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Integrating socially assistive robotics into mental healthcare interventions: Applications and recommendations for expanded use

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HIGHLIGHTS

- Socially assistive robots are already being used in mental healthcare applications.
- These robots have served in three primary roles: companion, coach, and play partner.
- Robots have a wide range of potential applications in mental healthcare.
- Psychologists must collaborate with roboticists to shape the direction of this work.

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ABSTRACT

As a field, mental healthcare is faced with major challenges as it attempts to close the huge gap between those who need services and those who receive services. In recent decades, technological advances have provided exciting new resources in this battle. Socially assistive robotics (SAR) is a particularly promising area that has expanded into several exciting mental healthcare applications. Indeed, a growing literature highlights the variety of clinically relevant functions that these robots can serve, from companion to therapeutic play partner. This paper reviews the ways that SAR have already been used in mental health service and research and discusses ways that these applications can be expanded. We also outline the challenges and limitations associated with further integrating SAR into mental healthcare. SAR is not proposed as a replacement for specially trained and knowledgeable professionals nor is it seen as a panacea for all mental healthcare needs. Instead, robots can serve as clinical tools and assistants in a wide range of settings. Given the dramatic growth in this area, now is a critical moment for individuals in the mental healthcare community to become engaged in this research and steer it toward our field's most pressing clinical needs.

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The overwhelming burden that mental illness places on the individual and on society has been well documented (e.g., World Health Organization [WHO], 2010). In a given year, 25% of Americans meet criteria for a diagnosable psychiatric condition, with approximately 50% of the population meeting criteria for a disorder at some point in their lives (Kessler & Wang, 2008; Kessler et al., 2009). In addition to the personal distress and impairment inherent in these disorders, psychiatric diagnoses also are associated with huge financial costs to society in terms of medical care, earnings loss, and criminal justice expenses (Jason & Ferrari, 2010). In spite of these grim statistics, the majority of individuals in need of mental healthcare services will never receive treatment (Kessler et al., 2005). In the U.S., 33% of individuals with a psychiatric diagnosis receive mental health treatment, leaving an even smaller percentage who receive evidence-based care. This lack of treatment is not due to the fact that effective treatments are unavailable; indeed, many psychological interventions have been developed and systemically evaluated for the treatment of mental health problems (e.g., National Registry of Evidence-based Programs & Practices, 2012). For example, a recent U.S. government source estimates that over 320 evidence-based interventions exist for mental health problems (U.S. Department of Health & Services, 2014). While developing and refining interventions remains an important goal for mental healthcare, a major challenge lies in connecting individuals who need services with the available treatment options.

As a field, mental healthcare is working to address these unmet needs through several different strategies, including increased emphasis on dissemination of effective interventions (e.g., McHugh & Barlow, 2010; Weisz, Ng, & Bearman, 2014), the development of novel models of treatment (e.g., task shifting, best-buy interventions; Kazdin & Rabbitt, 2013), and the use of technology to expand the reach of existing interventions (e.g., Internet-based treatments; Carlbring & Andersson, 2006; Cummings, Wen, & Druss, 2013). Indeed, technological innovations already have changed how people receive mental healthcare services. For example, web-based interventions have become increasingly common for a wide range of psychological problems (e.g., depression, bulimia nervosa, social phobia; Andersson et al., 2005, 2006; Ljotsson et al., 2007). During these interventions, patients typically access online treatment programs at their own convenience with varying degrees of therapist support (e.g., telephone check-ins to monitor progress; Spek et al., 2007). Results from a number of clinical trials on Internet-based interventions suggest that users experience clinical benefits from the programs (e.g., reduction in symptom severity, improvement in functioning) and that the treatments are well tolerated (e.g., low drop-out rates, strong therapeutic alliance; Knaevelsrud & Maercker, 2007; L'Abate & Kaiser, 2012; Spek et al., 2007).

Of course, technological advances in treatment are not limited to web-based programs. Among the other new and emerging technology-based treatment options, socially assistive robotics (SAR) is a particularly exciting area for expanding mental healthcare services. SAR refers to robots that provide assistance to human users through social interaction (Feil-Seifer & Matarić, 2011). These robots can serve a variety of therapeutically relevant functions, including providing education and feedback, coaching patients through tasks, assisting with treatment compliance, and monitoring treatment progress. In fact, socially assistive robots have already been used in mental healthcare applications with multiple patient populations, primarily children with autism spectrum disorder and older adults with dementia (e.g., Moyle et al., 2013; Vanderborght et al., 2012). However, these robots also can be used to address many clinical problems and can serve individuals struggling with a wide range of clinical concerns, including adults with mood and anxiety disorders and children with disruptive behavior problems as well as individuals who do not meet criteria for a diagnosis but experience mental health concerns (e.g., high levels of stress). Unfortunately, the existing SAR work and its potential for expanded use is not widely familiar to mental health professionals (e.g., researchers, practitioners) who might meaningfully inform the next mental healthcare applications of SAR. In spite of the nascent nature of this work, the potential applications for SAR, particularly in relation to addressing unmet service needs, is emerging. Robots can help to fill niches that are currently vacant (e.g., in rural areas where few mental health providers are available) and can assist human providers in their ongoing efforts to deliver services (e.g., by serving as helpful tools within treatment sessions with a provider). In addition, robots can take on therapeutic roles (e.g., naïve peer) that may even be counterproductive for a clinician to adopt in treatment. In this context, robots serve as a complement to many other models of delivery or can be of assistance to patients by providing in-home resources and services. At this stage of development, it is critical to engage the mental healthcare community in this work to ensure that it is serving our field's most urgent clinical needs.

This article highlights current SAR advances and applications in mental healthcare. We begin with background information on socially assistive robotics and provide readers with examples of SAR from the broad field of healthcare. With that context established, we then review the diverse and clinically relevant ways that these robots have already been used in mental healthcare, with specific emphasis on the functions that robots have served (i.e., companion, therapeutic play partner, coach). Next, we propose important lines of clinical research that are needed in order to integrate SAR with the current demands on the mental healthcare field. Finally, we identify and discuss practical concerns that consumers (e.g., clients, therapists) may have regarding the use of SAR in mental healthcare.

1. Socially assistive robotics: Relevant background

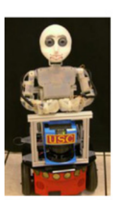
1.1. Definition and examples

Before reviewing the different ways that socially assistive robots have been used in mental healthcare applications, it is first essential to describe this group of robots. SAR refers to a unique area of robotics that exists at the intersection of assistive robotics, which is focused on aiding human users through interactions with robots (e.g., mobility assistants, educational robots), and socially interactive or intelligent robotics, which is focused on socially engaging human users through interactions with robots (e.g., robotic toys, robotic games; Feil-Seifer & Matarić, 2005). An example of a traditional assistive robot is the MIT-Manus arm system, which helps stroke victims by physically guiding them through exercises (Prange, Jannink, Groothuis-Oudshoorn, Hermens, & IJzerman, 2006). The robot interacts physically (but not socially) with the user by moving the user's body through the appropriate motions. On the other hand, socially intelligent robots are capable of socially engaging with users but may not be designed to specifically help people. For example, Leonardo is an extraordinarily sophisticated socially intelligent robot that is capable of expressing a wide range of facial and body expressions, visually tracking the face of human users, responding to physical touch, and engaging in social learning (MIT Personal Robots Group, 2014). However, Leonardo is not designed specifically to aid people and, therefore, is not considered a socially assistive robot.

The essential feature of SAR is the social component of the interaction as a means of helping a human user (e.g., through coaching, education, and motivation). Although the specific details of robotic design will be discussed later, it is important to note that the robots used in SAR work can and do take a variety of forms, from one-of-a-kind robots developed in specialized university laboratories to commercially available toys that are adapted and doctored to create more specialized systems (see Table 1 for a sampling of socially assistive robots used in mental health research). As the reader might imagine, the cost and availability of these robots vary considerably, depending on the specific robotic form that is used. For example, a unique system designed in a laboratory may cost tens of thousands of dollars (and upward) and require significant time to produce, while adapting commercially available toys is often a significantly less expensive endeavor (e.g., several hundred dollars). However, in both of these cases, it is important to note that SAR systems are generally expensive and time-consuming to create.

In SAR, a robot faces significant demands; it must perceive its environment, interact with human users, display appropriate social cues, and effectively communicate with human users (Okamura, Matarić, & Christensen, 2010). Certainly, creating robots that can participate in the often complex and subtle aspects of human social interactions is a challenging task (Tapus, Matarić, & Scassellati, 2007). Because of this complexity, many (but not all) of the robots described in this article operate either partially or fully under human control, giving the human and robot roles similar to puppeteer and puppet, respectively (Lu & Smart, 2011). Of course, the long-term goal of this research is to create SAR systems that operate autonomously and can be used without any type of human operator controlling the interaction.

Table 1
Sample robots used in clinically relevant SAR research.

Clinical Function	Sample Robots
Companion	(A) 
Coach or Instructor	(B)  (C) 
Other	 (D)

Note. A: Image courtesy of Paro Robots, B: Image courtesy of Prof. M. Matarić, C: Image courtesy of B. Scassellati, D: Image courtesy of B. Vanderborght. Additional information (including photos) are available through the following websites: http://www.parorobots.com/, http://robotics.usc.edu/interaction/, and http://probo.vub.ac.be. SAR = socially assistive robotics.

As indicated in this description, SAR is an interdisciplinary field that combines robotics, engineering, medicine, communication, and psychology and has a wide range of real and potential applications. Indeed, these robots can assist in tasks ranging from guiding visitors through museums to helping elderly patients eat their meals (Ghosh & Kuzuoka, 2013; McColl & Nejat, 2013). Within the broad field of healthcare, SAR has already been used in several different clinical roles, including stroke rehabilitation, recovery for cardiac patients, weight-loss and exercise programs, and patient education (e.g., Fasola & Matarić, 2010; Henkemans et al., 2013; Kang, Freedman, Matarić, Cunningham, & Lopez, 2005; Kidd & Breazeal, 2005). In each of these applications, the relevant SAR research is characterized by small samples and limited patient populations, as is often the case in research in any newly emerging field. However, these examples provide illustrations of how SAR has been used in ways that are also relevant to mental healthcare.

SAR systems have successfully been used to coach elderly patients in physical exercise (Fasola & Matarić, 2013). In a recent trial, older adults were randomly assigned to one of two groups: a robotic exercise instructor (i.e., a physically present robot, Bandit) or a screen depiction of the robot (i.e., a virtually present robot). Participants in both group engaged in a series of four 20-minute exercise sessions over a two-week period. In both conditions, the robot modeled a variety of exercises for the participants, offered feedback on the participants' performance of the exercises, and encouraged and praised the participants for their efforts. In terms of exercise performance (e.g., number of exercises completed, amount of time required per exercise), participants across both groups demonstrated similar, high levels of task performance and were compliant with the instructions provided by the real and virtual robots. While the lack of differences between groups may reflect true similarities across conditions, the observed findings in exercise performance also may be due to the relatively small sample size ($N = 33$) and inadequate power to detect effects between groups. However, participants who interacted with a physically present robot rated the interaction as significantly more enjoyable and significantly more useful than participants who were interacting with a screen depiction of the robot. They also rated the physically present robot as more helpful and attractive than its screen version. These findings suggest that a robotic instructor can effectively lead older adults through activities and that a robot may be preferable to similar computerized or screen-based activities.

Encouraging work also is available for weight loss. For example, in a randomized controlled trial (RCT), overweight adults who expressed interest in participating in a weight-loss program were assigned to one of three groups: a robotic weight-loss aid (called Autom), a desktop computer with the same weight-loss software used in the robot, or a paper-and-pencil log (which was part of the standard weight-loss treatment; Kidd & Breazeal, 2008). Autom was designed as a weight-loss coach that could interact with participants once or twice each day and provide personalized feedback about health and weight loss tracking. In addition to assisting participants with monitoring their calorie consumption and exercise, Autom was also capable of engaging in small talk and providing varied conversations and interactions depending on several factors (e.g., time of day, time since last interaction). Over the course of a 6-week trial, participants across the three treatment conditions lost similar amounts of weight, which was consistent with study hypotheses given the relatively short timeframe of the program. However, significant differences emerged among conditions when engagement in the programs was examined. Participants who worked with Autom took part in the weight-loss program for significantly more days (mean = 50.6 days — more than a week after the official end of the program!) than participants assigned to either the computer program (36.2 days) or the paper log conditions (26.7 days). In terms of therapeutic relationship, participants who worked with Autom reported a significantly stronger working alliance than participants in either the computer or paper log conditions (which were not different from each other). Much like the exercise program described previously, this research on Autom indicates that robots can be integrated into treatment regimes in ways that are acceptable to users and that robots may provide benefits (e.g., increased enjoyment, improved compliance) over computer-based programs.

As both of these SAR examples illustrate, SAR systems have been used in multiple ways and with encouraging outcomes. Perhaps most importantly, human users were receptive to receiving help from SAR systems and engaging with them for their designed purposes. One can easily imagine how similar SAR systems could be effectively used in mental healthcare interventions to provide assistance in monitoring treatment participation, to offer encouragement and support, and to lead users through clinically relevant activities and tasks.

1.2. Understanding human reactions to socially assistive robotics

Thus far, socially assistive robots have been presented as a uniform and homogeneous group. Before considering the variety of roles these robots can and have occupied in mental healthcare research, it is critical to acknowledge that the robots themselves vary considerably. Indeed, socially assistive robots – much like robots in general – are a very diverse group from a design perspective and can take many different physical embodiments, including animal-like, machine-like, and human-like forms (e.g., Fong, Nourbakhsh, & Dautenhahn, 2003). The robot's physical form is particularly important to consider in SAR work because it facilitates the human tendency to engage with and ascribe social characteristics to even relatively simple robotic forms (Okamura et al., 2010). Within the existing mental healthcare applications, a variety of SAR forms have been used (see Table 1). Many animal and related animal-inspired designs have been used in SAR applications, including dogs, cats, seals, and dinosaurs. However, humanoid designs, which range from strikingly life-like to more machine-like forms, also have been employed. Caricatured robots – robots that do not have a realistic human form (e.g., specific facial features) but are able to evoke enough human-like qualities (e.g., two lights that appear like eyes, a face-like focal point) – have also been included in SAR applications. Finally, although less common, SAR systems that are completely non-anthropomorphic have been used. For example, a spherical robot that can move around has been used to engage toddlers in interactive tasks (Michaud & Caron, 2002; Michaud et al., 2005). As evidenced by Table 1, even within these broad categories of robotic forms, great variety exists in the physical appearance of these robots.

In terms of mental healthcare applications, one of the benefits of the varied physical forms of SAR is that many specific physical features and functions of robots can be manipulated (e.g., facial design, voice pitch, speech style) to increase impression of sociability and likeability in the robot and, presumably, facilitate positive and productive human–robot interactions. For example, users react differently to robots with different facial proportions, rating some robots as more sociable based on this characteristic (e.g., Powers & Kiesler, 2006). Similarly, how a robot speaks to a user affects that user's experience with the robot. When a robot calls a person by name, that individual is more likely to rate the robot as friendlier and behave in a more socially engaged way (e.g., pay closer attention, speak more to the robot; Kim, Kwak, & Kim, 2012). People also tend to respond more positively to robots that appear more animated and that demonstrate emotional responses (e.g., appropriate facial expressions, animated verbal content) during an interaction (Leite, Pereira, Martinho, & Paiva, 2008). User personality traits and the "match" between user personality and robot style is another factor that might facilitate human–robot engagement. A match between user personality and robot "personality" (e.g., content of feedback and style of feedback) is associated with increased time spent with the robot (Tapus & Matarić, 2008). As these examples illustrate, the use of SAR in mental healthcare creates exciting opportunities for robots to be designed in the service of specific roles and functions for mental healthcare. This flexibility encourages robots to be used with diverse clinical populations, in a variety of clinical settings, and in a wide range of clinical functions (Okamura et al., 2010).

Issues of personalization aside, it is important to acknowledge that users generally respond quite positively to robots across a wide range of design forms. This is not to say that all users (e.g., from different cultures, with different experience levels) react to robots in the exact same manner. Indeed, variability exists and has been documented in how people view and respond to robots (e.g., Wang, Rau, Evers, Robinson, & Hinds, 2010). Even so, users across the lifespan tend to be quite open to interactions with robots. Children and young people tend to react positively to robots, readily engaging in play activities with them (e.g., Bernstein & Crowley, 2008). Older adults and the elderly frequently report being willing to accept assistance from robots in a variety of tasks, including household activities and medication reminders (e.g., Smarr et al., 2012). Additional experience and time interacting with robots seems to foster even more positive reactions. Even over relatively short periods of time (e.g., weeks), users who repeatedly interact with a robot appear to become more comfortable and change their behavior with the robot accordingly (e.g., increased physical closeness to the robot) to reflect their increasing comfort level (Koay, Syrdal, Walters, & Dautenhahn, 2007).

2. Socially assistive robotics in mental healthcare

Although it is a relatively new field, SAR has already found exciting applications in mental healthcare. As is often the case with an emerging area, the research on SAR applications in mental health is characterized by relatively small sample sizes (e.g., N typically <50, which is small by RCT standards) and simple methodological approaches (e.g., lack of adequate comparison conditions, use of pre–posttest designs). Even with these obvious limitations noted, SAR research has already been conducted for a variety of mental health concerns (e.g., dementia, depressed mood, autism spectrum disorder) and with a diverse group of patients (e.g., young children, the elderly). Of particular import, socially assistive robots have already served in a variety of clinically relevant roles. Below we will review several of the roles that SAR systems have served, including companion, therapeutic play partner, and coach or instructor, in clinical research and other clinically relevant work. While these roles are not exhaustive, they provide a helpful overview for considering the extent research and how it can be applied further.

2.1. Companion

One of the more commonly employed functions of SAR in mental healthcare has focused on robots in the role of a companion. In much of this work, SAR systems function in a way that is analogous to a trained therapy animal (e.g., a therapy dog). Although a review on the use of animals in mental healthcare interventions is beyond the scope of this discussion, a growing literature documents the therapeutic value of interactions with animals (e.g., Nimer & Lundahl, 2007). Unfortunately, there are practical concerns with bringing live animals into clinical settings (e.g., therapy offices, hospitals, long-term care facilities) including issues related to animal welfare, patient allergies, and risk of illness or infection (e.g., Shibata, 2012). Socially assistive robots are seen as a way of harnessing some of the clinical benefits associated with animal-assisted interventions while avoiding the challenges inherent in work involving live animals. Although a wide range of pet-like robots currently exist, most of this work has focused on Paro, a robot designed to look like a baby harp seal, and Aibo, a small robotic dog (Broekens, Heerink, & Rosendal, 2009; see Table 1 for an image of Paro).

Many of the studies examining socially assistive robots in the role of a companion have focused on elderly patients, many of whom either were identified as having dementia-related cognitive impairment (e.g., Shibata & Wada, 2010) or were at high-risk for depression (e.g., Banks, Willoughby, & Banks, 2008). The benefits reported for the use of SAR systems in a companion role are encouraging. Participants in pilot and case studies generally report positive experiences and appear engaged during interactions with the robots (e.g., Libin & Cohen-Mansfield, 2004; Marti, Bacigalupo, Giusti, Mennecozzi, & Shibata, 2006). In terms of clinically relevant changes noted during and after interactions with robots, multiple studies have noted improved mood and decreased self-reported feelings of depression following the introduction of a socially assistive robot into a long-term care facility for the elderly (Wada, Shibata, Saito, Sakamoto, & Tanie, 2005). Patients have also been noted to spend increased time in public areas and around other patients and staff members after the robots were introduced (Wada & Shibata, 2006). In addition, reductions in physiological stress levels (as measured by salivary and urinary hormones) have been noted after interactions with a socially assistive robot (Kanamori et al., 2003; Wada & Shibata, 2007). This accumulating set of findings in case studies and pilot research indicates that there may be an array of psychological benefits of SAR in elderly populations (e.g., improved mood, stress reduction) and additional more rigorous evaluation is warranted.

Even more encouraging, published RCTs also document the benefits observed in smaller-scale studies. In a recent RCT with elderly adults living in a nursing home or hospital facility, participants who regularly interacted with the robotic seal Paro experienced a significant reduction in self-reported loneliness while their peers who were assigned to recreational activities reported no change in these feelings (Robinson, MacDonald, Kerse, & Broadbent, 2013). Of additional interest, the setting in which this study was conducted also received regular visits from a therapy dog, allowing comparisons between participants' behavior during interactions with Paro and their behavior during interactions with the facility's dog. Participants talked to and touched Paro significantly more than the resident dog. Moreover, Paro seemed to encourage increased interaction among the study participants. More residents were involved in the discussion about Paro and more overall conversation occurred relative to the conversation about the dog (Robinson et al., 2013). Another recent RCT involving Paro suggests that patients with dementia experienced other mental health benefits as a result of interacting with the robot (Moyle et al., 2013). In this study, a randomized crossover design involved elderly patients with mid- to late-stage dementia engaging in five weeks of interactions with Paro and five weeks of a control condition (a reading activity). Participants reported an improved quality of life and increased pleasure following their interactions with Paro. In fact, these results were so encouraging that the same team of researchers is now working on a larger-scale RCT using Paro (Burton, 2013).

Positive findings are not limited to Paro. In another small trial that included the robotic dog Aibo, residents at three different long-term care facilities were randomized into three treatment groups: weekly interactions with Aibo, weekly interactions with a trained therapy dog, or no interactions with a robotic dog or therapy dog (Banks et al., 2008). At the end of the program, residents in the robot and therapy dog conditions both reported significant reductions in self-reported loneliness compared to residents in the control conditions. Of particular note here, the residents in the two active intervention conditions were no different from each other in terms of self-reported loneliness and in terms of attachment to the dogs (living or robotic), indicating that the robotic dog was associated with changes similar to those observed after interactions with a trained therapy animal. Studies like these suggest two very important findings. First, socially assistive robots can be integrated into treatment settings (e.g., hospitals, long-term care facilities) for use with clinical populations. Second, there appear to be positive clinical outcomes associated with the use of these robots.

Interestingly, positive responses have also been observed in staff members working in facilities that use SAR systems with patients. Stress levels of nursing staff at facilities that introduced socially assistive robots were lower after the robot was introduced compared to their levels before the program started. For example, during the course of a five-week program with the robotic seal Paro, staff members' self-reported indictors of 'burnout' decreased, suggesting that the staff stress levels were reduced following the introduction of the robot (Wada, Shibata, Saito, & Tanie, 2004). These findings are hypothesized to be the result of positive changes observed in the patients at the facility. That is, the elderly residents in this facility reported significantly improved mood after interactions with the robot, a pattern that was maintained over the course of the program's five-week duration. The positive mood changes experienced by the residents and the time spent engaged in activities with the robot are believed to have decreased the burden placed on that staff, therefore reducing their stress levels. Given these positive findings, applications to clinical populations of individuals experiencing higher levels of mood disturbance and stress are warranted because of the potential psychological benefits to patients and to their caregivers.

2.2. Therapeutic play partner

Another line of research on SAR applications to mental healthcare has focused on robots as play partners who aid children in practicing or building clinically relevant skills, most often in children with autism spectrum disorder (ASD; Diehl, Schmitt, Villano, & Crowell, 2012; Scassellati, Admoni, & Matarić, 2012). In much of this work, socially assistive robots are used along with human providers (e.g., therapists, research assistants) to increase engagement and offer additional opportunities for social interaction and skill building within an interaction (e.g., Atherton & Goodrich, 2011). These socially assistive robots elicit positive social responses from children and are generally experienced as a novel and engaging addition to treatment (Scassellati, 2007). However, the treatment potential for SAR in ASD surpasses simple novelty effects. Socially assistive robots can serve many different clinically relevant functions, including engaging children in tasks, modeling appropriate social cues (e.g., making eye contact), facilitating joint attention tasks, and serving as partners for practicing critical social skills (e.g., taking turns in play; Scassellati, 2007; Scassellati et al., 2012). Given the wide range of functions that these robots can serve, it is unsurprising that a diverse array of robots have been used in the extant literature. Unlike the work exploring SAR as a therapeutic companion (which focused on a relatively small number of robotic systems), this area of work includes robots that range from life-like humanoid robots to very simple caricatured designs. The activities included in this area of research are usually designed to be fun and engaging and are often framed in terms of games. Therefore, the SAR systems included in the research are often used as a therapeutic toy or a therapeutic play partner.

To illustrate the range of these applications, it is helpful to review some of the case studies and laboratory-based research currently being done in this area. Encouraging case study work speaks to the potential value of social robots in engaging children with ASD in joint attention activities (Kozima, Michalowski, & Nakagawa, 2009; Kozima, Nakagawa, & Yasuda, 2007). In a series of case studies with young children with developmental disorders (including children specifically diagnosed with ASD), children were observed during interactions with a Keepon, small interactive robot (Kozima et al., 2007). From a design perspective, Keepon is quite simple; it resembles two tennis balls, one resting atop the other, and its "head" has two eyes but no other facial features. Including its pedestal, Keepon is about 10 in. in height. In spite of this simple design, Keepon can express attention (by orienting its face and eyes toward different objects) as well as emotional states (by bouncing up and down in pleasure or excitement). Over several months of interactions with Keepon, young children (i.e., toddlers and preschoolers) displayed increased social engagement with the robot. For example, the robot served as a focus of joint attention for a young child with ASD. When the robot moved, the child responded with looking and smiling at a parent and therapist. In addition, the robot "imitated" the child's behavior, leading the child to share a social smile with a caregiver. These relatively simple social gestures can be quite challenging to evoke in young children with ASD, and the potential value of simple robots like Keepon deserve additional experimental work in clinical populations.

More rigorously controlled laboratory-based research also supports the hypothesis that socially assistive robots are helpful tools for engaging children with ASD. Many children with ASD struggle with social communication, particularly initiating and maintaining conversation. In a recent lab-based study, children with autism spectrum disorders engaged in three different tasks (Kim, Paul, Shic, & Scassellati, 2012; Kim et al., 2013). In the paradigm, the target child and a study confederate were seated at a table together. While they were both seated, the child participated in three activities that involved building or working with blocks: a robot partner condition (where the child and robot completed the task together), an adult partner condition (where the child and another, non-confederate adult complete the task together), and a computerized block activity. The adult and robot interactions were designed to elicit several social behaviors from the children, including taking turns with the interaction partner and identifying the interaction partner's emotions and preferences. Pleo, a robot designed to look like a baby dinosaur that can move (e.g., walk, jump) and demonstrate socially expressive vocalizations and behavior (e.g., wag its tail), was used as the robot partner. Children spoke more overall during the robot interaction than they did during either the interaction with the adult partner or during the computer task. Of additional clinical interest, the children directed more speech toward the study confederate during the robot interaction than in the other two conditions.

The value of this type of outcome – a robot facilitating human–human interactions – must be underscored. Often the SAR literature focuses on human–robot interactions (e.g., how a human user rated their experience with a robotic system, a human user's willingness to interact with the system again). While value exists in exploring and understanding these human–robot metrics, using SAR to facilitate meaningful interpersonal interactions and social engagement with other people is a vital part of SAR research. Indeed, an important goal of SAR research is understanding how interactions with robots and skills learned or rehearsed with an SAR system can be translated into real-world situations and in interactions with other people. In fact, the greatest value in these systems may be understanding benefits from interactions with SAR after the robot is no longer physically present.

Among the issues to consider in using SAR in these types of therapeutic play situations is how or why these robots may be particularly helpful clinical tools for children with ASD. Researchers in this area have suggested that the robots may serve as embedded reinforcers of social behavior (Kim et al., 2013). That is, the robots themselves can serve to both elicit social behavior from children as well as reward the behavior when it occurs. Considering the interaction with the robot as being rewarding unto itself, one can imagine how socially assistive robots could be integrated into clinically relevant tasks for children in ways that are fun and engaging while also meaningfully targeting relevant problem behaviors.

2.3. Coach/instructor

A third role that socially assistive robots have occupied in mental health research is that of a coach or instructor. Much like the examples provided previously of Autom, the weight loss coach, and Bandit, the exercise instructor, socially assistive robots can provide direct instruction and supervision to patients or clients engaged in relevant treatment activities (Fasola & Matarić, 2013; Kidd & Breazeal, 2008). Considering the examples of Autom and Bandit, terms such as coach or instructor may be too simplistic in terms of the function that SAR systems can serve in mental healthcare. These robots can describe and model tasks, monitor patient performance, provide corrective feedback, and offer encouragement and support. Even so, the idea of a coach of instructor helps to convey the spirit of a robot guiding users through tasks.

To clarify with an example, a recent pilot study included a sample of older adults with dementia interacting with a social robot in an attention and memory task (Tapus, Tapus, & Matarić, 2009). The robot included in this study was a humanoid torso robot (i.e., it included a head, upper body, arms, and hands). Instead of a lower body, the robot was mounted on mobile base that resembles a cart on wheels (see Table 1 for a similar robot). The activity was framed as a "Name that Tune" game in which participants were presented with a set of four songs, each with a corresponding button. Songs were randomly played from the set, and participants were instructed to select the correct button as quickly as possible. The robot instructor explained the task to the participants and guided them through this activity once a week for six months. In addition, the robot was programmed to increase the difficulty of the game (e.g., avoid providing hints) as participants demonstrated improved performance in the task over time. Throughout the interactions, the robot provided positive encouragement to the participants. Results from this pilot work indicate that the robot was able to effectively sustain the participants' attention in this therapeutic activity. In addition, the robot adapted its behavior to the participants' ability level, which suggests a clinical flexibility that could be valuable in other clinical applications.

Of course, one can imagine how this type of coaching or instruction could be used in a wide variety of therapeutic activities, both inside and outside of treatment sessions. Within a treatment session, socially assistive robots can lead patients through tasks that a human provider has identified as clinically relevant and meaningful to their treatment program in a manner similar to the robot leading participants through the music task. However, the robots can also be used outside of treatment sessions. In this way, the robots can serve to engage and encourage patients in performing treatment relevant activities outside of the therapy room, essentially helping to extend a therapist's reach into a patient's home. Related, these robots can assist patients in monitoring their compliance with other aspects of treatment (e.g., medication adherence) through a structured and positive coaching style. This SAR function could be helpful to many different clinical populations beyond adults with cognitive impairment.

2.4. General comments

Socially assistive robots have functioned in roles beyond those highlighted here. One of the interesting ways that these robots can be further used in mental healthcare is to adapt them into existing interventions. In this way, the robots can be integrated into existing and effective treatment programs, ideally in ways that reduce the time-demand placed on human treatment providers. Little published data is available for robots functioning in this role of novel delivery platform for treatment. However, a small pilot study for children with ASD provides relevant information. The study used Probo, an animal-like robot with a trunk like an elephant and an emotionally expressive face (Goris, Saldien, Vanderborght, & Lefeber, 2011; Goris, Saldien, Vanderniepen, & Lefeber, 2009). Probo stands approximately 30 in. tall and is covered in bright green fabric (see Table 1). Probo was integrated into Social Stories, an existing treatment program for children with ASD. In Social Stories, short scenarios are written or personalized for children with ASD, with the goal to improve understanding of specific, challenging social situations, and are typically delivered by a human therapist (Gray, 2010). In a recent adaptation of the program, Probo was used to deliver Social Stories and, in a series of single-case studies, Probo and a human therapist were compared in their delivery of the treatment (Vanderborght et al., 2012). Children responded positively to both treatment platforms (human and socially assistive robot). Interestingly, child performance on the behaviors specifically targeted in the Social Stories improved significantly more following the robotic intervention.

As this example with Probo highlights, SAR research in mental healthcare is truly an emerging literature. This work is characterized by small studies (e.g., case studies, pilot research), with restricted samples and in limited settings (e.g., laboratories, long-term care facilities), and frequently without adequate methodological controls and comparison conditions. Even studies that employ a randomized and controlled design often include small sample sizes, leaving open the possibility that some failures to note significant differences could be due to inadequate power (e.g., Banks et al., 2008). Perhaps even more importantly from a clinical perspective, no work to date has indicated lasting clinically relevant changes as the result of interactions with SAR systems.

In light of the aforementioned limitations, we view current applications of robotics to clinical domains as *proof of concept or principle*. That is, can SAR be applied to psychological domains that are impairing or distressing? Once they can be applied, is there any evidence that interaction with socially assistive robots may lead to change on dimensions (e.g., symptoms, impairment) that are clinically relevant and would be used in outcome research? The answer to both of these questions at this point is yes. With these proof of concept tests as well as clinical applications, SAR certainly warrant attention among mental health researchers to exploit the principle that robots can play a role in helping individuals with psychological problems or sources of impairment.

3. Priority directions for clinical research and applications of SAR

The emerging role of SAR in mental healthcare interventions serves as a well-timed opportunity to address major gaps in provision of services to those in need of care. In order to meet this need, several critical research priorities exist. These priorities are certainly not an exhaustive list; instead, they represent a launching point for systematic empirical work on robotics interventions for mental health problems. We view these priorities as being among the most pressing issues that deserve attention in order to responsibly implement robotics interventions.

3.1. Expanding clinical applications of SAR

One of the priority research areas is the application of robots to a broader range of mental health domains to evaluate the benefits among clinical as well as community populations. First, attention is warranted to a broader range of areas of clinical dysfunction than currently available. As reviewed earlier, much of the work in SAR interventions has focused on older adults (e.g., in the treatment of dementia; Bemelmans, Gelderblom, Jonker, & De Witte, 2012) and children (e.g., in the treatment of ASD; Scassellati et al., 2012). In extending robots to clinical dysfunction, one place to begin would be for dysfunctions with high prevalence or greatest unmet need. Although extension of SAR to the full range of clinical dysfunction (e.g., psychiatric diagnosis) and subclinical problems (i.e., below diagnostic threshold) are viable options for next steps in research, we will use one disorder to convey the lines of research that can be pursued.

As an illustration of steps for research, consider major depressive disorder, which has the highest lifetime prevalence among psychiatric disorders in the U.S. (e.g., Kessler et al., 1994; Kessler et al., 2005) and is associated with tremendous cost to the diagnosed individual (e.g., personal suffering) and society (e.g., work absenteeism; Kessler, 2012). In 2004, the burden of depressive disorders (e.g., years of good health lost because of disability) was ranked third among the list of mental and physical diseases (World Federation for Mental Health, 2011). By 2030, depression is projected to be the number one cause of disability, ahead of cardiovascular disease, traffic accidents, chronic pulmonary disease, and HIV/AIDS (WHO, 2008).

Developing SAR interventions for depression has the potential to assist a huge number of people and to address a pressing public health need. First, SAR can be used as a tool for maintaining adherence to treatment protocols (e.g., medication compliance, psychotherapy homework) and remaining engaged outside of a session with a human therapist. Having a robot physically present to provide reminders and encouragement is associated with better compliance to treatment protocols than other self-monitoring strategies (e.g., computer programs, paper-and-pencil tracking; Kidd & Breazeal, 2008). Second (and related), socially assistive robots could be helpful in facilitating engagement with self-help treatment programs. Several programs have been developed and evaluated for the treatment of depression (Bennett-Levy, Richards, Farrand, Christensen, & Griffiths, 2010; Harwood & L'Abate, 2010). Given that the presence of a physically embodied robot is associated with improved task compliance and more positive perceptions of the interactions (e.g., Bainbridge, Hart, Kim, & Scassellati, 2011), self-help programs quite possibly could receive a critical boost by including a robot that can guide patients through therapeutic programs. In this way, robots could help to move self-help interventions toward an interactive therapeutic experience. Finally, socially assistive robots can serve as a source of social interaction and engagement. In the treatment of depression, social support in the form of casual discussions or practice might be a valuable adjunct to treatment. Decades ago psychotherapy was characterized as the “purchase of friendship” (Schofield, 1986). Robotic “friends” might be immediately offensive; however, as an aid, complement, and extra source of social interaction, robots may have a meaningful role. In fact, robots offer some unique benefits. Unlike typical friends and therapists, robots are available for round-the-clock social engagement, including times (e.g., very late at night, very early in the morning) when most people are not easily accessed.

A priority for research is to extend robots to a range of clinical applications. We used depression to illustrate some of the lines of work that might be pursued but, of course, depression is not a necessary first step. An initial step and research priority is to expand the uses of robots in relation to clinical problems. This will involve collaborations of treatment researchers with those involved in robotics. Many working with SAR already are focusing on human–robot interactions and how humans respond in clinically relevant situations. It is not a leap to expand on how robotics could help with more clinical and subclinical populations.

3.2. Establishing a strong evidence base for SAR in mental healthcare

Robots can be clinically meaningful additions to treatment and have impact on mental health outcomes (e.g., symptoms, social behavior). The use of robots may be feasible for a diverse group of patient populations (e.g., children, the elderly) and clinical problems (e.g., social skill deficits in ASD, cognitive impairment in dementia). The evidence-base for the use of robots in treatment warrants concerted attention. The path toward establishing a treatment as evidence-based is a lengthy process that occurs over many years and through many separate trials and replications. Furthermore, as highlighted by the review of the diverse ways robots have been used in mental healthcare, SAR interventions are not a singular treatment program. Rather, they are a new category of treatment that comprises many different specific subtypes and exemplars of robots. Therefore, the process of establishing an evidence base of support will be the one that unfolds over time as data accrue for different types of robots with varied “abilities,” as applied to different problems and clinical dysfunctions.

There are several ways to begin the process of establishing an evidence base for robotic interventions; three pathways may be ideal starting points. First, single-case experimental designs might be a very useful point of departure. Developing robots for therapeutic use will require an iterative process to ensure that clinical goals, treatment processes, and robotic behavior are working together. There is no off-the-shelf set of robotic therapists from which to choose, and, so, initial work requires building the robot to behave in the way the clinical researcher wishes to achieve particular therapeutic goals. Trying this out on a small scale but with controlled designs might be the path of least resistance in developing programmatic robotic research. There are already case studies that show the applicability of robotics to mental health problems. In fact, case studies are often used to evaluate the feasibility of using a new robot for a specific clinical problem (e.g., ASD; Kozima et al., 2007; Robins, Dautenhahn, & Dickerson, 2009). Single-case assessment and evaluation would add an evaluative component that would clarify the impact and role of robots in therapeutic change.

Second, researchers may consider finding ways to incorporate robotics into existing evidence-based interventions. Rather than developing a theoretically novel treatment program, robots could be integrated to assist at strategic points in existing programs, bolstering the effectiveness of the intervention. We mentioned that homework and practice activities span a large range of psychosocial treatments and for widely used treatment, such as CBT, a wide range of dysfunctions to which the treatment is applied (Kazantzis & L'Abate, 2007; L'Abate, 2011). If robots serve no other purpose than to increase in vivo practice and homework, that alone would be a remarkable contribution. Robots could not only increase activities currently prescribed in treatment but could augment with additional activities that technology (e.g., monitoring, real time feedback) already offers (e.g., in apps).

Finally, ultimately RCTs will be needed that directly address the limitations inherent in preliminary studies. Given the attention already provided to ASD and dementia (and related conditions), these diagnoses would be logical candidates for the first larger-scale intervention studies. Large-scale RCTs may be further down the line in research on SAR because there are basic issues to address about the form the robot takes, the precise activities that are programmed, and how these interface with therapeutic goals. Even so, already there are exemplary studies in which interactions with robots have been examined in randomized designs, as mentioned previously in the context of mood symptoms and loneliness in elderly populations (Banks et al., 2008; Robinson et al., 2013).

3.3. Forging strong collaborations with roboticists

Both of the other priorities (i.e., expanding clinical application and establishing an evidence base) require individuals in the mental health field to effectively engage and create ongoing collaborations with computer scientists, engineers, and roboticists that are responsible for developing and refining SAR systems. In order to produce the work needed in this area, it is critical for mental health professionals and researchers to become more familiar with some key aspects of robotics research, including the following points:

- The motivations and rewards for robotics research are often different than the motivations and rewards for mental healthcare research. Unlike psychology, which places a premium on peer-reviewed journal articles, computer science considers conference papers the preferred way to communicate new ideas and research. Robotics researchers typically focus on short-term projects, which means that long-term research studies are difficult to complete. In general, the field rewards innovative designs and the development of new robot capabilities and does not focus on establishing the validity of these capabilities or on evaluating systems in RCTs. This, of course, poses a challenge for creating a viable collaboration. Special effort must be expended to ensure that both groups find value in the collaboration.
- There are substantial technological advancements that are needed before the field has generally applicable SAR systems. Most systems today have very limited autonomy, or are carefully constructed to limit the perceptual or cognitive skills that the robot requires. This means that small changes to the operation of the robot could be trivial or could be impossible with today's technology. It is essential for psychologists and mental health professionals to recognize what robots are capable of and to work closely with robotics experts that can provide critical feedback on what tasks robots can reasonably do, which will shape the design and execution of intervention studies.
- Corporate claims about robots may not align with the research work being conducted in academic settings. While there are a large number of research groups engaged in SAR, there are also a growing number of robotics companies that are marketing toward SAR applications. These systems often look on the surface similar to those used in research (and sometimes even are the same hardware), but offer very different software functionality.

4. Special challenges and concerns

In considering the expansion of SAR in mental healthcare, multiple challenges can be readily identified. The use of robotics is sufficiently novel in this area as to raise many reasonable concerns among all parties involved (e.g., mental health professionals, patients, family member of clients). We now consider a few of the salient challenges and how they may affect the delivery and consumption of the interventions.

4.1. Technological considerations

One potential concern is that the technological knowledge needed in order for mental healthcare consumers (e.g., patients, therapists) to use robots effectively may be beyond the existing skill sets of some users. For example, a challenge for some therapists that use robots in treatment may be the knowledge of computer systems that is necessary in order to work with robots on an ongoing basis (Giullian et al., 2010). Over the course of weeks or months, the focus of treatment will likely change. A robot will need to be programmed for different relevant tasks during treatment; for practical purposes, it would be ideal for therapists to have the ability to complete this programming themselves. For example, when a robot is used in treatment for ASD, the specific foci that a therapist addresses in given session are likely to change over time for an individual patient (e.g., because a patient makes progress and masters skills, because a patient enters a new environment that poses new challenges) and across different patients (e.g., because of different presenting problems, because of different levels of functioning). Getting technological consultation and programming assistance before every session are not feasible for a variety of reasons (e.g., cost, time). Therefore, therapists and other users must be able to manage and understand how to use the robot for a variety of clinical needs.

While a seemingly daunting proposition (at least for some of us), new programming platforms for socially assistive robots (with the non-expert user in mind) currently are being developed and evaluated, with the goal of creating user-friendly robots (e.g., Atherton & Goodrich, 2011; Gorostiza & Salichs, 2011). In addition, it is not necessary for users (e.g., therapists, patients) to have an intimate understanding of the technology of how and why the robot works in order to use it (Lin, Abney, & Bekey, 2011). Indeed, many of us know little (if anything) about computer programming but are able to use personal computers, smartphones, and tablets without difficulty. Over time, the technological challenges for using robots in assessment, diagnosis, or treatment are likely to be resolved. However, the fact remains that all existing SAR systems are experimental; right now, they are not off-the-shelf treatment systems that can simply be purchased and immediately used for mental health application. There are fundamental technological components involved in making these robots adapt to individual users, in making the robots engaging over long periods of time, and in building stable and robust perception systems for these robots, among other issues, that are all research topics currently. The goals of these research endeavors are to create systems that can be easily and readily used for treatment applications.

Apart from the challenges of using robots among practitioners, there will be an inevitable reticence or resistance to their use by professionals and clients alike. We are suggesting that robotics can play helpful roles in mental health services and not suggesting broad applications in the immediate future. Robotics in manufacturing and medicine (e.g., the da Vinci® robot-assisted surgery) have been introduced gradually for specialized uses before expanding more broadly and routinely (Christensen, Grossman, & Hwang, 2009; Rogers, 2003). The usual path of introducing innovations is narrow use that extends as the innovations become more convenient and accessible. Obviously, we are at an extremely early stage of utilizing robotics in mental healthcare. Impetus of this article is to delineate the areas to begin next step applications and evaluations.

4.2. Ethical and related clinical concerns

Robot based or facilitated interventions can raise a variety of special ethical issues or variants of well-elaborated issues. For example, deception is a potential concern even if there is complete transparency regarding the robot and what it can and cannot do. Users may not understand that the robot is a machine. Concern already has been voiced about users (e.g., child and elderly populations) being falsely led to believe that a robot has capabilities (e.g., emotional understanding) that it simply does not have. Clients may subsequently develop a relationship with the robot under this pretense, clearly of ethical concern (Sharkey & Sharkey, 2010, 2012). In fact, some manufacturers do try to make robots *appear* as skilled and life-like as possible to increase the likelihood that they will be seen as animate and skilled interaction partners and will be attributed to have abilities that they actually lack. There is another side. Robots engage in an increasingly set of social behaviors and properties that are lifelike and this naturally leads to attributions that go well beyond what the robots are and can do. For example, most children interacting with a robotic dog see the robot as offering social companionship and having mental states, and many engage with it in ways similar to their interactions with living dogs (e.g., offering it a toy ball; Melson et al., 2009). We merely note the challenge of ensuring that there is no deception but also the natural tension that transparency alone may not dispel attributions of putative qualities and characteristics of the robots.

Other issues or concerns about the use of robots may not rise to the level of ethical issues but are no less significant. Among the concerns would be the prospect that robots would be seen or used as substitutes for social contact with humans, similar to how video games for children and adults seem to detract from family interactions and activities. Yet, in the context of therapy, social behavior usually is viewed as pivotal; one would want to utilize robots in situations where there is a net gain (e.g., more practice opportunities) in social contact. For example, SAR for older adults is not intended to be a replacement for social interactions with people and animals (Calo, Hunt-Bull, Lewis, & Metzler, 2011). On the contrary, robots are used to encourage increased social engagement and more meaningful social experiences. As mentioned previously, existing evidence indicates that contact with robots is associated with positive social outcomes in elderly users including decreased feelings of loneliness and improved mood ratings (e.g., Banks et al., 2008; Kramer, Friedmann, & Bernstein, 2009). Moreover, robots will be used along with ongoing therapeutic interactions with a human mental health professional. They will not replace human therapists; they will support their work and expand their reach. Consistent with this position, to date, no SAR researchers have suggested that robots can or should replace human providers (Feil-Seifer & Matarić, 2010). Of course, over time (and with a stronger evidence base established), SAR-based interventions have the potential to extend into self-help models of care that do not require the guidance of a trained mental health professional; this pattern has been observed in other mental healthcare interventions which can be consumed successfully in the absence of professional guidance (Harwood & L'Abate, 2010).

Relationship issues are central to therapy and can raise multiple concerns in the context of providing mental health services. People who are in regular contact with robots are likely to get emotionally attached to these machines (Kalvi Foundation, 2012). Two issues emerge, one of which we have noted already, namely, that one would not want machine substitutes for socialization with people and animals. The second issue has to do with termination of treatment with a robot as technology becomes obsolete or new and improved versions emerge (as we see regularly with technology). Addressing the concern of the relationship and breakdown of that begins with transparency about the possibility of these types of technological problems so that users are not shocked if they occur (Kalvi Foundation, 2012). This may help users to have more realistic understandings of the limitations of using SAR and may help them avoid attributing skills beyond the robots' abilities. Of course, knowledge of the possibility of breakdown is unlikely to prevent attachment to SAR systems and distress at the prospect of robot replacement. Users can become quite attached to robots to simple domestic robots (e.g., Roomba; Forlizzi, 2007). At this point, the risks associated with more socially engaging robots that are being used to help people address sensitive mental healthcare needs are not well understood but certainly merit additional attention.

4.3. Other concerns briefly noted

Another consideration is the cost associated with implementing any type of mental health intervention that includes a robotic component. Just as the robots that we have discussed vary in appearance and function, they also vary widely in price. There is a real and significant cost for many of the robots used in the extent treatment research. This includes the initial cost for purchase of the robot itself as well as many other costs, such as programming the robot and performing maintenance and repairs. It is challenging to estimate other expenses, like training clinical staff to use the robot, as these vary considerably depending on the baseline knowledge of the user, the technological specifications of the robot, and the way that the robot will be used clinically.

Concerns about costs are certainly valid but must be considered in the context of broader issues related to the costs associated with mental illness and mental healthcare. First, the astronomical cost of mental illness is already placing an enormous financial burden on individuals with mental health problems and society in general. For example, consider that substance use disorders, the most prevalent mental disorders in the U.S., cost approximately $500 billion annually (Jason & Ferrari, 2010). Second, our field's dominant treatment model (i.e., one–one–one psychotherapy with specially trained professionals) is an extremely costly model when the expenses and time demands associated with training and supervising those professionals are considered. These contextual factors aside, researchers are already creating low-cost robots for therapeutic purposes (e.g., Boccanfuso & O'Kane, 2011) and directly addressing clinician concerns related to robot programming (e.g., Atherton & Goodrich, 2011), with the goal of creating cost-efficient robots for treatment purposes. Furthermore, technology-based costs (e.g., robot development, robot hardware) fall considerably with increased volume. Developing and building a single robot are extraordinarily expensive. However, creating 1000 units significantly cut the cost, and creating 1,000,000 units can make the robots a relatively inexpensive option.

Another reasonable question for users, including mental health providers and patients alike, involves the safety of a robot (Feil-Seifer, Skinner, & Matarić, 2007). Could a robot designed to help, actually cause harm? Safety issues with socially assistive robots exist, but the threat of physical harm is likely quite small. Indeed, there is no need to have a mobile robot (e.g., a robot that walks) to help with patient homework, practice relevant therapeutic skills, or maintain treatment adherence in the home. For example, recall Autom, the robotic weight-loss coach described previously. Autom was immobile and designed to remain in a single location (e.g., on a table or countertop). For young children, robots are likely to be in the form of stuffed toys, pets, and other animals and can be designed with physical safety issues specifically in mind. Existing robots, such as Probo, serve as an excellent model in this regard. Probo was designed for child users and is covered with a thick layer of soft foam (to prevent dangerous hard edges) as well as a removable fur casing that can be washed and disinfected as needed. Other robots (e.g., Pleo, the dinosaur described earlier in work with ASD) use existing toys as their hardware base; these robots represent no greater physical risk to children than the toys themselves, which often undergo rigorous safety testing and are held to high manufacturing standards. In short, safety is a concern in any use of machinery and we do not wish to be dismissive. To be sure stereotypes about robots may affect the perceived safety of robots and both real and perceived safety concerns are impediments.

Finally, mental health practitioners may be concerned about how introducing more robots into the field might impact the jobs of human providers. Indeed, given ongoing worries about industrial robots taking over positions held by human workers (e.g., Ackerman, 2011), the idea of robots as a threat to job security is understandable. However, in reality, robots have multiple roles with varying degrees of human direction, including working directly under human service providers as assistants (e.g., robot-assisted surgical procedures where a human surgical team is aided by the precision of a robotic device) but also programmed to operate more independently (e.g., space exploration vehicles on multi-year missions). In some of these more independent functions, as in the case of assembling line manufacturing, robots have replaced human workers because the machines can either do precise tasks in more reliable ways or because the tasks themselves represent a significant danger or threat to human workers (e.g., International Federation of Robotics, 2012). SAR in our presentation focuses on broad applications in mental healthcare. First, robots can serve in a complementary role, where the robot does not infringe on the role of a human service provider, and, instead, works alongside a human therapist. For example, pet-like robots, such as the seal Paro, nicely illustrate this point. Just as animal-assisted therapy includes a therapy animal work in conjunction with a human provider, pet-like robots can serve as a treatment partner or assistant. Second, robots can help to extend the service reach of providers by taking on some clinical tasks. Here, too, the robot does not replace any service providers; in order to be helpful, robots will need input from human therapists. However, one therapist may be able to serve twice as many clients (or more!) because some clinical activities are being done with a robot, which reduces the time burden on the human provider. For example, a provider may introduce a new clinical skill to a client and then have a robot serve as a partner for practicing that skill, leaving the therapist free for a portion of time that was previously occupied.

5. Summary and conclusion

In the U.S. and certainly worldwide, we are not meeting the treatment needs of people with mental health problems, resulting in incalculable costs in terms of human suffering and societal burden. A problem of this magnitude requires a number of and wide variety of solutions that build on the enormous gains that have been made in the context of traditional forms of psychosocial treatments and their delivery. SAR is a field ripe with innovation in which new developments are constantly expanding the limits of what robots can do and how they can be used to serve human interests. Consistent with this, robots are *already* being used – with encouraging clinical findings – in mental healthcare. We suggest that the applications of robots be expanded in mental healthcare in order to help address our current treatment crisis.

SAR can be integrated into treatment protocols in a variety of ways. At this time, a robot used along with human therapist is the primary way in which treatment has been implemented. However, potential applications of robots expand far beyond that of therapist assistant. These machines can provide therapeutic services in client homes, reaching individuals who are unable to receive treatment in traditional settings (e.g., those living in rural settings, individuals housebound because of physical impairments). At some point in the future, robots will likely be capable of assuming therapeutic activities previously completed by human mental health professionals. However, we are not suggesting that robots be used to replace or eliminate human therapists. Quite the opposite; we desperately need every available mental health professional to help address the huge unmet treatment demands facing society today. Instead, we are proposing that robots be used along with mental health professionals, providing them with the opportunity to expand their clinical reach to better serve people with mental health problems.

We know that SAR cannot singularly solve this problem and happily there is no need to assume that it could, does, or should. On the contrary, we recognize that there are real hurdles to address (e.g., physical design, user perceptions) as well as valid concerns related to ethics, safety, and costs. But, we also recognize that these are solvable problems and that the use of robotics can help those who receive no care and those whose care might be improved by some aid to help in everyday life, to deliver an intervention, to promote adherence to another type of intervention, or to provide some form of interaction.

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