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Sharing stressors with a social robot prototype: What embodiment do adolescents prefer?☆

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ABSTRACT

Social robots may be an effective and appropriate technology to help reduce stress in adolescents, thereby improving mental health. Designing appropriate and engaging human–robot interactions must take into consideration the effect of the robot embodiment. Therefore, we conducted an exploratory, within-person study with 66 US adolescents (ages 14-19) in local high schools and a university setting. We compared stress disclosure interactions with a social robot prototype in three distinct embodiments: physically present, digitally rendered on a computer screen, and in immersive virtual reality. We compared participants' responses to attribute ratings as well as their verbal engagement for all embodiments. After interacting with all three embodiments, participants completed exit surveys and interviews in which they identified and discussed their interaction experiences and their preferred robot embodiment. Participants suggested that sharing stress with the robots was helpful and they clearly articulated their individual views on the benefits and detriments of each robot embodiment. Overall, the physical robot was rated most comfortable. However, more adolescents preferred the interaction with the virtual embodiment than the digital or physical. Statistically significant gender differences were found in verbal engagement. Both quantitative and qualitative data from this study provide a preliminary understanding of how adolescents experience interactions with social robots as well as their preferences for certain embodiments.

1. Introduction

Adolescence is a period of dramatic growth including social, emotional, and identity development (Steinberg, 2014). Psychological stress is common in adolescents and typically stems from school. Eighty-three percent of teens report that school is a significant source of stress, and 34% predict that the next school year will be even more stressful than the last (Association, 2014). Therefore, it is no surprise that the current generation of adolescents report more stress than any other generation, with 31% of US teens reporting being overwhelmed as a result of stress (Association, 2014). Chronic stress negatively impacts cognitive function and learning (Vogel & Schwabe, 2016) and is correlated with increased school drop out rates (Dupéré, Leventhal, Dion, Crosnoe, Archambault, & Janosz, 2015). Unfortunately, many schools lack the resources (time and personnel) to implement and maintain sufficient school-based mental health programs (Eiraldi, Wolk, Locke, & Beidas, 2015) and programs to reduce stress appear only effective for a small group of adolescents (van Loon et al., 2020).

Given that many teens' lives are mediated through a variety of digital technologies (Davies & Eynon, 2013), using a digital device to support adolescents in reducing their school stress may be contextually appropriate, accessible, and desirable. To address the challenge of stress in adolescents, our overall project aims to develop a school-based, social robot designed to gather anonymous, stress-related data while providing a brief, stress-reducing intervention. Human-to-human stress disclosure is an interaction that has been successful in reducing stress in humans (Hofmann, Asnaani, Vonk, Sawyer, & Fang, 2012; Kahn, Achter, & Shambaugh, 2001; Zhang, 2017) and shows therapeutic promise in human–robot interactions (Birnbaum et al., 2016; Martelaro, Nneji, Ju, & Hinds, 2016). Adolescents have shown desire to share emotions and stressors anonymously with a social robot (Björling, Rose, Davidson, Ren, & Wong, 2019a) and have suggested a school setting is appropriate (Björling, Xu, Cabrera, & Cakmak, 2019b). However, whether a physically present robot for

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teen–robot stress disclosure is necessary or the most comfortable embodiment has not been explored.

Therefore, our current investigation explored the experiences of adolescents disclosing stressors to a social robot prototype in three different embodiments: physical, digital, and virtual. See Fig. 1 for examples. Our current study set out to explore how adolescents experience stress disclosure interactions with each of the three robot prototype embodiments (via verbal engagement and robot attribute ratings).

2. Related work

2.1. Adolescent stress and mental health

Adolescents are defined as children ages 10–19, in the second decade of their life (Organization, 2020). Adolescents are a unique population as during this period individual differences emerge (Steinberg, 2014). This is also a time of great growth and creativity, suggesting that appropriately designed and engaging supports could have a strong positive impact (Little et al., 2013). However, given this period of dramatic growth, adolescents are a unique population, negatively affected by stress and mental health issues (Association, 2014; Gunnell, Kidger, & Elvidge, 2018) making them even more vulnerable to mental health issues in adulthood. Increased stress has also been shown to negatively impact learning and memory (Vogel & Schwabe, 2016) as well as educational achievement (Gautam & Pradhan, 2017). Chronic stress is correlated with high-risk sexual behavior, early parenthood, negative impacts on social, work and family relationships (Colten, 2017). Mental distress has accounted for suicide, the third leading cause of death for US youth ages 10 to 24 (Young & Dietrich, 2015). Although the demand for adolescent mental healthcare has significantly increased in the past decade Mojtabai and Olfson (2020), we have been unable to meet the demand (Alderman, Breuner, et al., 2019). It has been argued that given the growing mental health population, innovative and scalable and engaging models of delivery are needed (Kazdin & Rabbitt, 2013). Social robots represent such a technology.

2.2. Current technologies to reduce stress for teens

Although technologies exist to improve mental health in adults via smartphone apps (Þórarinsdóttir, Kessing, & Faurholt-Jepsen, 2017) and web interventions (Heber et al., 2017), few are focused specifically on adolescents. Designing specifically for teen mental health can support teens in becoming more self-reliant, developing unique coping strategies for dealing with stress, helping them connect with a community for support and shared experiences in both online and collocated spaces (Rebecca Grist & Stallard, 2017). A body of research is beginning to unravel the potential of designing specifically for teen mental health (Bisafar & Parker, 2016; Rose & Björling, 2017; Slovák et al., 2016, 2018).

Currently, smartphone applications are the most common technology for mental health improvement in adolescents. In a recent review of mental health applications for adolescents, Rebecca Grist and Stallard (2017), reviewed 15 different smartphone applications ranging from mood monitoring, depression and anxiety treatment, to suicide prevention. Overall, they found that more evaluation is needed to determine the potential efficacy of mental health applications. Although acceptance rates of smartphone applications were high, use was only moderate, suggesting engagement could be improved.

However, the adolescent developmental stage is one of typically strong social development (Blakemore, 2018). Socializing with peers and having strong social relationships may be a strong buffer against the negative impacts of stress in adolescents (Colten, 2017). Typically static internet and smartphone applications lack the social interaction characteristics made available through social robots.

2.3. Mental health and social robots

Social robots provide a variety of benefits and can assist humans by fulfilling currently unmet needs (Feil-Seifer & Mataric, 2005). Social robots can provide therapy and assessment of mental health in a variety of populations (Breazeal, 2011) including those that are vulnerable (Kim et al., 2013). Socially Assistive Robots (SARs), unlike smart phone and computer applications, are embodied, physical agents, capable of human–robot interaction through audio, visual, and haptic channels (Feil-Seifer & Mataric, 2005).

A recent review of SARs for mental health identified only five robotic devices (mostly animoids) studied have shown some evidence of efficacy in terms of reducing anxiety or increasing social interactions in elderly populations (Scoglio, Reilly, Gorman, & Drebing, 2019). None of the studies reviewed included children or adolescents.

One of the most studied SARs that has shown effective at reducing anxiety is the robot Paro. Paro (Wada, Shibata, Saito, Sakamoto, & Tanie, 2005) is a plush seal originally designed for seniors in assisted living environments to reduce stress and stimulate social interaction. Paro has shown reduction of anxiety and increased social interactions in seniors in assisted living (Kang, Makimoto, Konno, & Koh, 2019) and has been shown to reduce physiologic stress in adults (Aminuddin & Sharkey, 2017). However, studies of Paro to reduce stress or anxiety in children is limited. One study explored stress reduction with Paro in children (ages 9–12) after experiencing a socially induced stress task, children who interacted with the robot showed increased positive mood, but no difference in stress or arousal compared to the inactive or no robot conditions (Crossman, Kazdin, & Kitt, 2018). However, in a small study of young children and adolescents, Paro did significantly reduce anxiety and pain when used in hospital settings during a family interaction (Okita, 2013).

Studies suggest that robot interactions can reduce stress in the elderly (Wada et al., 2005), promote physical and emotional verbal expressions in children (Jeong, 2017), reduce workplace (Yorita, Egerton, Oakman, Chan, & Kubota, 2018) and mental stress in adults (Kühnlenz et al., 2018) as well as physiological stress in in-fants (Williams, MacLean, Guan, Collet, & Holsti, 2019).

2.4. Design of social robots for children

Given the therapeutic potential of social robots, many SARs have been designed specifically for children. For example, social robots have been designed specifically to support children with autism (Dehkordi, Moradi, Mahmoudi, & Pouretemad, 2015; Hoa & Cabibihan, 2012). SARs have also been designed for educational settings in a variety of roles such as teacher, peer, or novice (Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018a; Causo, Vo, Chen, & Yeo, 2016; Kanda, Hirano, Eaton, & Ishiguro, 2004), and have even been designed for vulnerable populations such as English Language learners (Belpaeme et al., 2018b) and teaching language to infants who are born deaf (Scassellati et al., 2018). SARs have also been designed to help reduce anxiety in hospitalized children (Jeong, Breazeal, Logan, & Weinstock, 2017; Jeong et al., 2015; Meghdari et al., 2016). In our own work using co-design methodologies, we found adolescents embrace the idea of an appropriately designed social robot for the purpose of helping teens to manage stress (Björling, Cakmak, Thomas, & Rose, 2020a; Björling et al., 2019b; Rose & Björling, 2017). Given the potential benefit of social robots as a therapeutic tool, the exploration of a robot specifically designed to reduce adolescent stress is a novel application. However, in order to determine whether this an appropriate technology to support teens at school, it is critical to examine how different embodiments affect the interaction.

Fig. 1. Examples of each robot embodiment. A: Physical, B: Digital, C: Virtual Reality.

2.5. Factors affecting robot interaction

Based on the existing literature, two factors appear to be crucial in human–robot interaction. Social presence (Biocca, 1997; Lee, Jung, Kim, & Kim, 2006; Oh, Bailenson, & Welch, 2018), defined as the degree to which a user feels access to the intelligence, intentions, and emotions of another being, is an integral part of a social interaction. Intimacy, or the feeling of connection that communicators feel during an interaction (Short, Williams, & Christie, 1976) is also an important factor that must be explored when examining the effect of embodiment. However, the extent to which social presence and intimacy translate to digital or virtual embodiments is not well studied in adolescents.

2.5.1. Physical robot versus digital

A body of experimental work has investigated how different embodiments affect the quality of social interaction between a human and a robot. More specifically, researchers have explored how a robot's physical presence affects human judgments of the robot as a social partner (Bainbridge, Hart, Kim, & Scassellati, 2011). In this experiment, participants collaborated on simple book-moving tasks with a humanoid robot that was either physically present or displayed via a live video feed. They found that participants had overall a more positive interaction with the physically present robot. Another study found that a physically present robot tutor produced increased cognitive learning gains compared to on-screen or voice-only tutors (Leyzberg, Spaulding, Toneva, & Scassellati, 2012). Furthermore, another study demonstrated that people empathized more with a physically present robot experiencing harm than with a simulated robot (3D model or live video feed) (Seo, Geiskkovitch, Nakane, King, & Young, 2015). Yeong, et al. compared three SAR embodiments (stuffed toy bear, physical bear robot, or bear robot avatar on a tablet) in young children (3–10) in a hospital setting (Jeong et al., 2017). They found that children are the most physically and verbally engaged when interacting with the physical robot compared to the other two embodiments.

A large survey of experimental works examined 33 studies exploring the effect of physical presence on people's psychological response to social robots (Li, 2015). In this survey, physical presence refers to how a robot is presented to others. For example, a robot that is in the same physical space as the user is considered to be "co-present" and one that is being shown as a live video feed on a screen or projection is "telepresent". A majority of the evidence suggests that co-present robots were found to be more persuasive and perceived more positively than telepresent robots. In addition, co-present robots resulted in better task performance.

2.5.2. Virtual reality versus digital

While most of the existing studies focused on comparing the interaction between a physical co-present robot versus a telepresent robot, only a few studies have explored the effect of social interaction between users and a co-present robot within virtual reality (VR). The embodiment of virtual reality offers an alternative digital environment where users can experience a digital form of co-presence with the robot, as both the robot and the user share the same virtual space (Li, 2015; Schuemie, Van Der Straaten, Krijn, & Van Der Mast, 2001).

A study comparing VR and computer-display found that performance on collaborative tasks with a robot was significantly higher in VR simulations compared to 2D robotic simulations (Liu, Rakita, Mutlu, & Gleicher, 2017). Although this study does not focus on social interaction, the results suggest advantages of VR for depth perception in a collaborative task where perception is a critical factor.

2.5.3. Physical robot versus virtual reality

In a pilot study, a group of researchers compared the effectiveness of a VR social robot to a physical robot in storytelling for children (Shariati et al., 2018). They found no significant difference in robot attribute ratings such as likeability, perceived intelligence, animacy, anthropomorphism, and perceived safety between the two embodiments and concluded that the VR embodiment has the potential to be an auxiliary substitute for the real social robot. On the other hand, another group of researchers explored proxemics and presence of VR compared to a physical robot (Li, van Almkerk, van Waveren, Carter, & Leite, 2019). They found that people perceived the virtual robot in VR to be more discomforting than a physical robot and had a significantly lower feeling of presence in the VR embodiment.

2.6. Human–Robot Disclosure

Disclosing stressful experiences and feelings has been shown to be therapeutic in helping humans to manage their stress (Hofmann et al., 2012; Kahn et al., 2001; Zhang, 2017). Disclosure of stress has been shown to decrease depressive symptoms (Kahn & Garrison, 2009). Specifically, compared to written disclosure, verbal stress disclosure has been shown a protective factor against depression (Esterling, Antoni, Fletcher, Margulies, & Schneiderman, 1994). Disclosing stress has been found successful and therapeutic in human–computer (Moon, 2000) and human–robot interactions (Ling & Björling, 2020; Martelaro et al., 2016).

In the context of stress intervention, clinical research has shown that empathy and trust in a physician–patient relationship are associated with improved therapeutic outcomes (Jani, Blane, & Mercer, 2012). While the role of a social robot for mental health intervention is far from that of a human therapist, empathy and trust are important factors when exploring the outcomes of human–robot interactions. Previous research has shown that children empathized more with a physical robot than one displayed on a screen (Kwak, Kim, Kim, Shin, & Cho, 2013). Similarly, people have also shown more trust toward a physical robot than one mediated by a screen (Kidd & Breazeal, 2004; Powers, Kiesler, Fussell, & Torrey, 2007). Finally, to assess the acceptance and future viability of platform, a crucial component to measure is participant's willingness to re-engage in future interactions with that platform (Lee & Choi, 2017).

In our own research, we have found that teens embrace the idea of sharing stressors with a social robot at school (Rose & Björling, 2017). In our previous studies, teens have interacted with our social robot in and described school as both an appropriate and desirable setting in which to talk about stress with a robot (Björling et al., 2019a). Finally, as part of this current study, we conducted an analysis of the effect of the robot interactions on momentary stress and found that adolescent momentary stress levels significantly decreased across robot interactions (Björling, Ling, Bhatia, & Dziubinski, 2020b). Therefore, for the current study we explored the following research questions:

(1) Which robot embodiment do teens prefer?
(2) Which embodiment resulted in the strongest engagement (via word count?)
(3) How did adolescents' attribute ratings differ across robot embodiments?

3. Method

3.1. Human-centered design

As part of a larger project aimed to design and develop a social robot specifically for adolescents (Björling et al., 2019a; Björling, Rose, & Ren, 2018; Rose & Björling, 2017) using a human-centered methodology (Cooley, 2000), we intentionally engaged adolescents with a generic, low fidelity robot interaction to better understand their experience and preferences across three distinct social robot embodiments.

The current study utilized a mixed-methods, comparison design study to explore interactions with (1) a physical robot, (2) a digital robot rendered on a computer screen, (3) and a virtual robot in immersive virtual reality. We opted for a within-subject, comparison design as it allowed participants to reflect on their experience and compare different embodiment designs of the robot. In the following section, we detail the participants and recruitment process, the unique in-the-wild school setting, the design of the interaction, and our methods of data collection.

3.2. Participants and ethics of participation

After obtaining university Internal Review Board approval and school district research review, adolescents ages 13–21 with English proficiency were recruited through convenience sampling and word of mouth with local area schools and one university. Parental permission was required for participants under 18 years of age and gathered at the start of the study. The study occurred at the participants' respective schools to not only maintain contextual validity, but also for comfort and familiarity. In addition, previous social robot interactions at school demonstrated participants' desire and comfort with interacting with a social robot in a school setting (Björling et al., 2020a, 2019a, 2019b).

Upon introduction to the study, researchers ensured that all participants read, understood, and retained a copy of the consent/assent form. Any questions from the participants were immediately answered by the researchers. Participation was voluntary and participants could disengage at any time. All photos and videos of participants were used only for research analysis purposes. Because transparency is important when working with adolescents (Björling & Rose, 2019), participants were told they would be interacting with the robot in a setting with the researcher present and operating the robot.

Fig. 2. Physical Robot.

3.3. Distinct robot prototype embodiments

The **physical robot prototype** used in this study is a prototype of a social robot previously co-designed by researchers and adolescents to ensure likability and appropriateness as part of our larger project (Björling et al., 2020a, 2019b). The physical robot consists of two stacked, felt-covered boxes, each with a slot for a Google Nexus 7 tablet. One tablet is used as the robot's face, which is a web application running on a web browser on the tablet. The face has two eyes that blink and its facial expression can be customized and modified easily by teens. This tablet is also used to project the robot's voice through the browser's text-to-speech capability. The other tablet, located at the robot's belly, is intended to be used as an additional input/output touch screen for communication. This was not used in this study. See Fig. 2 for embodiment.

For this particular study, we created a generic and simple robot interaction to explore the true effect of the robot embodiment itself. This included a simple and appropriate robot face. Therefore, a small group of high school adolescents ($n = 21$) were invited to customize our physical robot as a "good listener" using our end-user programming software. The teens gave the robot large, dark, blinking eyes, a blue background color because it was "calming" and a small mouth, as they wanted to convey that it does not talk a lot. In addition, they helped us to design a "listening" voice (through modifications of various male and female voices) and decided upon a young female voice with a slight robot reverberation and a subtle Chinese accent.

Our **virtual and digital social robot prototypes** were modeled to replicate the physical robot at the exact scale in an application created through the Unity engine (Unity Technologies, 0000). For the current study, we ran the Unity engine in an immersive virtual reality environment (virtual robot) using an HTC Vive headset. The virtual environment was designed for seated gameplay given all robot embodiments included seated interactions. For the digital robot, the Unity engine was displayed on a flat screen monitor.

To maintain consistency across all three embodiments, we designed a tele-operator interface to ensure consistent teleoperation among the research team. Because the robot's face was pre-rendered, only the robot's speech was controlled through a customized browser-based "Wizard of Oz" interface. The control interface had a series of questions designed to elicit stress stories from the participants. See Table 1. Operators followed a clear path through four stages: introduction, momentary stress and mood, stress story, and exit. A small number of impromptu buttons corresponding to simple pre-specified utterances (*e.g.* "I see", "I'm sorry I didn't hear that") aided operators in responding to the user's utterances. Additionally, there were a set of empathetic responses such as "Thanks for sharing that with me", and "That sounds stressful", to ensure that the participant felt heard.

3.4. Study design

As an exploratory study, we designed a within-person, mixed-methods study allowing each participant to experience all three robot embodiment interactions and reflect upon that experience. In order to maintain contextual validity (Rogers & Marshall, 2017), the research team, along with all equipment, traveled to various local high schools and a university and conducted the study "in the wild" through designated classrooms or common areas during the school day or after school. At each study location, the research team adjusted the room set up to accommodate the three interaction stations one for each embodiment type.

3.5. Intake and stress stories

Participants arrived in a group of three. Upon arrival, participants were given a consent form to review and an opportunity to ask questions. After consent, they completed an intake survey which included demographic information (age, self-reported gender, and ethnicity) as well as their attitudes toward robots using the Negative Attitudes Toward Robots Scale (Nomura, Suzuki, Kanda, & Kato, 2006). We also captured their past experiences with social robots and virtual reality technologies through two items asking; "How many times have you used virtual reality technology?" and "How many times have you interacted with a social robot (such as robotic pets, any physical robots) in the past?", with five response options ranging from *never* to *more than five times*.

After the survey, participants were asked to make brief notes related to three recent stressful events. To elicit recall we gave them a paper form that invited them to state what the event was and to note any significant feelings related to the event. Most participants wrote only one or two summary sentences or simply listed items in response to this prompt. Participants were informed that they would be sharing one of these events with each of the three robot embodiments and they could reference their notes before or during each of the interactions.

3.6. Robot interactions

After completing intake surveys, participants interacted with all three different robot embodiments. The ordering of interaction was coordinated in a way to ensure counterbalance. After we assigned participants with their robot order, they each walked to their designated station where another researcher/operator was present. After one robot interaction was completed, the participant immediately responded to a post-interaction survey (described below). They then moved on to the next designated station to continue their next interaction until they had interacted with all three embodiments. See detailed participant flow in Fig. 3 for more detail. During each robot interaction, participants engaged in a stress-sharing activity modeled after many psychological and human–computer interaction studies cited previously. Given that transparency is an important component of our participatory relationship with adolescents, our operators were visible

Table 1
Social robot's prompts to elicit stress stories and details.

Prompts
First:"I really like to hear stories. Would you like to share a stress story with me?"
Second:"Do you want to tell me more about that?"
Third:"How did that make you feel?"

to each participant during the entire study. However, headphones were used by participants and operators in every interaction in order to help isolate the robot's voice for the participant, and from environmental noise at each study location.

Participants' verbal interactions (word count) were captured through video as a measurement of engagement with the robot. We chose this over length of interaction due to the range of speed in which adolescents tend to speak. In addition, we chose word count over eye gaze given eye gaze was not easily measured in virtual reality.

3.7. Interaction surveys

In order to capture immediate responses and avoid recall bias, a brief survey was administered immediately after each robot interaction to collect participant's ratings. We compiled salient items from existing instruments to create a brief post-interaction survey. We slightly modified items to ensure the survey was contextually appropriate for our study. In order to measure participants' responses regarding *social presence*, we included three items from Lee et al. (2006) depicting the robot's human-likeness, sensitivity, and socialness. To capture *robot empathy*, we included two items from the Modified Interactant Satisfaction Survey (Riek & Robinson, 2008) regarding whether the robot recognized a participants' emotions and expressed appropriate feelings. Based on Lee and Choi (2017), we included one item on *participant's feeling of closeness* with the robot to capture intimacy and another item to capture participant's trust. Finally, to capture *participant's willingness to re-engage in future interactions*, or "intention for future use", we developed two items, one on the participant's level of comfort, and the other on how likely they were to share another stress story with the robot in that particular embodiment.

3.8. Exit survey and interview

After participants had interacted with all three robot designs, they completed a customized final exit survey. This survey captured their final preference for a particular robot embodiment as well as how often they might use it in the future. Participants were then asked open-ended questions regarding which robot they preferred most and why. Interviewers also asked about what they disliked about embodiments that were not preferred. Participants were interviewed individually or in small groups by research staff as the final activity. The study took around 20 min to complete and participants were rewarded with a $10 gift card after participation.

4. Results

Overall, 66 adolescents, 55% female (ages 14–19, m = 17.26) participated in our study. The participants came from 3 urban pacific northwest high schools (n = 45) and one public university setting (n = 21). See Table 2.

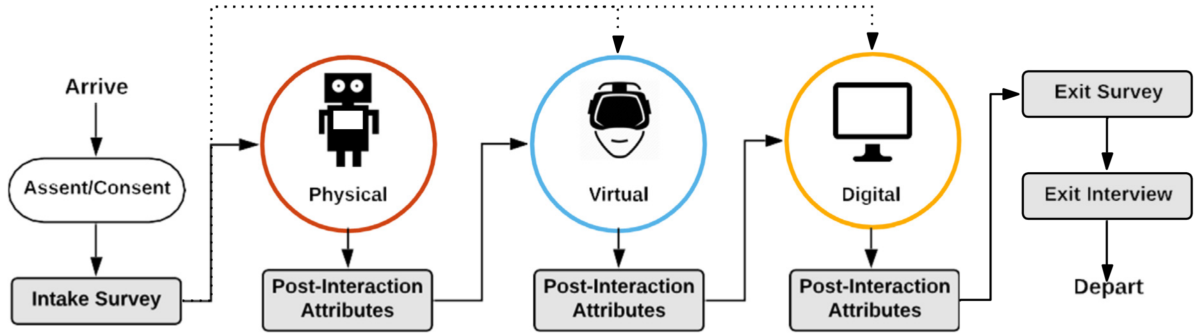

Fig. 3. Diagram one possible order of participant flow.

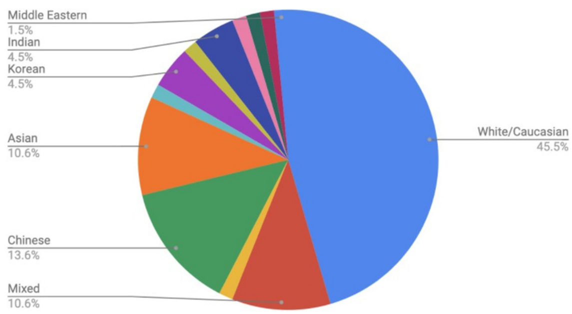

Fig. 4. Distribution of ethnicities across our panel, with 45.5% identifying as White/Caucasian.

4.1. Demographics

The participants self-reported their ethnicity in an open ended item on the intake survey. From these data, ten broad ethnic categories emerged across all participants. See Fig. 4 for more detail regarding ethnicity's distribution.

Exposure to robotic and virtual reality technologies varied across the sample. There were no significant differences for age, gender or school for technology exposure. More than half of our sample (55%) reported no exposure to a social robot and a third (30%) said they had no exposure to virtual reality prior to our study.

4.2. Attitudes toward robots

Adolescents' negative attitudes toward robot ranged from 21 to 58 ($M = 38.14$, $SD = 8.38$). A two-tailed, independent sample Welch's t-test revealed significant gender differences. Females ($M = 40.16$, $SD = 8.45$) scored significantly higher than males ($M = 35.55$, $SD = 7.67$), [$t\ (62.58) = 2.32$, $p = .02$]. In examining sub-scales, the negative attitudes about situations involving robots (S1) was significantly higher for females ($M = 15.22$, $SD = 3.29$) than males ($M = 12.21$, $SD = 3.49$) [$t(58.55) = 3.56$, $p < 0.01$]. For the negative attitudes toward social influence (S2), females ($M = 16.08$, $SD = 3.68$) scored significantly higher than males ($M = 14.14$, $SD = 3.52$), [$t(55.4) = 2.36$, $p = 0.02$]. The negative attitudes toward emotions (S3) did not differ between females ($M = 8.86$, $SD = 2.88$) and males ($M = 9.21$, $SD = 2.55$), [$t(62.96) = 0.51$, $p = 0.61$]. Although this is still a somewhat small sample, these findings suggest that the female adolescents in our study had more negative attitudes toward robots than the males. See Fig. 5 for more details for the NARS sub-scale and overall scores, by gender.

Table 2
Descriptive demographics by school site.

School Setting	n	Age (m)	Female (%)
High school 1	8	16.375	100
High school 2	28	16.25	32.14
High school 3	9	18	66.67
University	21	18.62	66.67
Total	66	17.26	56.06

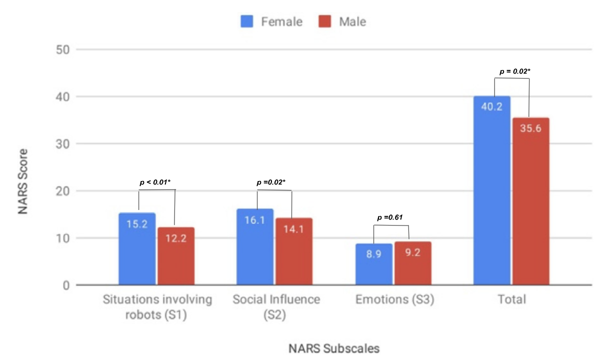

Fig. 5. Average NARS sub-scale and overall scores by gender.

4.3. Robot interactions

Overall, participants seemed engaged in the robot interactions. It is important to note that during the interaction, participants were asked by the robot if they wanted to share a stress story. In each of the 198 robot interactions gathered in this study, the participant agreed, saying "yes" or "sure" and continued. When interacting with the prototypes, participants mainly shared academic-related stressors. Academic stressors included having too much work to do, feeling overwhelmed by extracurricular demands in addition to school, or high stakes exams (such as final examinations). More rarely, participants shared stressors about transportation, home life, or personal relationships, such as a fight with a friend. After participating in the three robot embodiment interactions, the responses were encouraging as most adolescents seemed optimistic about the idea of having interactions with robots about their stress. When asked on a Likert scale how often participants would share their stressors with the robot embodiment they preferred (1 "not very often" to 7, "very often") 51% of participants selected a 4 or 5 ($M = 3.78$, $SD = 1.51$). Though not significantly different, males participants ($m = 4.36$, $sd = 1.45$) reported they were slightly more likely than females ($m = 4.09$, $sd = 1.48$) to share stressors with a robot in the future.

During the exit interviews, adolescents provided more insight into how they experienced disclosing stressors with a social robot. One participant said,

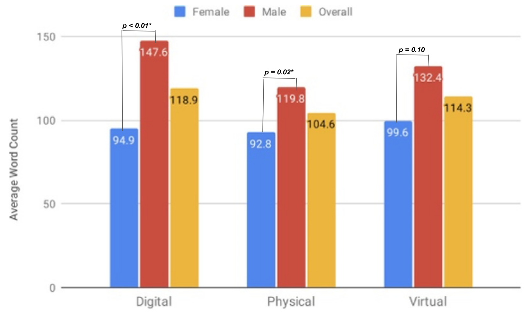

Fig. 6. Average word count for each embodiment by gender.

I think a lot of people, might talk to these robots. I thought it was good that I could share some of my stories. Just like how people keep diaries and write out how they feel.(P221, male, school 2)

Another adolescent suggested that this type of interaction might appeal to those who do not normally have such conversations with friends.

I think it could be helpful for the right kind of person. I'm not someone who usually likes to have these kinds of conversations in general so I don't know if I would have them with a robot. But I know for sure that for some people it would be helpful for them. Somebody who doesn't have close friends that could help them in that regard. (P301, male, school 3)

However, not everyone enjoyed talking to a robot. There were a small minority of adolescents who found the interactions awkward, strange or "cold". For example, one participant in the very beginning of her interaction said, "This is weird", after the robot began to speak. Then when asked about her stress she said, "I'm having finals, so maybe I'm not in a very delightful mood. I'm stressed when I interact with a non-human" (P424, female, school 4).

4.4. Verbal engagement

Verbal engagement ranged widely among participants. Although no age, school, or grade differences emerged when exploring verbal engagement with the various robot embodiments, we did find some significant gender differences. See Fig. 6 for more details.

Across all embodiments, males participants had a significantly higher average word count ($M = 142.09$, $SD = 87.21$) compared to female participants ($M = 96.32$, $SD = 42.90$), [$t(38.55) = -2.5917$, $p = .01$]. When exploring individual embodiments, the digital had the highest overall length of engagement for males with a mean of 147.58 words ($SD = 60.00$) compared to a mean of 94.90 words ($SD = 44.56$) for females [$t(45.40) = -3.70$, $p < 0.01$]. The physical robot embodiment also had a significantly higher engagement for males ($M = 119.79$, SD c $= 41.14$) compared to females ($M = 92.78$, $SD = 49.38$), [$t(61.67) = 2.39$, $p = .02$]. For the virtual reality embodiment, no significant difference is found between female participants ($M = 96.95$, $SD = 52.44$) and male participants ($M = 132.41$, $SD = 93.68$), [$t(41.79) = 1.68$, $p = .10$]. Finally, in order to explore within person changes in verbal engagement over time, we ran a repeated measures ANOVA and found extremely similar lengths of engagement across all participants' word counts for their first (m = 112.74, sd = 70.12), second (m = 112.73, sd = 56.33) and third (m = 111.63, sd = 57.76) interactions. This suggests that there was not a warming up effect, nor a decrease in engagement after repeating the interaction.

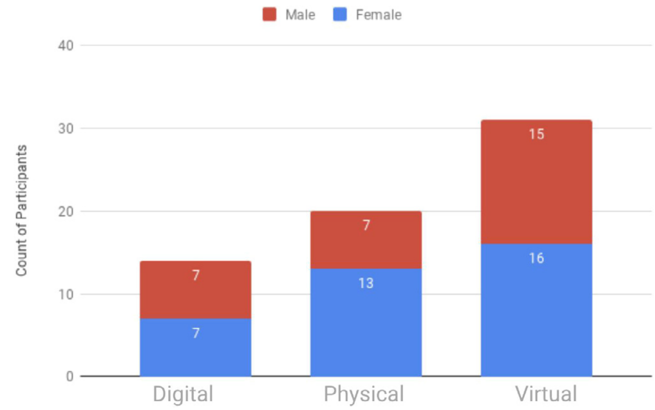

Fig. 7. Embodiment Preferences by gender.

4.5. Robot attribute ratings

Adolescent responses to robot interactions differed across the three embodiments. The virtual reality prototype was rated highest for future intention to use, presence, empathy, and trust. The physical prototype received the highest rating for intimacy and word count was highest for interactions with the digital prototype. See Table 3 for full descriptive detail.

When examining robot attributes, we found statistical significance in several Wilcoxon signed-rank pairwise comparisons after Bonferroni adjustment. For intimacy, physical embodiment ($M = 3.83$, $SD = 1.45$) scored significantly higher than the digital embodiment ($M = 3.48$, $SD = 1.25$). For social presence, virtual embodiment ($M = 3.80$, $SD = 1.17$) scored higher than its digital counterpart ($M = 3.44$, $SD = 1.03$). See Table 3 for more details.

4.6. Embodiment preference

Of the 65 participants who completed the exit survey, more participants (47.7%) preferred the virtual embodiment for future stress disclosure interactions in comparison to the physical (30.8%) or digital (21.5%) embodiments. The virtual reality and digital embodiment were close to evenly split across genders. However, 65% of participants that chose the physical robot embodiment were female. See Fig. 7 for an illustration of gender distribution.

In order to better understand why participants chose the embodiment they did, we used applied thematic analysis (Guest, MacQueen, & Namey, 2011) to explore the exit interview question, *which embodiment would you prefer and why?* Descriptive themes emerged related to each embodiment type and are described below.

Adolescents who preferred the physical robot, described its form factor as *"huggable"*, *"fuzzy"* and *"comfortable"*. Participants who chose it also described it as feeling more lifelike.

I think the physical one. Out of the three I felt like it felt the most real, in a way. Because the digital one, it just kind of felt like, I dunno, it just didn't seem as real, the digital one was like a video game and the VR one also felt like a video game. Yeah, I think the physical one felt most real to me. (Female, Unknown Age, School 3)

The digital embodiment was described as *"cold"* by participants who did not prefer it. However, 21.5% of adolescents chose the digital embodiment as their preferred interaction. Their reasoning, however, often resulted from practicality (e.g. their schools already had computers and people know how to use computers) or familiarity.

Table 3
Robot Embodiment Attribute Ratings M(SD), as well as repeated measure ANOVA and Bonferroni-adjusted pairwise Wilcoxon ranked signed tests for robot attributes & word count. Huynh–Feldt epsilon is used as the test statistic.

Attribute	Physical	Digital	Virtual	ANOVA		Physical v. digital	Physical v. virtual	Virtual v. digital
				F(2, 124)	p	p	p	p
Future	4.22 (1.65)	4.00 (1.59)	4.38 (1.54)	2.57	0.08	0.68	0.76	0.18
Intimacy	3.83 (1.45)	3.48 (1.25)	3.79 (1.33)	3.05	>0.05	**0.01**	1	0.14
Presence	3.77 (1.24)	3.44 (1.03)	3.80 (1.17)	4.23	**0.02**	0.06	1	**0.03**
Empathy	4.24 (1.43)	4.06 (1.22)	4.40 (1.32)	2.84	0.06	0.81	0.62	0.08
Trust	4.30 (1.55)	4.29 (1.66)	4.67 (1.63)	3.48	**0.03**	1	0.11	0.07
Word count[a]	104.40 (50.47)	119.38 (59.05)	107.55 (55.86)	0.93	<0.05	0.13	1	0.27

[a]Sphericity assumption violated, **Bold** denotes $p < 0.05$.

> I feel like I'd use the computer [digital]. I felt like VR... felt kind of weird not being able to see who was around me...And the physical one, also felt kind of weird, considering how small it was... On the computer [digital], it felt more like something I was used to. (Male, 19, School 4)

As one participant articulated, the digital embodiment was more like a video game.

> I'm more of an 'off the grid' kind of person in that regard...So for that reason I think the PC one was the best. It kind of feels like a video game and less consequential. (Male, 18, School 3)

More adolescents (47.7%) chose virtual reality, in comparison to other embodiments, as their preferred program for stress interactions. Many of those who chose it described it as feeling more private. For example,

> I'd say VR cause you're not in the real environment anymore and where it seems like anyone is going to overhear you any second. (Male, 17, School 2)

One adolescent described her stress as feeling less real, given the virtual environment.

> I just felt more comfortable talking to the robot in VR. I think it's more comfortable for me in VR because when I was speaking to the robot in VR, my stress just seemed less real and, and when I was in the real world I just felt my stress piling on a bit. (Female, 19, School 4)

5. Discussion

Overall, adolescents embraced the activity of sharing their stressors with the robot prototypes in all three embodiments. After experiencing each embodiment, more participants reported a preference for virtual reality for future interactions in comparison to interactions with other embodiments. The preference for the virtual reality environment could be resulting from several affordances that VR provides. For instance, some participants noted that VR helped them to truly "escape the real world". Although virtual reality offers a sense of presence likely similar to that of interacting with a collocated, physical robot, it also is able to block out all real world sound and visual stimuli. This may offer a sense of intimacy that encourages stress-related disclosures or makes the interaction more personable. Although the virtual reality system was set up in a public space similar to the other embodiments, some participants reported that the interaction felt private or even intimate. There is preliminary evidence that virtual reality may match human to human disclosure interactions. In a recent study exploring face-to-face, virtual reality and texting disclosure with university students (Baccon, Chiarovano, & MacDougall, 2019) VR interactions resulted in similar therapeutic disclosure when compared to a face to face interaction. If the benefit of self-disclosure is similar to human-to-human interactions and the virtual environment adds the component of intimacy, this may explain why many of our participants chose the virtual environment for future interactions.

All participants were verbally engaged with each of the robot embodiments, but male participants talked significantly more than female participants, especially with the digital embodiment. This finding was surprising, perhaps because there are data to suggest that overall, adolescent girls tend to be more verbal than boys (Rose & Rudolph, 2006; Valkenburg, Sumter, & Peter, 2011). However, it may be that a social robot presents a more comfortable environment for social interaction for adolescent males. This may also be why social robots are increasingly successful interventions in adolescents with social deficits, such as those with autism (Costa et al., 2009; Costa, Santos, Soares, Ferreira, & Moreira, 2010; Jordan, King, Hellersteth, Wirén, & Mulligan, 2013). Because female participants scored significantly higher in their negative attitudes toward social robots before interacting with the prototypes, it is also plausible that their negative attitudes led to reduced verbal engagement or hesitancy during the interactions.

We were successful in our attempt to create a brief interaction that repeatedly engaged a wide range of participants. With 66 participants and a very low fidelity interaction, we assumed a small portion of participants would refuse to interact with the prototypes or disengage after finding the interaction not satisfying. However, all of our participants completed the three robot interactions. This suggests that even low-fidelity and simple disclosure interactions are engaging for some adolescents. We also saw that their level of engagement did not change over time. It would not have been surprising if the third interaction (being so similar to the first) resulting in a lower word count as participants would be looking forward to finishing the study. But this also did not happen. In fact, word count levels were extremely similar across all interactions regardless of order.

Finally, it is important to note the variation in experiences across individual participants in this study. Although more teens preferred the VR embodiment compared to the digital or physical embodiment, it was not a majority of the sample. This likely reflects the individuality of the adolescent stage of development and requires further research into individual preferences and the contexts in which those preferences emerge. It is quite likely that offering a range of embodiments or even offering on the fly customization may be necessary to meet the needs of such a diverse population. Adolescents are unique and it is quite likely that a one-size fits all technical solution for stress management is not feasible. The variation in their responses and their reasoning for their preferences speaks to the diversity that exists within this population. This diversity needs to be acknowledged and taken into consideration in all new technology designs.

6. Limitations and future research

There were several limiting factors in this study. First, given that we conducted all of these interactions at school sites in order to maintain ecological validity, we also introduced quite a bit of variation in terms of the environment in which the study was conducted. Second, to maintain transparency with our participants, they were aware that the robot was operated by researchers who were obviously overhearing the participants' stress story. The presence of the researcher likely affected the teen–robot interaction as teens may behave differently with an autonomous robot. However, in our previous studies in school settings (Björling et al., 2019a, 2019b), regardless of the location of the robot, teens volunteered to interact with the robot with researchers and peers present within earshot and described the experience as comfortable. In addition, having others present during the robot interaction may be ecologically valid given the robot is being design for a public school setting. Third, the design (robot voice and face) of the robot prototype, though created through codesign with teens, likely influenced the interactions in ways that were not measured. Further research exploring the effect of the robot design is necessary to tease out its impact on engagement and the effect of the interaction. Fourth, although we tried to replicate a simple, generic interaction in the three distinct embodiments, the size of the social robot in the digital environment was dependent upon the screen size (which varied slightly from school to school) and was dependent upon where the participant was sitting in relation to the screen. For this reason, it is not assumed that each participant had the same visual interaction in all conditions. Finally, although we saw no significant differences between high school and university students on any of our measurements, we are aware that developmentally, there may be large differences in these two populations. Therefore, future studies should explore differences between these two populations.

7. Conclusion

This was a very preliminary study exploring the experiences of adolescents disclosing stressors to a social robot in three distinct embodiments. Overall, we were able to create a brief, stress-reducing social robot activity that appears effective for adolescents. After experiencing this disclosure activity across all three embodiments, more adolescents preferred the virtual embodiment, in comparison to other embodiments, even though the physical robot was most stress reducing. In addition, a virtual embodiment may offer increased intimacy which may be valuable when asking adolescents to share emotions. Virtual reality offers a novel and unique sense of presence that deserves further exploration in relation to stress-reduction. Further exploration is needed to (1) determine what factors influence increased verbal engagement with social robots for adolescent males and (2) what factors affect negative attitudes toward social robots for adolescent females. In addition, future work exploring repeated use of disclosure over a longer period of time, ideally in-situ, will help to determine the true effect of a stress-reducing interaction with a social robot.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Alderman, E. M., Breuner, C. C., et al. (2019). Unique needs of the adolescent. *Pediatrics*, *144*.

Aminuddin, R., & Sharkey, A. (2017). A paro robot reduces the stressful effects of environmental noise. In *Proceedings of the European conference on cognitive ergonomics 2017* (pp. 63–64).

Association, A. P. and others (2014). Stress in america 2013 highlights: Are teens adopting adults' stress habits.

Baccon, L. A., Chiarovano, E., & MacDougall, H. G. (2019). Virtual reality for teletherapy: Avatars may combine the benefits of face-to-face communication with the anonymity of online text-based communication. *Cyberpsychology, Behavior, and Social Networking*, *22*, 158–165.

Bainbridge, W. A., Hart, J. W., Kim, E. S., & Scassellati, B. (2011). The benefits of interactions with physically present robots over videodisplayed agents. *International Journal of Social Robotics*, *3*, 41–52.

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018a). Social robots for education: A review. *Science Robotics*, *3*, eaat5954.

Belpaeme, T., Vogt, P., Van den Berghe, R., Bergmann, K., Göksun, T., De Haas, M., et al. (2018b). Guidelines for designing social robots as second language tutors. *International Journal of Social Robotics*, *10*, 325–341.

Biocca, F. (1997). The cyborg's dilemma: Progressive embodiment in virtual environments. *Journal of Computer-Mediated Communication*, *3*, JCMC324.

Birnbaum, G. E., Mizrahi, M., Hoffman, G., Reis, H. T., Finkel, E. J., & Sass, O. (2016). What robots can teach us about intimacy: The reassuring effects of robot responsiveness to human disclosure. *Computers in Human Behavior*, *63*, 416–423.

Bisafar, F. I., & Parker, A. G. (2016). Confidence & control: Examining adolescent preferences for technologies that promote wellness. In *Proceedings of the 19th ACM conference on computer-supported cooperative work & social computing* (pp. 160–171). ACM.

Björling, E. A., Cakmak, M., Thomas, K., & Rose, E. J. (2020a). Exploring teens as robot operators, users and witnesses in the wild. *Frontiers in Robotics and AI*, *7*, 5.

Björling, E. A., Ling, H., Bhatia, S., & Dziubinski, K. (2020b). The experience and effect of adolescent to robot stress disclosure: A mixed-methods exploration. In *International conference on social robotics* (pp. 604–615). Springer.

Björling, E. A., & Rose, E. (2019). Participatory research principles in human-centered design: engaging teens in the co-design of a social robot. *Multimodal Technologies and Interaction*, *3*, 8.

Björling, E. A., Rose, E., Davidson, A., Ren, R., & Wong, D. (2019a). Can we keep him forever? teens' engagement and desire for emotional connection with a social robot. *International Journal of Social Robotics*, 1–13.

Björling, E. A., Rose, E., & Ren, R. (2018). Teen-robot interaction: A pilot study of engagement with a low-fidelity prototype. In *Companion of the 2018 ACM/IEEE international conference on human-robot interaction* (pp. 69–70). ACM.

Björling, E. A., Xu, W. M., Cabrera, M. E., & Cakmak, M. (2019b). The effect of interaction and design participation on teenagers' attitudestowards social robots. In *2019 28th IEEE international conference on robot and human interactive communication (RO-MAN)* (pp. 1–7). IEEE.

Blakemore, S. (2018). Development of the adolescent brain: implications for executive function and social cognition. *European Neuropsychopharmacology*, *28*, S1.

Breazeal, C. (2011). Social robots for health applications. In *Engineering in medicine and biology society, EMBC, 2011 annual international conference of the IEEE* (pp. 5368–5371). IEEE, http://dx.doi.org/10.1109/iembs.2011.6091328.

Causo, A., Vo, G. T., Chen, I. M., & Yeo, S. H. (2016). Design of robots used as education companion and tutor. In *Robotics and mechatronics* (pp. 75–84). Springer.

Colten, M. (2017). *Adolescent stress: Causes and consequences*. Routledge.

Cooley, M. (2000). Human-centered design. In R. E. Jacobson (Ed.), *Information design* (pp. 59–81). Cambridge: MIT Press, chapter 10.

Costa, S., Resende, J., Soares, F. O., Ferreira, M. J., Santos, C. P., & Moreira, F. (2009). Applications of simple robots to encourage social receptiveness of adolescents with autism. In *2009 annual international conference of the IEEE engineering in medicine and biology society* (pp. 5072–5075). IEEE.

Costa, S., Santos, C., Soares, F., Ferreira, M., & Moreira, F. (2010). Promoting interaction amongst autistic adolescents using robots. In *2010 annual international conference of the IEEE engineering in medicine and biology* (pp. 3856–3859). IEEE.

Crossman, M. K., Kazdin, A. E., & Kitt, E. R. (2018). The influence of a socially assistive robot on mood, anxiety, and arousal in children. *Professional Psychology: Research and Practice*, *49*, 48.

Davies, C., & Eynon, R. (2013). *Teenagers and technology*. Routledge.

Dehkordi, P. S., Moradi, H., Mahmoudi, M., & Pouretemad, H. R. (2015). The design, development, and deployment of roboparrot for screening autistic children. *International Journal of Social Robotics*, *7*, 513–522.

Dupéré, V., Leventhal, T., Dion, E., Crosnoe, R., Archambault, I., & Janosz, M. (2015). Stressors and turning points in high school and dropout: A stress process, life course framework. *Review of Educational Research*, *85*, 591–629.

Eiraldi, R., Wolk, C. B., Locke, J., & Beidas, R. (2015). Clearing hurdles: The challenges of implementation of mental health evidence based practices in under-resourced schools. *Advances in School Mental Health Promotion*, *8*, 124–140.

Esterling, B. A., Antoni, M. H., Fletcher, M. A., Margulies, S., & Schneiderman, N. (1994). Emotional disclosure through writing or speaking modulates latent epstein-barr virus antibody titers. *Journal of Consulting and Clinical Psychology*, *62*, 130. http://dx.doi.org/10.1037/0022-006x.62.1.130.

Feil-Seifer, D., & Mataric, M. J. (2005). Defining socially assistive robotics. In *9th international conference on rehabilitation robotics, 2005. ICORR 2005* (pp. 465–468). IEEE.

Gautam, P., & Pradhan, M. (2017). Stress as related with conduct and achievement in adolescent students. *Indian Journal of Health & Wellbeing*, *8*.

Guest, G., MacQueen, K. M., & Namey, E. E. (2011). *Applied thematic analysis*. Sage Publications.

Gunnell, D., Kidger, J., & Elvidge, H. (2018). Adolescent mental health in crisis.

Heber, E., Ebert, D. D., Lehr, D., Cuijpers, P., Berking, M., Nobis, S., & Riper, H. (2017). The benefit of web-and computer-based interventions for stress: a systematic review and meta-analysis. *Journal of Medical Internet Research*, *19*, Article e32.

Hoa, T. D., & Cabibihan, J. J. (2012). Cute and soft: baby steps in designing robots for children with autism. In *Proceedings of the workshop at SIGGRAPH Asia*, (pp. 77–79).

Hofmann, S. G., Asnaani, A., Vonk, I. J., Sawyer, A. T., & Fang, A. (2012). The efficacy of cognitive behavioral therapy: A review of metaanalyses. *Cognitive Therapy and Research*, *36*, 427–440. http://dx.doi.org/10.1007/s10608-012-9476-1.

Jani, B. D., Blane, D. N., & Mercer, S. W. (2012). The role of empathy in therapy and the physician-patient relationship. *ComplementaryMedicine Research*, *19*, 252–257.

Jeong, S. (2017). *The impact of social robots on young patients' socioemotional wellbeing in a pediatric inpatient care context* (Ph.D. thesis), Massachusetts Institute of Technology.

Jeong, S., Breazeal, C., Logan, D., & Weinstock, P. (2017). Huggable: Impact of embodiment on promoting verbal and physical engagement for young pediatric inpatients. In *2017 26th IEEE international symposium on robot and human interactive communication (ROMAN)* (pp. 121–126). IEEE.

Jeong, S., Logan, D. E., Goodwin, M. S., Graca, S., O'Connell, B., Goodenough, H., et al. (2015). A social robot to mitigate stress, anxiety, and pain in hospital pediatric care. In *Proceedings of the tenth annual ACM/IEEE international conference on human-robot interaction extended abstracts* (pp. 103–104).

Jordan, K., King, M., Hellersteth, S., Wirén, A., & Mulligan, H. (2013). Feasibility of using a humanoid robot for enhancing attention and social skills in adolescents with autism spectrum disorder. *International Journal of Rehabilitation Research*, *36*, 221–227.

Kahn, J. H., Achter, J. A., & Shambaugh, E. J. (2001). Client distress disclosure, characteristics at intake, and outcome in brief counseling. *Journal of Counseling Psychology*, *48*, 203. http://dx.doi.org/10.1037/0022-0167.48.2.203.

Kahn, J. H., & Garrison, A. M. (2009). Emotional self-disclosure and emotional avoidance: Relations with symptoms of depression and anxiety. *Journal of Counseling Psychology*, *56*, 573. http://dx.doi.org/10.1037/a0016574.

Kanda, T., Hirano, T., Eaton, D., & Ishiguro, H. (2004). Interactive robots as social partners and peer tutors for children: A field trial. *Human-Computer Interaction*, *19*, 61–84.

Kang, H. S., Makimoto, K., Konno, R., & Koh, I. S. (2019). Review of outcome measures in paro robot intervention studies for dementia care. *Geriatric Nursing*.

Kazdin, A. E., & Rabbitt, S. M. (2013). Novel models for delivering mental health services and reducing the burdens of mental illness. *Clinical Psychological Science*, *1*, 170–191.

Kidd, C. D., & Breazeal, C. (2004). Effect of a robot on user perceptions. In *2004 IEEE/RSJ international conference on intelligent robots and systems (IROS)(IEEE Cat. No. 04CH37566)* (pp. 3559–3564). IEEE.

Kim, E. S., Berkovits, L. D., Bernier, E. P., Leyzberg, D., Shic, F., Paul, R., et al. (2013). Social robots as embedded reinforcers of social behavior in children with autism. *Journal of Autism and Developmental Disorders*, *43*, 1038–1049.

Kühnlenz, B., Erhart, M., Kainert, M., Wang, Z. Q., Wilm, J., & Kühnlenz, K. (2018). Impact of trajectory profiles on user stress in close human–robot interaction. *At-Automatisierungstechnik*, *66*, 483–491.

Kwak, S. S., Kim, Y., Kim, E., Shin, C., & Cho, K. (2013). What makes people empathize with an emotional robot?: The impact of agency and physical embodiment on human empathy for a robot. In *RO-MAN, 2013 IEEE* (pp. 180–185). IEEE, http://dx.doi.org/10.1109/roman.2013.6628441.

Lee, S., & Choi, J. (2017). Enhancing user experience with conversational agent for movie recommendation: Effects of self-disclosure and reciprocity. *International Journal of Human-Computer Studies*, *103*, 95–105. http://dx.doi.org/10.1016/j.ijhcs.2017.02.005.

Lee, K. M., Jung, Y., Kim, J., & Kim, S. R. (2006). Are physically embodied social agents better than disembodied social agents?: The effects of physical embodiment, tactile interaction, and people's loneliness in human–robot interaction. *International Journal of Human–Computer Studies*, *64*, 962–973.

Leyzberg, D., Spaulding, S., Toneva, M., & Scassellati, B. (2012). The physical presence of a robot tutor increases cognitive learning gains. In *Proceedings of the annual meeting of the cognitive science society*.

Li, J. (2015). The benefit of being physically present: A survey of experimental works comparing copresent robots, telepresent robots and virtual agents. *International Journal of Human-Computer Studies*, *77*, 23–37.

Li, R., van Almkerk, M., van Waveren, S., Carter, E., & Leite, I. (2019). Comparing human–robot proxemics between virtual reality and the real world. In *2019 14th ACM/IEEE international conference on human-robot interaction (HRI)* (pp. 431–439). IEEE.

Ling, H. Y., & Björling, E. A. (2020). Sharing stress with a robot: What would a robot say?. *Human-Machine Communication*, *1*.

Little, L., Bell, B., Defeyter, G., Read, J. C., Fitton, D., & Horton, M. (2013). Behaviour change interventions: teenagers, technology and design. In *Proceedings of the 12th international conference on interaction design and children* (pp. 610–612).

Liu, O., Rakita, D., Mutlu, B., & Gleicher, M. (2017). Understanding human–robot interaction in virtual reality. In *2017 26th IEEE international symposium on robot and human interactive communication (RO-MAN)* (pp. 751–757). IEEE.

van Loon, A. W., Creemers, H. E., Beumer, W. Y., Okorn, A., Vogelaar, S., Saab, N., et al. (2020). Can schools reduce adolescent psychological stress? a multilevel meta analysis of the effectiveness of school-based intervention programs. *Journal of Youth and Adolescence*, *49*, 1127–1145.

Martelaro, N., Nneji, V. C., Ju, W., & Hinds, P. (2016). Tell me more: Designing hri to encourage more trust, disclosure, and companionship. In *The eleventh ACM/IEEE international conference on human robot interaction* (pp. 181–188). IEEE Press.

Meghdari, A., Alemi, M., Khamooshi, M., Amoozandeh, A., Shariati, A., & Mozafari, B. (2016). Conceptual design of a social robot for pediatric hospitals. In *2016 4th international conference on robotics and mechatronics (ICROM)* (pp. 566–571). IEEE.

Mojtabai, R., & Olfson, M. (2020). National trends in mental health care for us adolescents. *JAMA Psychiatry*.

Moon, Y. (2000). Intimate exchanges: Using computers to elicit selfdisclosure from consumers. *Journal of Consumer Research*, *26*, 323–339. http://dx.doi.org/10.1086/209566.

Nomura, T., Suzuki, T., Kanda, T., & Kato, K. (2006). Measurement of negative attitudes toward robots. *Interaction Studies*, *7*, 437–454. http://dx.doi.org/10.1075/is.7.3.14nom.

Oh, C. S., Bailenson, J. N., & Welch, G. F. (2018). A systematic review of social presence: definition, antecedents, and implications. *Frontiers in Robotics and AI*, *5*, 114. http://dx.doi.org/10.3389/frobt.

Okita, S. Y. (2013). Self–other's perspective taking: The use of therapeutic robot companions as social agents for reducing pain and anxiety in pediatric patients. *Cyberpsychology, Behavior, and Social Networking*, *16*, 436–441.

Þórarinsdóttir, H., Kessing, L. V., & Faurholt-Jepsen, M. (2017). Smartphone-based self-assessment of stress in healthy adult individuals: a systematic review. *Journal of Medical Internet Research*, *19*, Article e41.

Organization, W. H. (2020). Adolescence: a period needing special attention recognizing-adolescence. https://apps.who.int/adolescent/. (Accessed on 08/31/2020).

Powers, A., Kiesler, S., Fussell, S., & Torrey, C. (2007). Comparing a computer agent with a humanoid robot. In *Proceedings of the ACM/IEEE international conference on human–robot interaction* (pp. 145–152). ACM, http://dx.doi.org/10.1145/1228716.1228736.

Rebecca Grist, J. P., & Stallard, P. (2017). Mental health mobile apps for preadolescents and adolescents: A systematic review. *Journal of Medical Internet Research*, *19*, 5.

Riek, L. D., & Robinson, P. (2008). Real-time empathy: Facial mimicry on a robot. In *Workshop on affective interaction in natural environments (AFFINE) at the international ACM conference on multimodal interfaces (ICMI 08)*. Citeseer: ACM.

Rogers, Y., & Marshall, P. (2017). Research in the wild. *Synthesis Lectures on Human-Centered Informatics*, *10*, i–97.

Rose, E. J., & Björling, E. A. (2017). Designing for engagement: Using participatory design to develop a social robot to measure teen stress. In *Proceedings of the 35th ACM international conference on the design of communication* (p. 7). ACM.

Rose, A. J., & Rudolph, K. D. (2006). A review of sex differences in peer relationship processes: potential trade-offs for the emotional and behavioral development of girls and boys. *Psychological Bulletin*, *132*, 98.

Scassellati, B., Brawer, J., Tsui, K., Nasihati Gilani, S., Malzkuhn, M., Manini, B., et al. 2018. Teaching language to deaf infants with a robot and a virtual human. In *Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 1–13).

Schuemie, M. J., Van Der Straaten, P., Krijn, M., & Van Der Mast, C. A. (2001). Research on presence in virtual reality: A survey. *CyberPsy Chology & Behavior*, *4*, 183–201.

Scoglio, A. A., Reilly, E. D., Gorman, J. A., & Drebing, C. E. (2019). Use of social robots in mental health and well-being research: systematic review. *Journal of Medical Internet Research*, *21*, Article e13322.

Seo, S. H., Geiskkovitch, D., Nakane, M., King, C., & Young, J. E. (2015). Poor thing! would you feel sorry for a simulated robot? a comparison of empathy toward a physical and a simulated robot. In *2015 10th ACM/IEEE international conference on human-robot interaction (HRI)* (pp. 125–132). IEEE.

Shariati, A., Shahab, M., Meghdari, A., Nobaveh, A. A., Rafatnejad, R., & Mozafari, B. (2018). Virtual reality social robot platform: A case study on arash social robot. In *International conference on social robotics* (pp. 551–560). Springer.

Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. John Wiley & Sons.

Slovák, P., Rowan, K., Frauenberger, C., Gilad-Bachrach, R., Doces, M., Smith, B., et al. (2016). Scaffolding the scaffolding: Supporting children's social-emotional learning at home. In *Proceedings of the 19th ACM conference on computer-supported cooperative work & social computing* (pp. 1751–1765). ACM.

Slovák, P., Theofanopoulou, N., Cecchet, A., Cottrell, P., Altarriba Bertran, F., & Dagan, E. others (2018). I just let him cry...: Designing socio-technical interventions in families to prevent mental health disorders. *Proceedings of the ACM on Human- Computer Interaction*, *2*, 160.

Steinberg, L. (2014). *Age of opportunity: Lessons from the new science of adolescence*. Houghton Mifflin Harcourt.

Unity Technologies, . Unity. URL: https://unity.com.

Valkenburg, P. M., Sumter, S. R., & Peter, J. (2011). Gender differences in online and offline self-disclosure in pre-adolescence and adolescence. *British Journal of Developmental Psychology*, *29*, 253–269.

Vogel, S., & Schwabe, L. (2016). Learning and memory under stress: implications for the classroom. *npj Science of Learning*, *1*, 16011.

Wada, K., Shibata, T., Saito, T., Sakamoto, K., & Tanie, K. (2005). Psychological and social effects of one year robot assisted activity on elderly people at a health service facility for the aged. In *Robotics and automation, 2005. ICRA 2005. Proceedings of the 2005 IEEE international conference on* (pp. 2785–2790). IEEE.

Williams, N., MacLean, K., Guan, L., Collet, J. P., & Holsti, L. (2019). Pilot testing a robot for reducing pain in hospitalized preterm infants. *OTJR: Occupation, Participation and Health*, *39*, 108–115.

Yorita, A., Egerton, S., Oakman, J., Chan, C., & Kubota, N. (2018). A robot assisted stress management framework: Using conversation to measure occupational stress. In *2018 IEEE international conference on systems, man, and cybernetics (SMC)* (pp. 3761–3767). IEEE.

Young, C. C., & Dietrich, M. S. (2015). Stressful life events, worry, and rumination predict depressive and anxiety symptoms in young adolescents. *Journal of Child and Adolescent Psychiatric Nursing*, *28*, 35–42.

Zhang, R. (2017). The stress-buffering effect of self-disclosure on facebook: An examination of stressful life events, social support, and mental health among college students. *Computers in Human Behavior*, *75*, 527–537.