaviors instill a sense of responsiveness in conversation partners. But can a robot also behave in a way that will make it seem responsive to the human?

To answer this question, we look at three components of responsiveness behaviors examined by Maisel *et al.*: understanding, validation, and caring [19]. They based this on Reis and Patrick's theoretical model of responsiveness [22]. *Understanding* includes "active listening", showing attention, interest in the conversation, and understanding of the discloser's words. *Validation* is aimed to make the conversation partner feel respected and to reinforce their self-views. This includes behaviors that acknowledge the significance of the events described. *Caring* includes expressions of love, care about the other's well-being, and showing a joint stake in the issues discussed.

Each of these components of responsiveness behavior could be translated into the human-robot domain; Some of them are sophisticated and require complex AI, but others can be readily implemented on a conversational robot with state-of-the-art technology. A robot can, for example, direct its gaze, nod, and summarize human speech to display understanding, or touch a human gently to show caring. In Table 1 we tried to list possible behaviors a robot could display for the different components of Reis's model of responsiveness.

Table 1: Three components of responsiveness behaviors implementable by robots conversing with humans

Responsiveness component	Behavioral elements adaptable for robot behavior
Understanding	Nodding; backchannel signals; directing gaze attention; summarizing human speech
Validation	Relating events to the resulting feelings; affirming discloser's positive traits
Caring	Affective touch; affirming emotional caring verbally

That said, there are also challenges that arise when we consider the possibility of a robot being perceived as responsive: Humans' expectations of other humans' appropriate behavior might not translate to a robot listening to a human's disclosure; the relationship context (e.g., strangers, peers, partners) might not be as clear in a human-robot dyad as in the human-human case; human nonverbal behavior is tied to a common biological morphology, making it predictably interpreted by a human conspecific, while robotic morphologies are more varied; and finally, being a machine, a robot might never be perceived as positively or negatively responsive, because this could be a human-specific relation.

Thus, it is not clear whether it is possible for a robot to be responsive, and what behaviors would be perceived as responsive. All this before even asking about downstream outcomes of robot responsiveness.

2.1 Robots Listening to Humans

Several HRI research projects have been concerned with robots listening to humans, and how the robot's behavior affects the interaction. Kobayashi *et al.* tackle the analysis of human speech with the intention of the robot providing active listening [8, 15]. The latter paper, in particular, highlights the difficulty of accurately providing responsiveness behaviors of the "understanding" kind.

Research in robots listening to children has shown that children were as likely to share a secret with a robot as with a human, when these use a similar amount of prompting [2]. Similarly, it was demonstrated that 7 to 9 year olds respond very similarly to a robot interviewer as they would to a human interviewer [31]. In another study, researchers have implemented empathy behaviors in a persuasive setting with both robots and virtual characters [18], including a methodological implementation of techniques drawn from the client-therapist literature.

Our work extends the literature of attentive robots by providing the first systematic investigation into the notion of robot responsiveness, proposing possibilities for designing responsive behaviors in non-anthropomorphic robots, and investigating how perceived robot responsiveness relates to personal event disclosure.

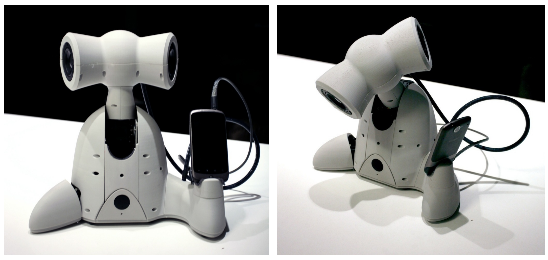

Figure 1: Travis, the robot used in the experiments. Left: in an attentive position; right: in a distracted position, looking at its mobile phone.

2.2 Designing Robot Responsiveness

The responsiveness behaviors in our study were implemented on a non-anthropomorphic desktop robot (Fig 1). We have long been interested in in the social capabilities of simple low-DoF robots with no apparent human-like features [12, 10], as these robots best model commercially plausible machines, with near-term potential for real-world availability. Non-anthropomorphic robots have been shown to be socially and emotionally expressive and readable in a number of HRI studies [16, 25]. But can a robot with minimal DoFs, no face, and no human shape fulfill a socially sensitive function such as responsiveness to human disclosure?

In our attempt to design responsiveness, we combined two modalities: nonverbal gestures and textual responses. The nonverbal channel mostly corresponds with the "Understanding" component of responsiveness in Table 1. The textual modality corresponded to the "Validation" component. We did not attempt supporting "Caring" as a responsiveness component in this study, although people may perceive the robot as caring, because they may interpret his gestures and verbal reactions as expressions of intimacy.

We tried to keep the nonverbal modality to a minimum. To display positive responsiveness, we had the robot maintain a forward focus towards the human, gently sway to display animacy, and implemented short affirmative nods in response to human speech. In the negative case, the robot's would show decreased animacy, no confirmation gestures, and occasional distraction behaviors, in the form of looking away from the human conversation partner (Fig 1, right).

On the verbal channel, we used positively and negatively responsive speech acts, following a previously established protocol of human responsiveness to negative event disclosure [3]. Our responsiveness behaviors are detailed in Section 5.1 and in Table 2.

We found in a pretest, that several participants perceived any movement of the robot as responsive. This could be because the robot did not have a face or eyes, or perhaps because even the robot's sideways gaze could be interpreted as a "lending an ear" gesture. These findings also emphasize the difficulty of designing nonverbal responsiveness behaviors for low-DoF non-anthropomorphic robots.

3. RESEARCH QUESTIONS

To summarize, in this study, we were interested whether the notion of responsiveness carries over from the human-human to the human-robot domain; whether it is possible for an abstract non-anthropomorphic robot to be responsive; how that robot's responsiveness would affect people's impression of the robot; and whether known outcomes from human responsiveness also occur with robot responsiveness.

3.1 Hypotheses

To evaluate the above, we tested the following hypotheses:

Hypothesis 1 (Perceived Partner Responsiveness) — A robot performing positive responsive behaviors to negative event disclosure would be perceived as more responsive on the PPR scale by the disclosing human than a robot displaying negative responsive behaviors.

Hypothesis 2 (Impression of Agent) — A robot performing positive responsive behaviors to negative event disclosure would cause the disclosing human to attach more positive character traits to the robot than a robot displaying negative responsive behaviors.

Hypothesis 2a (Social Perception) — A robot performing positive responsive behaviors to negative event disclosure would be perceived as more social than a robot displaying negative responsive behaviors. Namely, the robot would be perceived as more cooperative, warm, and friendly.

Hypothesis 2b (Competence Perception) — A robot performing positive responsive behaviors to negative event disclosure would be perceived as more competent than a robot displaying negative responsive behaviors. Namely, the robot would be perceived as more intelligent, reliable, and knowledgeable.

Hypothesis 3 (Attraction) — A robot performing positive responsive behaviors to negative event disclosure would be more attractive to the disclosing human than a robot displaying negative responsive behaviors.

To estimate these variables, we manipulated the robot's behavior in two conditions: positive responsiveness and negative responsiveness, and conducted a Wizard-of-Oz between subject experimental study.

4. ROBOTIC PLATFORM

We used the robot *Travis* [10, 13], a research platform we developed to examine HRI as it relates to nonverbal behavior, timing, and physical presence (Fig 1). Travis is a small non-anthropomorphic robot with a vaguely creature-like structure, but without a face. The robot stands about 28cm 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. The robot is capable of basic gesturing, using five degrees-of-freedom. Three DoFs are in the head, one in the "hand" holding the phone, and one in the foot.

All the robot's software runs on an Android smartphone, communicating positions and velocities to an ADK board, which then bridges those to the motors. A detailed description of the robot's design, hardware, and software modules is provided in a separate publication [10].

Part of the robot's design is that it "holds" the smartphone which runs it, allowing for the device to serve as an object of common ground and joint attention [11] between the human and the robot. Importantly for this experiment, this design enabled us to have the robot look at the phone as a non-responsive behavior indicating distraction or boredom.

To eliminate the possibility for estrangement associated with a robotic voice, we opted for the robot to display the text it "says" on a small screen leaning against the robot's body, instead of using audible speech. This screen was completely black except when the robot presented text. Then, a single sentence appeared on the screen for five seconds, before disappearing. We pre-tested the duration of the text display and found it adequate to read all the sentences that were part of the experimental protocol.

4.1 Wizard-of-Oz Setup

In this experiment, the robot was controlled remotely in a Wizard-of-Oz (WoZ) setup [23].We use WoZ here in place of automated speech recognition. While in our case, speech detection and recognition could have been acceptable to time and select the required gestures, and the gestures we used were simple and fixed, we did not want to risk "breaking the fourth wall" (revealing the WoZ deception) while participants were opening up about personally meaningful life events.

The setup had three main control components networked through a wireless network. In the control room, a PC was running a graphical user interface, which sent commands to the smartphone controlling the robot, and the tablet displaying the text the robot produced. The commands were sent in form of pre-programmed gestures to the phone, which ran a behavior system that arbitrated the gestures with the robot's breathing behavior, and translated them into timed motor commands (see: [13]). The robot's responses were sent as text strings to the tablet for display.

In addition to the control software, two cameras were monitoring the control room for the experimenter to be able to time the robot's behaviors to the participant's speech acts.

The control software included two parts: on top there were buttons enabling the experimenter to remotely select behaviors for the robot. At the bottom part of the screen, there was a free-text field, allowing the experimenter to type in responses that would appear on the robot's output screen. A history of ten phrases was kept for quick recall.

5. METHOD

We conducted a controlled laboratory experiment, in which participants were asked to disclose a personally negative event to the robot in front of them. The participants were told that we were testing a new speech understanding algorithm, and that the robot would try to respond to their story as best it could. The robot then behaved with either positive or negative responsiveness. We then had participants evaluate the robot's behavior.

5.1 Design

The robot's behavior was controlled by an experienced operator familiar with the research and the experimental protocol. We made an effort to keep the behaviors as constant as possible within conditions, by closely following a textual protocol, and fixed gestures. However, this had to be balanced with actually responding to the content of the discloser's story. For the textual responses, we adhered to an established protocol used for responsiveness behavior in online chat [3]. The wizard operator selected a single text response at the end of each paragraph from a bank of preset phrases, and only adjusted the phrases slightly to fit the context, if necessary. The same behaviors were used consistently, approximately three times per interaction, and roughly at the same time points in the disclosure.

We manipulated one between-subject variable, the robot's level of responsiveness, based on the behaviors described in Section 2.2. In the *POSITIVE* condition, the robot swayed gently forward and backward, and acknowledged the speaker's end-of-speech with either a single nod, or a double nod. In the *NEGATIVE* condition, the robot swayed, but with a smaller amplitude, and occasionally glanced at the smartphone in its hand, or at the wall clock hanging on the wall between the participants and the robot. In the *POSITIVE* condition, the robot displayed supportive text responses. In the *NEGATIVE* condition, the robot displayed slightly dismissive text responses. Table 2 summarizes the difference in behavior between the two conditions, including samples from the text response repertoire.

Table 2: Responsiveness behaviors used in the current experiment

Cond	Gestures	Speech act samples
POS	Nodding; deep sway	"You must have gone through a very difficult time"; "I completely understand what you've been through"
NEG	Glance at phone / clock; shallow sway	"That doesn't sound so bad to me"; "Are you sure that's the worst thing you can think of?"

After the participants were done, a questionnaire measured the participant's overall perceived robot responsiveness, their impression of the robot's positive human-like characteristics, and the participants' attraction to the robot.

Through video recording, we captured the participant's physical reaction to the experience. These recordings were not used in the currently presented results.

5.2 Participants

A total of 36 (21 female) undergraduate students participated in the experiment. The participants were students from a university in central Israel, and all communication was done in Hebrew. Participants were recruited from several departments voluntarily, or in return for class credit. Participants ranged from 21 to 27 ($M = 24.11$, $SD = 1.53$).

No significant differences were found between the experimental conditions for any of the sociodemographic variables we measured (age, gender, marital status, and past experience with robots or with artificial intelligence).

5.3 Procedure

The experiment was conducted in two experiment rooms with controlled lighting, no windows, and no outside distractions. Upon arrival, each participant was welcomed into the first room, where the experimenter explained the initial experimental guidelines. Each participant filled an informed consent form, and the demographic questionnaire. Next, participants were guided to the adjacent room, were asked to sit on the couch, facing the robot, and received a detailed explanation regarding the remainder of the experiment (Fig 2). The robot was raised from the table by circa 20cm, to make its head level with the seated human's head.

Based on [3], each participant was asked to "choose some current problem, concern, or stressor [they] are facing", such as "a recent argument with a friend or a family member, a grade in class, work or financial problems, or personal ill-

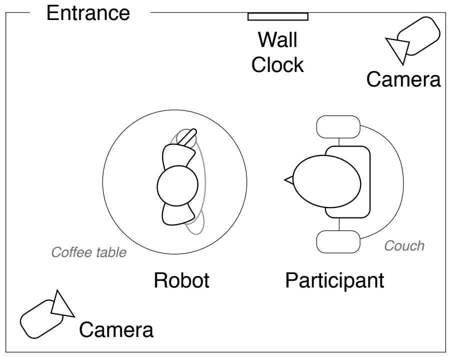

Figure 2: Experimental room layout diagram. The robot's head height is roughly in line with the seated human's eyes.

ness". They were told that the robot would try to understand what they say and respond with a relevant response, using artificial intelligence and speech recognition.

The participants were asked to divide the message into three "paragraphs": (a) the facts of the event; (b) the emotions and thoughts that arose in them during the event; and (c) the implications of the event on their life afterwards. At the end of each paragraph, participants were asked to use the statement "and that's it", which, according to the cover story, would signal to the robot that the part is done and that speech recognition can begin. This served two goals: The first was to make the robotic cover story more reliable in terms of its speech processing. The second was to provide more time for the experimenter to form a reply and choose a gesture. After indicating that he or she understood these instructions, the participant was left alone in the room to interact with the robot.

Upon completion of the interaction stage, the experimenter re-entered the room, and asked the participant to fill out the post-procedure questionnaires. Then, participants were interviewed by the experimenter, and were asked three open-ended questions about their experience ("How was the experience?", "What did it make you feel?", and "How did you interpret the robot's behavior?").

Participants were then fully debriefed, and were told that the robot was controlled by the experimenter. We made sure, especially in the negative responsiveness condition, that they felt good about their participation in the study before concluding the experiment.

6. MEASURES

All measures are on a 7-point Likert scale (from "strongly disagree" to "strongly agree").

6.1 Perceived Partner Responsiveness

We estimated the PPR of the robot using a composite instrument adapted from Birnbaum and Reis [3]. The scale has been validated and found reliable in prior studies. The current version used 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 really listened to me." This scale is factorally unidimensional and internally consistent in our sample as well (Cronbach's $\alpha = .92$).

6.2 Impression of Agent

Participants rated their impression of the robotic agent on a composite measure of ten items indicating positive character traits, including the robot's perceived friendliness, intelligence, confidence, warmth, cooperativeness, and sociability. This measure was validated and found reliable in previous studies [26, 9, 13], Cronbach's α was good for this scale (.83).

6.2.1 *Social Perception*

Social perception of the robot is as a sub-scale of the "Impression of Agent" scale, and consists of the four items that measured social aspects of the robot's traits (friendliness, cooperativeness, sociability, and warmth). Cronbach's α for this measure was good (.88).

6.2.2 *Competence Perception*

Competence perception of the robot is a complementary sub-scale of the "Impression of Agent" scale, consisting of five items that measure competence aspects of the robot's traits (intelligence, capability, reliability, knowledgeability, and sensibility). Cronbach's α for this measure was acceptable (.72).

6.3 Attraction to Robot

Responsiveness is known to affect attraction in human relationships. To assess whether similar social mechanisms come into play between humans and robots we implemented an attraction to robot measurement, which measured how attractive participants perceived the robot to be. This measure composite was a seven-item scale, and consisted of items such as "How attractive is the robot?", and "How sophisticated is the robot?". One item was excluded from the measure due to inadequate correlation levels. Cronbach's α for the remaining measure was found to be good (.81).

7. RESULTS

Participants were randomly assigned to interact with either a positively or a negatively responsive robot. Two participants were switched over from the negative to the positive responsiveness condition mid-way, due to the sensitive nature of their disclosed experience, and were excluded from further analysis.

Manipulation check. An independent means t-test on perceived partner responsiveness (PPR) yielded a significant effect, $t(32)$=2.79, $p < .01$. Perceived partner responsiveness was higher in the positively responsive robot condition ($M =$ 3.13, $SD = 1.09$) than in the negatively responsive robot condition ($M = 2.24$, $SD = .69$).

Impression of Agent An independent means t-test on the impression of agent scale yielded significant results, $t(32) = 3.82, p < .01$. The robot was rated higher in the positively responsive condition ($M = 5.01$, $SD = .92$), than in the negatively responsive condition ($M = 3.91$, $SD = .71$).

Social Perception An independent means t-test for the social perception sub-scale yielded significant results, $t(32) = 6.08, p < .001$. Participants in the positive response condition ($M = 5.72$, $SD = .72$) rated the robot more positively regarding social traits, as compared to participants in the negative response condition ($M = 3.72$, $SD = 1.17$).

Competence Perception An independent means t-test for the competence perception sub-scale yielded no significant differences between the conditions $t(32) = 1.29$, ns.

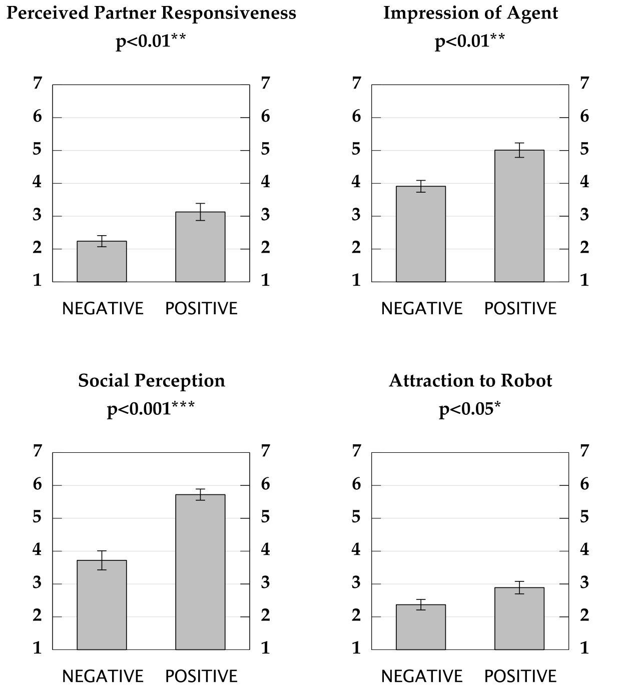

Figure 3: Perceived Partner Responsiveness, Impression of Agent, Social Perception, and Attraction to Robot by condition. Error bars denote standard errors from mean.

Attraction to Robot An independent means t-test for attraction to the robot yielded significant results, $t(32) = 2.06, p < .05$. It was perceived as more attractive when it was positively responsive ($M = 2.89$, $SD = .80$), than when it was negatively responsive ($M = 2.37$, $SD = .66$).

8. DISCUSSION

Our results show support for Hypothesis 1: A robot using positive responsiveness behaviors to negative event disclosure is perceived as more responsive by the human than a robot showing negative behaviors. We can say that our design for responsiveness was effective: Nodding and affirmative texts caused a significant increase in a validated PPR scale when compared to distraction behavior and slightly dismissive text. Indeed the levels and effect sizes we measured with perceived robot responsiveness were on par with those found in perceived human responsiveness. We thus show that PPR can transfer from human-human to human-robot interacting using extremely simple cues from a non-anthropomorphic robot, laying out promising design implications for robotic companions.

Hypothesis 2 was also supported: Positive responsiveness causes people to evaluate the robot's character traits higher than when the robot behaves with negative responsiveness. This relates to our previous findings which show that a joint experience can cause higher impression of the robot [13], adding responsiveness to the robotic behaviors that can positively impact this scale.

Out of the overall agent impression, social perception was significantly affected by the robot's responsiveness (Hypothesis 2a), but the robot's competence impression (Hypothesis

2b) was not. This indicates that responsiveness does not make the robot more positively evaluated across all traits, but that it is specifically related to the social aspects of its perceived character. People found the negatively responsive robot as competent as the positively responsive one. This finding partially rules out a sentiment override (i.e., global, nonspecific positivity or negativity) explanation.

When looking at the robot's desirability, we find support for Hypothesis 3. People find the responsive robot more attractive than the non-responsive one, albeit with a small effect size. Increased desirability or attraction could have implications on the robot's value to people, including monitory value, perhaps their willingness to interact with the robot, and the amount of time people would want to spend with it. These outcomes have implications for long-term human-robot relationships with caregiving robots.

These results were elicited with a minimal set of behaviors, using a simple non-anthropomorphic robot with no face and no audible speech. Indeed, all of the behaviors we used can be easily programmed into a social robotic system, and the robot we used is a commercially feasible device, lending the results near-term practical implications.

Our study, however, raises the question: Why even examine a negatively responsive robot? Clearly, no robot developer would want to program negatively responsive behaviors into a robot, especially one intended for caregiving roles. The response to this question is threefold: While it may be true that we do not want to design robots that are negatively responsive, we do want to determine whether or not humans perceive robots in the same manner as human partners in conversation. In order to understand the effects of a robot's responsiveness, we need to compare different kinds of responsive behavior.

Second, the kind of negative responsiveness displayed in our study is by no means different from what many consider appropriate behavior. Our negative manipulation was not extreme, but more of a cold shoulder, similar to how people intuitively respond to negative event disclosures. Trying to encourage people by telling them that one "doesn't need to take it so badly" is often considered a helpful response. Finally, a robot might need to look away from the user for practical purposes, making it worthwhile to understand the effects this behavior may have on a disclosing individual.

The use of robots listening to humans and displaying appropriate responsiveness behavior can be particularly important in scenarios in which a person cannot, or will not, talk to another human. Specifically, a person's situation could be so sensitive that they prefer to confide in a machine rather than a human. As Turkle points out, people's trust when confiding in a machine does not necessarily "speak to what they thought [the computer] would understand but to their lack of trust in the people who would understand." [29]. There are many populations (e.g., children who suffered abuse, hospitalized, isolated or confined people) who would perhaps prefer to disclose to a robot with limited understanding of the conversation's content, but which can evoke the appropriate sense of responsiveness necessary to support their disclosure in a positive way.

9. CONCLUSION AND FUTURE WORK

In this study we examined the notion of perceived partner responsiveness (PPR) of a robot to a human's negative event disclosure. PPR, the sense that one's partner is supportive of one's needs, is a central concept in human relationships, with positive effects on relationship and personal well-being. As such it is a crucial concept to design for when building robots for caregiving roles.

Our study demonstrates that even using a desktop-size non-anthropomorphic robot with abstract geometric components and no facial features or audible speech, we can design simple behaviors that significantly induce more PPR, at levels comparable with perceived human responsiveness measured in a similar context.

In addition to demonstrating robot PPR, we also showed significant outcomes of the robot's behavior on the agent's perceived positive human-like character traits, and in particular on the social subset of these traits. We also found a significant, if small, effect on the human's attraction to the robot as rated by a validated attraction scale.

In future work, we would like to tease out the relative contribution of the robot's textual responsiveness and the PPR induced by its gestures. In addition, we would like to look at a more varied demographic, as well as at age effects, in particular with robots for elderly care in mind.

Individual differences in personality (such as attachment style) have been shown to mediate PPR effects. We would like to evaluate these in the context of robotic PPR as well.

One limitation of this work was the absence of a neutral responsiveness control condition, in which the robot does not engage in any nonverbal behavior, and does not comment verbally beyond asking the participant to continue to the next paragraph. In our follow-up study, currently underway, we have included such a neutral condition in addition to the two conditions described above.

This work also only looked at responsiveness to negative event disclosure in a laboratory setting. It makes sense to study responsiveness in other contexts, for example positive event disclosure, health-care relationship, and in educational settings. Of course, effects of responsiveness in long-term human-robot relations, and the resulting effects on people's well-being, are an ambitious further step.

Finally, here we only evaluated self-report metrics. We would like to study behavioral outcomes of robot PPR. Does robotic PPR encourage more human disclosure, or reciprocating responsiveness by the human towards the robot?

Nonetheless, this is an important onset to understanding the notion of robot responsiveness to humans, which can inform the design of robots for healthcare, elderly care, education, and other personally meaningful human-robot relationships.

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