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Can We Keep Him Forever? Teens' Engagement and Desire for Emotional Connection with a Social Robot

Elin A. Björling[1] · Emma Rose[2] · Andrew Davidson[1] · Rachel Ren[1] · Dorothy Wong[1]

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Abstract
Today's teens will most likely be the first generation to spend a lifetime living and interacting with both mechanical and social robots. Although human–robot interaction has been explored in children, adults, and seniors, examination of teen–robot interaction has been limited. In this paper, we provide evidence that teen–robot interaction is a unique area of inquiry and designing for teens is categorically different from other types of human–robot interaction. Using human-centered design, our team is developing a social robot to gather stress and mood data from teens in a public high school. To better understand teen–robot interaction, we conducted an interaction study in the wild to explore and capture teens' interactions with a low-fidelity social robot prototype. Then, through group interviews we gathered data regarding their perceptions about social robots. Although we anticipated minimal engagement due to the low fidelity of our prototype, teens showed strong engagement and lengthy interactions. Additionally, teens expressed thoughtful articulations of how a social robot could be emotionally supportive. We conclude the paper by discussing future areas for consideration when designing for teen–robot interaction.

Keywords Teen–robot interaction · Engagement · Prototype · Human-centered design

1 Introduction

Many North American adolescents have been surrounded by technology since birth. And, their relationships with current technology are unlike previous generations [1] as much of their communication is now digital [2, 3]. Despite teens' strong relationship with technology, they remain a fairly underexplored population when it comes to technology interaction and design. Adults have always been the primary focus of design in Human Computer Interaction (HCI). It was not until the late 1990s that children became a focus in the budding field of Child-Computer Interaction [4]. However, researchers in this field focused primarily on children 10 and under, still overlooking teen users. It wasn't until the new millennium that researchers began focusing on teens as a unique population in technology [4].

Similar to HCI, teenagers are an audience that is overlooked in human–robot interaction (HRI). While there is a great deal of research in HRI related to children [5–7], adults [8, 9] and seniors [10, 11], few studies have explicitly explored interactions between teens and robots. Social robots have been found to be effective with vulnerable populations such as children with autism [6, 7, 12], adults suffering from trauma [8], to reduce loneliness [13] and depression [14]. Teens are also a unique and vulnerable population due to depression [15, 16] and stress [17, 18]. Given teens' already existing relationships with technology, social robotics seems a worthwhile exploration in an effort to provide support for this vulnerable population.

Project EMAR is an interdisciplinary, participatory, human-centered design project to design and deploy a social robot that captures stress and mood levels from teens in a school setting while simultaneously providing a micro-interaction to address stress. The Ecological Momentary

✉ Elin A. Björling
bjorling@uw.edu

Emma Rose
ejrose@uw.edu

Andrew Davidson
adavid7@uw.edu

Rachel Ren
rachren@uw.edu

Dorothy Wong
dwong51@uw.edu

[1] University of Washington, Seattle, USA

[2] University of Washington Tacoma, Tacoma, USA

Assessment Robot (EMAR) is designed to engage with teens and invite them to respond to momentary questions, in their real-world environment. Our team is researching what aspects of robot design lead to teen engagement. The following study details findings from a series of observational interaction studies with teens and a social robot prototype in their high school setting.

First, we provide an argument for why teens are a unique population for design in human–robot interaction. Second, we introduce EMAR, a social robot that is being developed through a human-centered approach for the purpose of collecting stress data from teens in a school setting. Third, we detail the methods used in a series of observational interaction studies with teens and a low fidelity robot prototype in their schools. Fourth, we share the findings from the study about engagement and interaction including empathy, anthropomorphizing, and natural interactions with the robot prototype. Fifth, we discuss the uniqueness of our findings in relation to current literature regarding teens. Finally, we conclude with limitations and areas for future work.

This paper makes several contributions to the field of human–robot interaction. First, it is one of a very small number of studies to specifically look at teens, a unique and vulnerable population. Second, it makes a contribution by employing a human-centered and participatory approach that starts with deep engagement with the target population, rather than starting with a technological solution. Third, it demonstrates that even low-fidelity robots can be beneficial probes for eliciting engagement, user needs, and requirements.

2 Background

In this section, we review research related to teens and robots and argue that teens are a unique population for consideration in human–robot interaction. Further, we explore how robots show promise for use in data collection.

2.1 Teens are a Unique and Vulnerable Population

The adolescent period is unique in that teens are no longer children and not yet adults. Current developmental theory, including new findings regarding the neuroplasticity of the adolescent brain [19], has led to the referring of adolescence as an "age of opportunity" [20]. The highlights of the uniqueness of adolescent development include the ability to think reasonably and logically [21] and simultaneously to think abstractly and in multidimensional ways [20]. Unlike adults, teens have a tendency toward individuality and are less likely to agree to social norms [22] and are beginning to develop their personal agency [23]. The uniqueness of teens suggests that their interactions with technology are also unique and warrant further investigation.

The same mechanism that allows for increased neuroplasticity in the adolescent brain [19], also allows for heightened sensitivity to the negative effects of stress [24, 25] and increased susceptibility to mood disorders [26, 27]. Adolescents are a vulnerable population. Today's teens face more stress [15, 28] and depression [27, 29] compared to other age groups and previous generations. Stress in teens has been correlated with mental and physical illness [18, 27, 30, 31] and decreased learning abilities [32, 33]. Academic stress in particular, has been correlated with depression [34]. Stress has been shown to impair memory retrieval and reduce cognitive flexibility and problem solving [35], thus dramatically affecting learning and retention.

Teens experience high levels of stress that negatively impacts their learning, however, their learning environment is also a major contributor of stress. 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 [15]. Increased academic stress in high school students is also linked to substance abuse and risk-taking behavior [28]. Local public high schools are struggling to find ways to manage increasing stress experienced by students [36].

2.2 Teens and Social Robots

Teens are avid consumers and users of new technologies [37] and will continue to use technology throughout their lives. However, teens, as a distinct population, tend to be underexplored in technology design [38]. They offer valuable insights and have greater capacity for reflection in design than younger children [39].

While a variety of researchers in the field of Human–Computer Interaction have advocated for more research that specifically focuses on teens and technology [4], there is also very little research that explicitly focuses on relationship between teens and robots [41–45].

Two of the teen studies focused on perceptions and preferences of children in relation to social robots and included some teens. Liu [41], interviewed and surveyed young, Taiwanese adolescents (fourth, fifth and sixth graders) about their perceptions of educational robots. Liu found the most common theme was that educational robots were seen as a "plaything." The second most common theme was that learning robotics as a "way to high technology." Finally, children saw robots as a source of future employment. Sequiera and Ferreira [42] surveyed 120 school Portuguese children (ages 8–16) as part of a design study for a social robot intended to interact with children in a pediatric hospital. They specifically asked children what a robot is for, what are their qualities, and asked them to draw a robot. The researchers concluded that the visual representation of robots was still "under construction" for most children. They also concluded that the children's attitudes about robot images and robot attributes were clearly influenced by science fiction. Children favored images of robots that had a machine-like appearance, a serious personality, were round-shaped, and had a human-like voice that was gender neutral (p. 56).

Two studies specifically focused on teens' perceptions of robots and teen–robot interactions. Martelaro et al. [44] explored the concept of trust with high school students and robots. They found that perceptions of a robots' vulnerability lead to more trust and feelings of companionship. In addition, the perception of a robot as being expressive, lead to higher levels of disclosure by teens. A second study by Rose and Björling [45], studied teens' preferences of robot appearance and interactions with a low fidelity prototype with a group of 40, 12–18 year olds. Their findings reinforced the need to study teens separately from children and adults as their perceptions of robots were unique. This study found teens prefer clean and simple designs, draw from their existing impressions of robots from popular culture, and conceptualize robots as helpers.

The two final studies were experimental studies of teens and robots. Swift-Spong et al. [40] explored the use of a social robot as an exercise buddy for overweight teens. They compared a fictional and realistic backstory for a Nao robot. Although they found no real effect of two types of backstory, they did see a small change in intrinsic motivation after interacting with the robot. They also reported that teens embraced the idea of a companion robot for exercise. Bainbridge et al. [43] conducted an experimental study to compare undergraduate students' interactions with a physically present robot, versus a robot on a live video feed screen. Participants greeted and cooperated with the robot in both conditions. However, participants interacting with the physically present robot were more likely both to fulfill an unusual request (throw new textbooks into a garbage can) and gave more personal space to the physically present robot. Adolescents may be more complicit in following instructions from a physically present robot as a direct result of teens' preference to interact with a digital device.

Teens are already connecting to others via electronic media and messaging [3] and spend more time communicating digitally than face to face [46]. As heavy users of technology, it is not surprising that some teens are more comfortable with offering truthful, personal information to digital devices. Research has found that unlike adults, teens can be uncomfortable in face to face interviews [47] and prefer an automated phone diary to a written diary for sensitive information [48]. Therefore, using a digital format to gather data from them may increase the ecological validity of that data while maintaining their natural connection to technology.

However, capturing data repeatedly in a busy school setting requires both novelty and engagement that moves beyond current research tools found in static, ordinary smart phones and tablets. Social robots may be successful tools for capturing data from teens as already there is evidence for robots as survey tools for adults. Chung et al. [49] and Huang and Lau [50] have explored the use of mobile robots deployed in hotels and airports to survey customers about their satisfaction with the service. Social robots have also been part of long-term interaction to gather information about their users [51, 52].

2.3 Social Robots as Data Gatherers and Helpers

Given their strong physical and social connection to technology, teens may also benefit from interactions with a social robot. Breazeal [53] has proposed social robots as a tool for health assessment due to their ability for engagement and interaction. Scassellati [12, 54] similarly suggested using social robots to diagnose autism spectrum disorders.

Successful retention in teen data collection also relies upon engagement [55, 56], designing a social robot, to engage with students on a regular basis from within their stressful, school environment [34], may be a beneficial technology. Wood et al. [57] found that a social robot was significantly more successful in maintaining overall engagement and interview duration than a human when interviewing children. A social robot specifically designed for teens is a promising tool for gathering data and potentially providing intervention to adolescents in situ.

2.4 Project EMAR Exploring Teen–Robot Interaction

Given the potential of social robots as data gatherers and given the fairly unexplored territory of teen–robot interaction, our team is developing a social robot, called EMAR (Ecological Momentary Assessment Robot). EMAR is intended to live in a high school to engage and interact with teens. The plan is to design EMAR to gather stress and mood data while providing a micro-intervention to relieve student stress. Ecological Momentary Assessment (EMA) is a promising approach to gathering real-time data in the environment in which it occurs in order to avoid recall bias and to maintain ecological validity [58]. EMA has been found an effective approach to capturing longitudinal data from teens, specifically to capture teen stress [56, 59–62] Additionally, Ecological Momentary Intervention (EMI) is the use of mobile technology to deliver intervention as individuals go about their daily lives [63]. EMI has been shown to be effective and easy to use [58, 63] and is under exploration as a potential intervention for children and teens suffering from anxiety [64]. Given the potential benefits of EMA and EMI for teens, an engaging device that gathers momentary data within a teen's natural environment is likely to be successful for both data capture and the delivery of micro-interventions.

3 Methods

Given the vulnerability of the teen population and the novelty of designing a social robot specifically for teens, we recognized the need to be thoughtful in our choice of research methods. Typical HRI methods can risk trust and transparency and often lack the contextual validity necessary to understand the implications of HRI in the real world [65]. Qualitative methods are increasingly promoted in the field of human–computer interaction to better understand how humans behave when interacting with technologies [66–68], but they are far less common in HRI studies. In our previous studies, we have learned that teens prefer boxy form factors and low tech designs [69]. In addition, we have shown that teens are highly engaged with low fidelity prototypes and those prototypes are sufficient for valuable interaction designs [70]. Given the novelty of this endeavor, we knew qualitative, observational research was needed to best understand how teens feel and behave when interacting with robot prototypes with their peers. Therefore, using Human-Centered Design [71–73] to investigate teens' interactions with EMAR V2, a boxy, low-fidelity prototype. See Fig. 1a. These studies were conducted "in the wild" to capture data within the human social context of a school to maintain the ecological validity. By gathering data in the appropriate social context for which it is intended, we hoped to increase the potential to capture "emergent capabilities" as described by Sabonovic et al. [74]. Many studies exploring robots in the wild use similar observational [75] and ethnographic methods [76–78] to explore human behaviors and interactions with new technologies.

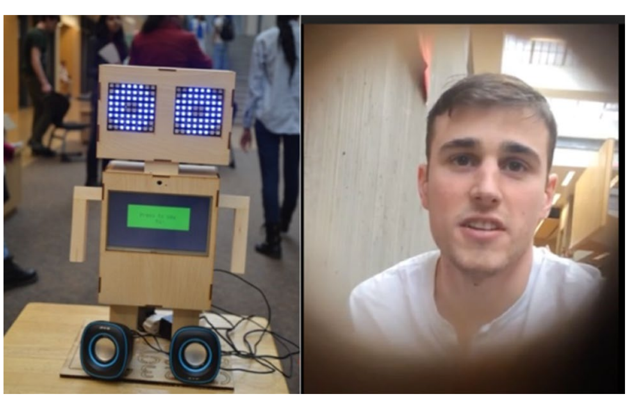

Fig. 1 **a** EMAR V2 Prototype (left), **b** view of student researcher from internal camera (right)

This research study was reviewed and approved by both our University's Institutional Review Board and the school district's research review committee. Because most participants are minors, as a condition of conducting the research, we agreed not to use any unique identifiers such as names or images of participants. As a result, any names used in this paper are pseudonyms and photos in this document are recreations using undergraduate students who were part of the research team.

To recruit for the study, we contacted several local high school principals to invite them to participate. Six interested principals connected the primary investigator with high school teachers in health, computer science, or robotics classes to schedule the observational interaction studies. Four schools were successful in coordinating and scheduling the study. Interested students at each of the four schools completed online assent forms including demographic information and we gathered school-required parental permission forms. We worked with schools to schedule the studies, which typically occurred after school in a classroom or meeting space at the high school.

3.1 EMAR V2 Prototype

After preliminary explorations with EMAR V1, EMAR V2 was designed specifically to capture data gathering interactions with teens. V2 is a portable robot prototype that can interact in real-time with participants, engaging in a scripted dialog and recording responses, see Fig. 1a.

EMAR V2 is constructed of laser-cut birch wood and is controlled by two Arduino microcontrollers mounted inside the body. It has two "eyes," an interactive touch screen, and speakers for audio output. The eyes are LEDs synchronized with the audio output to simulate various facial expression and have no vision capability. The eyes are formed by two NeoPixel LED matrices. EMAR's touch screen is a 7.0" TFT display with an LED backlight and a resistive touchscreen overlay. The speakers are ordinary powered computer speakers connected to an MP3 player on board the Arduino. Just above the touchscreen is a viewing hole for an internal camera, placed to record participants' facial reactions during interaction studies (see Fig. 1b).

EMAR V2's interactive script greets the participant, and then offers three questions regarding mood, stress level and energy level. Teens respond by selecting "Yes" or "No" on the touchscreen as well as manipulating a slider with a visual scale from 0 to 100 to describe their answers (stress level, mood, energy level), see Fig. 2.

The greeting, questions and responses are displayed as text on the touch screen and simultaneously "spoken" by EMAR V2 during interactions. The spoken parts were recorded digitally and filtered to make the voice gender neutral and less human-sounding. This audio is stored as

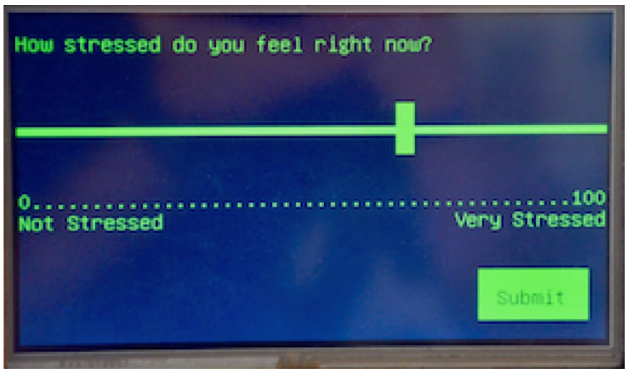

Fig. 2 Examples of EMAR V2's touchscreen

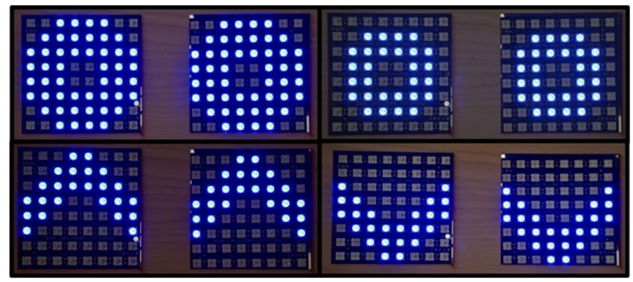

Fig. 4 Examples of EMAR V2's eye expressions; interested/listening (top left), waiting (top right), happy (bottom left), sad (bottom right)

MP3 files on the Arduino, and played back according to the interactive script. See the finite state machine, Fig. 3 for more detail.

During the interactive dialog, EMAR V2's eyes change their pattern to correspond with the answers that are played in audio. There are 4 different expressions that EMAR responds with: a, b, c, d. See Fig. 4 for examples of these expression patterns.

3.2 Observational Interaction Studies in the Wild

Human-centered design consists of an early focus on users and their tasks, empirical measurement, and iteration [79]. As a guiding methodology on this project, human-centered design reminds us that any robot designed for teens must be based on their needs, opinions and input. The team for this project consisted of multi-disciplinary team members including faculty, graduate, and undergraduate students with expertise in physical computing, health research, interaction design, qualitative and quantitative research methods, psychology, and rhetoric. The team worked together as part of a directed research group [80, 81].

Our qualitative, observational interaction studies included three levels of data capture in order to explore not just the individual interaction with the robot, but the social interactions as well. In addition, we captured post-interaction interviews with teens to discuss their experiences interacting with the low-fidelity prototype. See Fig. 5 for a graphical

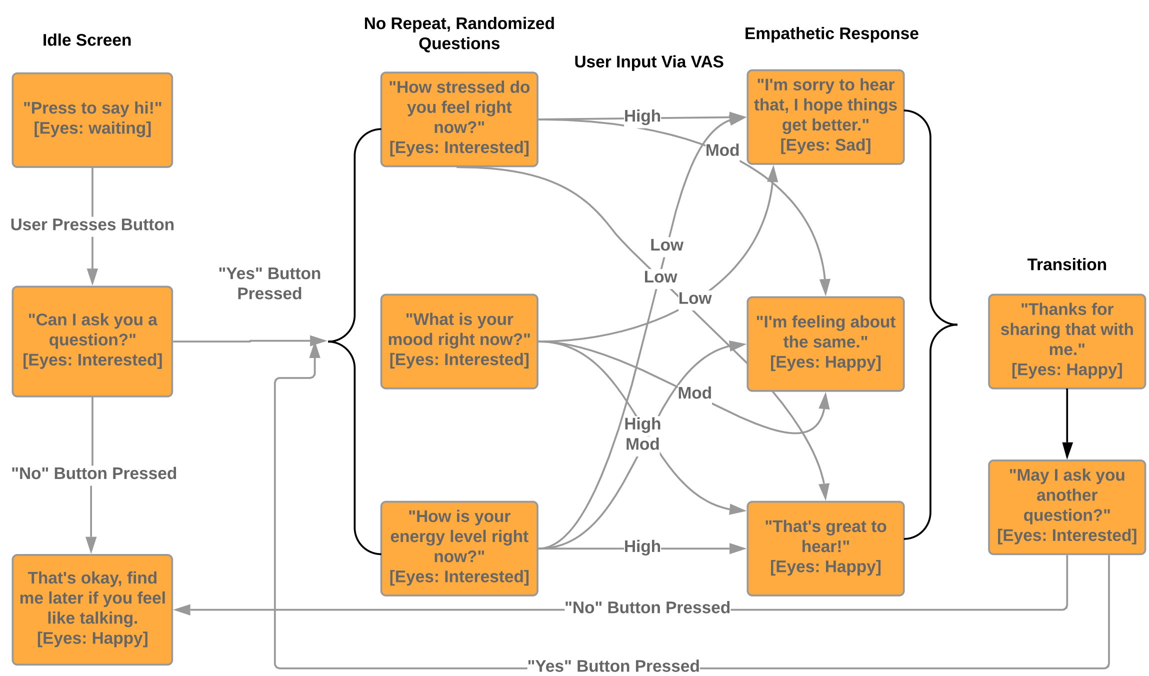

Fig. 3 EMAR V2 finite state machine

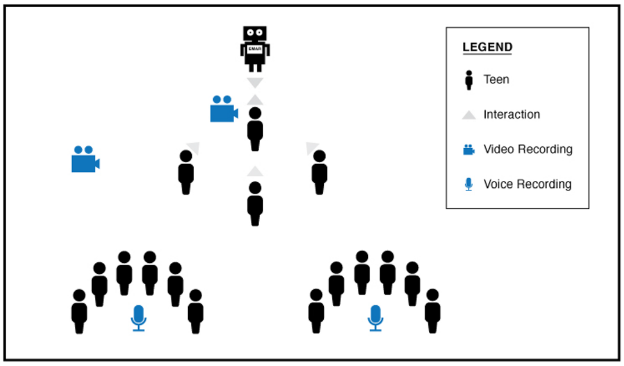

Fig. 5 Observational interaction study design setup

overview. First, individual interactions with the prototype were captured on an internal video camera (iPhone 5) located inside the robot with a view of the individual participant during interactions. See Fig. 1b for an example. Second, group interactions among teens observing and participating in the study were captured using an external DSLR video camera. Third, group interviews were conducted and digitally recorded in groups of 4-8 students immediately after the interaction with the robot.

Each group of participants was oriented to the study by the research staff. The purpose of Project EMAR and the process was explained. We then invited small groups (2–3 teens) to interact with EMAR V2. We introduced them to V2, but did not give them any other instructions or information as we wanted the interaction to be as natural as possible. After participants interacted with EMAR, they participated in group interviews and asked questions about their interaction with EMAR. Questions included, "How did it feel to interact with EMAR?" and "What would it be like if EMAR were living in your school?"

3.3 Data Analysis

Given the exploratory nature of this preliminary study, qualitative data were captured in order to best understand how teens experienced and felt about their interactions with the prototype. In addition, it is important to note that when exploring the data, there were no differences in engagement or interaction across the different school settings. Digital video data from internal and external cameras was uploaded to a password protected server. Digital audio was transcribed and both audio and textual files were maintained. A total of 103 min of video data were captured and 113 min of group interview data. All data were analyzed collaboratively by the research team using open coding. After initial coding began, the team discussed common themes and outliers and then began a more focused thematic analysis [82] of the data. The final thematic analysis resulted in a large, overarching theme

Table 1 High school sites and participants

	School or group description	Participants	Ages
1	High school robotics team	5	15–16
2	High school robotics team	14	14–17
3	High school computer science class	17	17–18
4	High school after-school convenience sample	9	15–18

of engagement which included several categories which are detailed in the following section.

4 Results

In this section, we provide an overview of the participants in the study. We then detail the results of how participants engaged with the robot prototype and detail the three categories that explore characteristics of this engagement using data collected from the study.

4.1 Participants

The team conducted four studies at four high schools with a total of 45 participants. The schools were all located with a major urban city in the Pacific Northwest. In some schools, the participants were members of a robotics team, others were members of a class (e.g. intro to computing), and others were informally gathered in an after-school session (see Table 1).

Participants were invited to complete a demographic form including their age, grade and write-in responses for their ethnicity and gender. In total, 26 males and 17 females, and 2 students who identified as undefined/non-binary participated in our study. Ages ranged from 14 to 18 years, and grades 9 through 12. Most participants self-identified as"white" or "Caucasian"although many other ethnicities were represented. See Table 2 below.

4.2 Engagement: "He's so cute. Can We Keep Him Forever?"

The main theme that emerged from the observational interaction study data was strong engagement with the low-fidelity prototype. All of the participants who interacted with the low-fidelity prototype seemed engaged. We expected that a few teens would prefer not to interact, but that was not the case. Within the context of engagement, we identified three components: empathy, anthropomorphizing, and natural interactions. From the internal and external camera data, we saw many participants with engaged and expressive faces. Of the 44 participants who directly engaged with

Table 2 Self-reported ethnicity of participants

Self-identified ethnicity	Percentage
White/Caucasian	58
Chinese	9
African-American	7
Filipino	7
Vietnamese	7
Mixed-Race	4
Indian	2
Mien	2
Laos	2
Cham	2

EMAR, only two teens showed an initial affect of disinterest or boredom, but then quickly became engaged and showed a strong interest with the prototype once the interaction began (School 3). With most interactions, once EMAR began to speak, the teens' expressed interest via smiling, or referencing their peers around them. In response to EMAR's questions, many teens showed strong engagement by leaning toward the robot, or using facial gestures of curiosity or thinking before responding to questions (schools 1–4).

4.2.1 Empathy

The teens showed empathy toward EMAR by mimicking its mood, or directly reacting to EMAR's responses. When EMAR responded, "I'm sorry to hear about that," many teens reacted with expressions of sadness or disappointment. In one case, a male (School 2) teen responded, "It sounds so dejected, it's so sad. Awwwww." In one example, a male (School 3). let out a deep, audible sigh of relief upon EMAR's statement, "I'm feeling about the same."

Additionally, teens expressed appreciation for EMAR's expressions of compassion, in particular, "If I said that I was really stressed, it was like, oh, I'm sorry to hear that. I hope your day gets better.' or something like that. I really like that." (male, School 4). Another said, "I really like that it matches your reaction" (Female, School 4).

Teens also expressed emotional attachment to EMAR. In one instance, a participant retold his interaction, "I said that I wasn't very stressed and he said he was glad to hear that, so that was nice." (Male, School 1). Another participant stated "When EMAR said, 'oh, I'm sorry to hear that,' I felt like, if I were in a bad mood, I'd like him to say that" (Male, School 4). Further, a third student said, "It's so cute you don't want to say no to it, you want to like talk to it, like, here let me explain my problems to you" (Male, School 4).

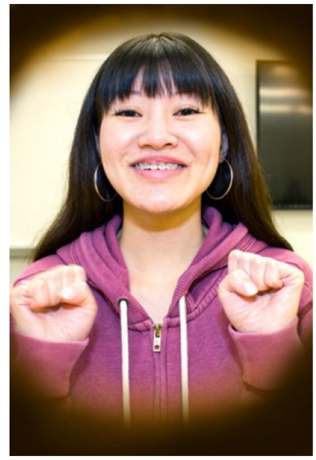

Fig. 6 A recreation of an excited teen as seen from the internal camera

4.2.2 Anthropomorphising

A second category we discovered that accounted for much of the data was *anthropomorphising*. Although our team is well-trained in avoiding the use of gendered pronouns when introducing and talking to teens about EMAR, teens consistently refer to EMAR as "he." After interacting with EMAR, one female teen said to one of the researchers, "Oh, he's so cute. Can we keep him forever?" (Female, School 4). Another female teen clapped her hands repeatedly and exclaimed, "He's so cute! He's so cute!" several times just as she sat down to interact with EMAR (Female, School 1). See Fig. 6 for re-enactment. When EMAR responding to a teen's high level of stress by saying, "I'm sorry to hear that," a male peer of the respondent said, "He sounds disappointed in you" (Female, School 2).

Finally, a discussion among three teens clearly articulated their empathetic connection to EMAR V2 and their attribution of EMAR as having emotions.

Female: You're not really talking to somebody you know, so you're not really as uncomfortable saying how you feel and stuff. But it's also like you're talking to somebody who kind of cares. It's weird, even though it's not an actual person, it kind of cares…

Male 1: You feel like if you said, 'Hey, you're not a person.' It would feel sad.

Male 2: Right, like it doesn't have emotion, but just like with how cute it is, like, I guess like you kind of, as a person, just kind of like give it the sense of like, this thing has emotions, I should be nice to it.

Male 1: Yeah.

Female: Yeah.

4.2.3 Teen–Robot and Teen–Teen Interactions

Teens immediately found EMAR engaging and the interaction easy as none asked for our help during the interaction. A few teens began by verbally talking to EMAR, but quickly figured out that the touchscreen was how to respond. When EMAR began talking, “Hello, I’m EMAR” some students instinctively began responding out loud “Hey, I’m Kevin, Bro!” (Male, School 3). One student said, “I could tell that EMAR was a machine, but EMAR was also so cute, that it was like, I could keep doing the EMAR thing over and over again, it didn’t really get boring because EMAR is just kind of adorable.” (Female, School 1). Another said, “I think other people may likely agree with me on this, but it’s adorableness is a stress reliever in and of itself” (male, School 4). “Interacting with the robot isn’t stressful, so that’s really nice” (Female, School 4).

We saw almost all teens reference peers while interacting with the prototype. Most often, when EMAR responded to them, they would look to their peers with a laugh or a smile and peers would smile back (School 2). One group of three male teens chose to interact with EMAR as a group and said it felt “natural” to do so. One would select “yes” to answer a question, then another would respond with his stress level and yet another would select “submit.” It was interesting how seamless this group interaction was as there was no confusion as to who was to do what (School 4). We also saw teens openly discuss their responses to EMAR’s questions with their peers and comment on one another’s responses.

EMAR: How stressed do you feel right now?

Male 1: Hmmmmm

Female: That’s honestly, how stressed you actually feel?

Male 1: [No response.]

Male 2: No one feels really that stressed once they’re finished with classes. (School 1)

EMAR: How stressed do you feel right now?

Male 1: I’m like a fourth quarter senior, so my stress level is right about here!

Male 2: Dude, that’s awesome.

Male 3: That’s solid, right there. (School 4)

A few teens expressed disappointment when the interaction was over, one male teen (School 2) exclaimed, “Oh, that’s it? Awwww” clearing indicating that he was disappointed his turn with EMAR was over. In a rare, but salient moment, we even witnessed a male teen offer physical affection toward EMAR. Upon completing his interaction with EMAR, he said, **“**Oh, that’s it? Bye…” [smiling] “I’m gonna give you a hug,” and gently hugged EMAR. His peers, awaiting their turn, smiled genuinely in the background (School 3). See re-enactment in Fig. 7.

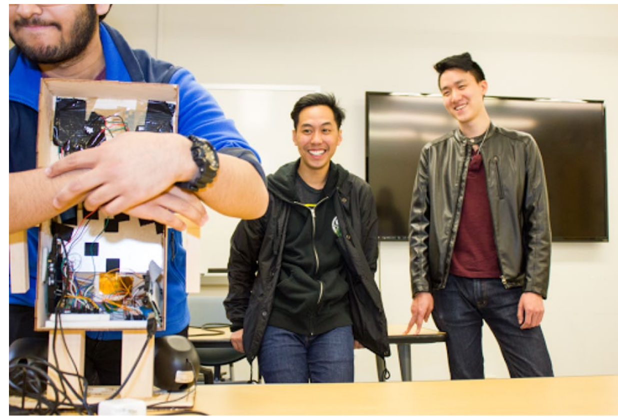

Fig. 7 A teen decides to hug the prototype after their interaction (recreation of actual photo to protect teens’ identities)

4.3 Meeting a Need: “…If At Least I Had Something to talk to…”

After the teens had a chance to interact with EMAR, we asked them to join small group discussions to imagine what it might be like to have a social robot living in their school. Teens discussed this idea in small groups and shared their thoughts with us. A few teens expressed concerns that the robot would lose its novelty or that students might give it false data. To this suggestion a teen responded, “If I did interact with it over time, I’d want to give it honest responses… just cause I feel like I don’t want to be annoying and just do all the wrong things…” (Male, School 2). Most teens gave compelling evidence for how a social robot in their school could be helpful to them. One conversation between two students suggested that because EMAR is not a personal acquaintance, it would be more comfortable to talk to.

Female: This is a good way to do it. Cause you don’t know the robot personally, so you can feel comfortable talking.

Male: It’s not about to judge you (School 2).

One female (School 3) teen clearly articulated that EMAR could provide someone other than a teacher to talk to:

I think it’s a good idea. Because teachers know that you’re stressed but they don’t know *how* stressed you are. They think that it’s just another day at school that you’re trying to make it through, but some people are actually really, really, stressed about something, and they don’t want to talk to teachers about it. They might not want to make the teacher mad, or something. So, EMAR is like, it won’t tell anyone what you’re thinking. It’s just recording you.

Several teens reflected on the fact that a robot would not have to respond to them and that just being a listener would fulfill a perceived need.

Male 1: If I could come in and talk to it for like five minutes or so, like about something? I'd use it.

Male 2: Honestly, I'm just thinking of this now, just when you said, like talk to it for a couple of minutes, right? If it could, even if it didn't respond, if it could kind of be there, so you feel like you're talking to somebody. If you need to get something off your shoulders, right? And you don't really feel comfortable going to another person. You just go over to the bot and you're like, 'Hey, this X,Y,Z has been happening and it kind of sucks.' And it just listens, right?

Male 1: Right, it doesn't even necessarily have to give back a response. Just like the fact that like something is listening to you like you can like rant…if at least I had something to talk to, I think that might make me feel a lot better. (School 4)

What was most striking from these conversations was the teens' repeated articulations about their desire to talk with someone other than a friend or counselor at school and how they easily envisioned that a robot could fit that role.

5 Discussion

The goal of this study was to explore the possibility of a social robot to support the mental health of teens. As detailed in the findings from the study, 45 teens across four schools, provided input on an early, low fidelity prototype to explore the potential for social robots within a school context. Key findings include strong engagement in the low fidelity prototype suggesting the promise of social robots in this context. Engagement was evidenced through participants expressions of empathy, anthropomorphizing, and natural interactions with the robot prototype. Further, participants expressed interest and enthusiasm for the idea of a social robot in their school and that a robot would offer a unique type of support in contrast to others in their life. In the following section, we discuss the findings from the study and how they indicate that teens have unique needs and experiences that need to be taken into account when designing social robots.

5.1 Teen–Robot Interaction

Surrounded by technology since birth, teens are most likely to have long-lasting relationships with high-level technology, including robots in their future work, education, and home settings. Engagement is a key factor in developing a successful social robot. Our finding that teens showed strong engagement with EMAR V2 was promising. A key component of engagement is the perception of empathy which is an integral component of social robotics [83, 84]. According to Braezeal [85], the challenge of robot design is "Endowing a robot with the ability to infer, understand, and reflect upon the emotive states of others" (p. 237). Likely this is a very important factor in capturing and maintaining teens' engagement and inviting them to share their stress and mood self-reports.

Given their known attachment to new technologies, it is not surprising that teens enjoyed interacting with our prototype. However, their level of engagement as evidenced by lengthy interactions and disappointment and sadness upon the separating from EMAR was surprising.

Anthropomorphizing was expected as it has been found common robot interactions [86, 87] with social robots. However, the empathy expressed by teens went far deeper than expected for such a short interaction. Research suggests that empathy is difficult to develop in social robots [88]. Teens articulations of not wanting EMAR to be sad and not wanting "to disappoint" EMAR suggested strong empathy toward the prototype. From a developmental perspective, this is also surprising given recent research suggesting adolescents are increasingly less empathetic toward others [89] and struggle to recognize emotional faces [90]. Our intent was to design EMAR V2 to convey empathy and our data provide evidence that teens felt empathy toward EMAR as well.

Interactions with the prototype seemed natural and easy, although clearly teens instinctively spoke to EMAR in response to EMAR's voice. Thus, voice recognition will be a priority for the further iterations.

5.2 New Solutions to Support Teens and Stress

Teens are a unique and vulnerable population. Teens are far more likely than other generations to suffer from stress [17, 18], depression [16] and anxiety [91]. Participants in our study confirmed these trends by acknowledging their own experiences of stress and their desire to express their negative feelings with our prototype.

Qualitative data from these interaction studies provide evidence that teens invite the idea of sharing emotional data with a social robot. The participants in our study expressed strong interest in engaging with a social robot specifically for the purpose of sharing emotions. Further, participants expressed that a school setting seemed appropriate for sharing their feelings. Teens have expressed a desire for more emotional support at school [92]. School-based data collection regarding mental health in teens has been shown more effective and accurate than home based data collection [93].

Recent successes in autonomous robo-therapists for adults, such as Woebot [94], suggest that human–computer therapeutic interactions can be effective and desirable. So, it seems logical that teens may desire a similar outlet for expressing and processing their feelings and that capturing those feelings in real-time, in their current environment, may be key to supporting them and understanding them.

According to Martelaro et al. [44], "Eliciting self-disclosure may lead to stronger companionship between people and robots and may also provide social and emotional support for people during various tasks" (p. 181). Robots have been shown to elicit self-disclosure as a mechanism for social support and thus relationship building with humans [95]. The teens desire to share their emotion with a social robot suggests that this may be a successful and appropriate technology to provide emotional support and gather much needed data about teen stress.

6 Limitations

In this early stage of our research, it is not possible to understand whether the interaction and engagement we are seeing with our prototype is merely due to its novelty. It has been shown that novelty is an important factor is social robotics [96–98]. Tanaka found that during long-term engagement in a school setting, children lost engagement fairly quickly as novelty wore off. It is quite likely that given our brief interaction studies, novelty is a factor that is increasing engagement and may taper over time [99].

Further, the majority of participants in our study were robotics and computer science students whose attitudes, expectations and behavior with robot prototypes may have a more positive attitude to technology and robots than typical teens. Therefore, future studies will focus on participants with a variety of curricular and extracurricular activities.

Due to restrictions from the school district research committee, we cannot publicly share the video data collected in the study. This is understandable, and yet unfortunate as seeing the teens' expressions during their interactions is quite moving. However, we did our best to describe the facial expressions and moods that were obvious in the video data.

7 Conclusion and Future Research

Our preliminary interaction studies provided strong evidence for both teens' engagement and their desire for sharing emotional information with a social robot. We also learned that even a low-fidelity prototype allowed for strong engagement and rich observational data. From these data, further iterations of the EMAR robot design will be made, such as increasing the conversational complexity, adding mobility, and physical behaviors. Future studies will explore the effect of more complex of interactions and longer term interactions with a mid-fidelity prototype.

Teens are a unique and vulnerable population deserving of further study in robotics and all technologies. Human-centered design is an ideal methodology for working with teens in order to capture their unique views on social robots. Studies of teen–robot interaction deserve further exploration in relation to robot design features, interaction, engagement and especially longitudinal deployment.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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Elin A. Björling, Ph.D. is a Senior Research Scientist in Human Centered Design and Engineering at the University of Washington. Her focus is on the design, development and evaluation of technologies to improve mental health in adolescents.

Emma Rose, Ph.D. is an Assistant Professor in the School of Interdisciplinary Arts & Sciences at the University of Washington Tacoma. Her research focuses on participatory and human-centered design approaches to meaningfully engage people and communities in the design of technology.

Andrew Davidson is a Senior Lecturer in Human Centered Design and Engineering (HCDE) at the University of Washington. His focus is on physical computing, prototyping interactive systems, and user-centered design. A former high school teacher, he directs the HCDE K-12 Outreach Program.

Rachel Ren is a senior undergraduate student in the Human Centered Design and Engineering program at the University of Washington. Her UX Design experience ranges from usability testing telekinetic robots to designing web layouts for airline, utility company, and homework help websites.

Dorothy Wong is now a M.S. Human Centered Design & Engineering alumni who is passionate about bridging the gap between humans and technology. She currently works as a product designer at a leading global brand in Seattle, solving complex problems and creating meaningful experiences through the lens of HCD.