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Social Robots for Health Applications

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Abstract—**Social robots are designed to interact with people in a manner that is consistent with human social psychology. They are a particularly intriguing technology in health domains due to their ability to engage people along social and emotional dimensions. In this paper, we highlight a number of interesting opportunities for social robots in healthcare related applications.**

I. Introduction

Social robots are designed to interact with people in a socio-emotional way during interpersonal interaction [1]. Researchers have found that if a robot communicates using the same sorts of non-verbal cues that people use, then people subconsciously interpret, form social judgments, and respond to robots much as they do when these cues are used by people [2]. For instance, researchers have shown in randomized controlled trials that people's social judgments of trustworthiness, liking, persuasiveness, engagement, and credibility toward a robot can be impacted by adjusting a robot's non-verbal behavior [e.g., 3-5].

Understanding this insight opens new possibilities for robots where its social attributes are a key part of its functionality that helps people achieve personal goals. Social robots (a.k.a. Socially Assistive Robots [6]) have been designed to leverage their social and affective attributes to sustain people's engagement as well as to motivate, coach, educate, facilitate communication, monitor performance, improve adherence to health regimen, and provide social support to people [7]. Possible indispensable applications, a.k.a *killer apps*, for social robots could be in health-related domains including eldercare, therapeutic interventions for children with autism, behavior change coaches in areas such as chronic disease management, health education, patient advocacy, or as a new kind of tele-medicine interface. In this short paper, we highlight three interaction categories for social robots and how they might be applied to health-related applications.

II. Societal Challenges and Opportunities

There are a number of societal trends that motivate the use of social robots in health applications in a wide variety of settings such as hospitals, clinics, living-in-place facilities and the home.

One significant trend is the global aging of society. Advances in medicine are increasing lifespan while a number of countries are also experiencing a reduction in birthrate. Demographic studies show that many countries have an increase in the percentage of elder citizens over the next few decades. Current projections estimate that by 2030 the United States will see an increase of 40%, Europe 50% and Japan 100%. The number of people over 80 years old will increase by 100% across all continents [8]. This shift to older societies will increase the prevalence of injuries, disorders and diseases, as well as a need for ongoing health education and care.

Compelling opportunities for social robots in the context of eldercare include their ability to educate, to facilitate elder's communication and social connection with others, and to assist with adherence to care regimen through social support. Interestingly, social robots have been found to not suffer from some of the "social baggage" that can be associated with even human care providers where patients may feel at risk of losing face. Studies focusing on elders (Figure 1) have shown that social robots (physical or virtual) are often perceived as being non-judgmental and ever patient in a way that reduces stress and fosters openness and willingness to disclose [9-11]. Social robots have the potential to augment human care providers in a way that can save costs while also yielding a highly satisfying and personalized patient experience.

Figure 1: A social robot's non-verbal cues can influence elder's willingness to self-disclose. See [9].

In the US, another significant trend is a growing shortage of health care professional in the face of growing demands of patients. This trend is exacerbated by rising number of patients suffering from chronic disease such as diabetes, obesity, heart disease, and asthma. Today an estimated 45% of Americans have at least one chronic disease [12]. People with chronic conditions are the most frequent users of health

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care in the United States. They account for 81% of hospital admissions, 91% of all prescriptions filled, and 76% of all physician visits [13]. Chronic diseases also account for the vast majority of health spending. In the United States, the total spending on public and private health care amounted to approximately $2 trillion during 2005 [14]. Of that amount, more than 75% went toward treatment of chronic disease [15]. By 2025, it is estimated that chronic diseases will affect 49% of the population [16]. Fortunately, many chronic diseases could be prevented, delayed, or alleviated through simple lifestyle changes. The U.S. Centers for Disease Control and Prevention (CDC) estimates that eliminating three risk factors such as poor diet, inactivity, and smoking in addition to consistent self-management and adherence to the prescribed care regimen would have a significant positive impact. The potential of social robots as affordable and scalable behavior change coaches that provide patients with a highly personalized, high-touch, and long-term decision-making support, education, and motivation is a tremendous opportunity for patients and care providers alike.

Another trend is the increasing rate of neuro-developmental and cognitive disorders in children. This includes attention deficit disorder, hyperactivity disorder, and autism spectrum disorder. The CDC estimates that current autism diagnosis rate in the US are 1 in 110 children, having quadrupled in the last 25 years [17]. This motivates the development of new technologies for improved screening and diagnosis, continual health assessment, and longitudinal intervention and therapy either in-home or in-clinic that is highly personalized and can continue to adapt to children's changing needs as they grow and develop.

Social robots have been demonstrated to be highly engaging and appealing for a wide range of children. Children often perceive social robots as something between a companion animal and a pal. This makes social robots an intriguing tool for play therapy where children can take safe risks to learn new skills and abilities. It also allows children to feel in a position of social empowerment, where the robot acts as a supportive subordinate. By doing so, social robots can engage children in a different social learning dynamic than with an adult -- having attributes of companion animal therapy, but where the robot can be programmed to engage a child in ways an animal cannot (e.g., [18]).

III. Social Medium

Social robots hold promise to transform current screen-based telecommunication to real world tele-interaction. It is intriguing to harness the physical and social embodiment of robots to enable people to interact much more richly with one another over distance. Many existing tele-presence robots are in effect a LCD computer screen on a mobile base where the remote operator's face and voice are streamed over the Internet along with navigation commands (e.g., see [19] where a physician can interact remotely with patients in hospitals). However, they can take the form of androids (human-looking robots), too [20].

Our prior work with a small tele-presense robot based on smart phone technology, called the *MeBot,* shows how physical and social co-presence mediated through a robot really does matter to people [21]. In randomized controlled trials, two people collaborated on a task involving the ranking of physical artifacts in their importance to solve a problem. The experimenter was in another room and used the *MeBot* to collaborate with the participant. We explored three conditions: screen-only, screen on a mobile base, and socially expressive robot where the robot had mobility and head and arm gestures capabilities (see Figure 2). In all three conditions the smart phone was used to stream the remote person's face and voice. We found that people rated the fully expressive robot the highest along dimensions of psychological empathy, engagement, liking, and desire to collaborate [21].

Fig. 2. The *MeBot* tele-presence robot. See [21].

There are a number of very interesting uses for social tele-presence robots in health related domains. Numerous research groups are exploring the use of tele-operated social robots as a therapeutic intervention to interact with children. For instance, *Keepon* is a small, yellow cartoonish robot that has been used as a therapeutic intervention for children with autism [22]. Anecdotal evidence has shown that the robot presents a simplified social stimulus (as compared to a human face) that is very engaging to children on the ASD spectrum. In some cases, these children exhibit social skills and behaviors that are difficult to evoke when interacting with people.

In pediatrics, we have had interest by doctors in using our teddy bear tele-presence robot, called the *Huggable*, as a way to engage children in hospitals in play therapy. Alternatively, this sort of technology may be a way for remote family and friends "jack into" robots like the *Huggable* to visit a sick child in a hospital through a physically comforting form factor [25].

With respect to eldercare applications, a recent paper [23] found that seniors are interested in using a social tele-presence robot to allow them to get out of the house and interact with people to avoid social isolation [23-24].

IV. Social Agent

Social robots can function autonomously as well -- to be social agents that collaborate with people as partners and build a social rapport. This class of social robot holds promise to sustain its user in a highly personalized, adaptive, long-term relationship through social and emotional engagement – in the spirit of a technological "Jiminy Cricket" that provides the right message, at the right time, in the right way to gently nudge its user to make smarter decisions. In general, the ability of these social robots to serve as personal coaches for people holds the potential to engage patients more consistently and to keep them motivated to adhere to their health care or therapeutic regimen. For instance, robot coaches in the context of physical rehabilitation have been developed to monitor performance and provide feedback [26].

As a behavior change coach, for instance, such robots can educate, motivate, provide feedback, help track behavior and set goals. To explore this, we developed a weight management robot coach, called *Autom*, that was designed to help people sustain engagement in a diet and exercise program [27].

The robot's social properties enabled it to build a successful working alliance with people -- to motivate its user to stay engaged and help him/her set goals and track progress toward those goals. The robot did this through engaging its user in a dialog modeled after behavior coaching. The robot could also perform some simple non-verbal cues such as making eye contact when speaking to its user, or sharing attention with its user around information on its screen (see Figure 3, the commercialized version of the robot). The robot also had explicit relational behaviors that enabled it to track the stability of the working alliance over a longitudinal time period and repair the relationship if necessary.

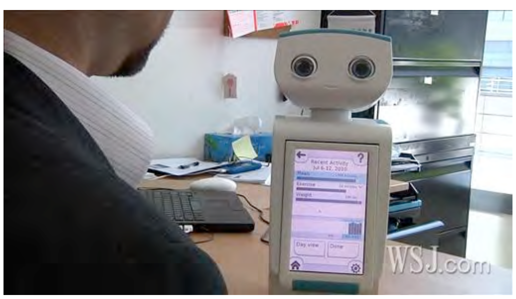

Fig. 3. The commercialized version of the Autom robot by Intuitive Automata, Inc.

We conducted a randomized controlled trial with three conditions: the *Autom* robot, a desktop computer running the same software (i.e., the advice and information gathering interaction was identical), and a pen-paper log. We deployed these interventions in people's homes in the Boston area over a 6-week period. At the conclusion of the study, we found that people's long-term engagement with the robot was significantly more (almost twice as much) as the other interventions. People also rated the robot significantly higher on measures of the quality of the working alliance including trust, credibility and emotional bond [28].

In related research, relational agents (often humanoid graphical agents) have been used to address a wide range of issues in healthcare – from long-term adherence, to educating patients about their condition, improving medication adherence, etc. [e.g., 29].

V. Social Networks

Finally, social robots are an interesting technology because they can straddle networks of technological gadgets as well as human social networks (Figure 4). Imagine a future version of a robot behavior change coach where the robot could help user to connect with his/her network of care professionals such as physicians, nurses, dieticians and exercise trainers -- so that the human care network can be better informed about the patients behavior and progress in order to provide better care and advice. The robot could serve as an advocate that extends the influence of the physician into the patient's life by helping the patient to adhere to his or her approved medical protocol while being always available to answer questions based on vetted educational materials. For those cases where the robot is unable to help, it could help connect the patient to the right care professional. The advantage for the care professional is that he or she is alleviated of the myriad of basic queries, giving him or her the time and attention to handle more complex queries that require more expertise. The advantage to the patient is that in many cases, their questions can receive immediate response through the robot to increase satisfication and to get access to the needed information when a decision is being made.

The robot could potentially serve as a node in its user's extended social network of friends and family to help

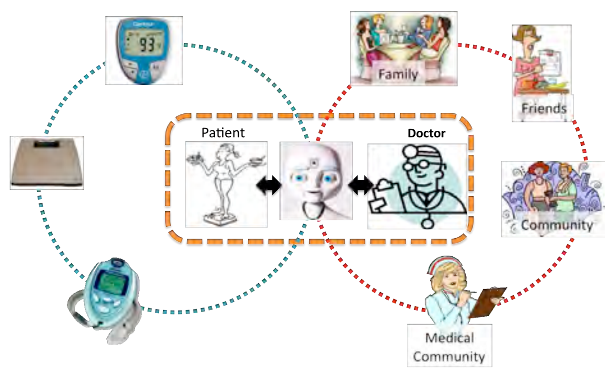

Fig. 4. Social robots can potentially help manage its users network of technological devices, as well as be a member of its user's human care network to help coordinate and inform the extended team.

connect him/her with others who share the same goals or medical condition -- potentially social robots could collaborate with their users to even help "nudge" the group to healthier behavior. The influence of social networks on health behavior and outcomes is well established [29]. As members of a health-related social network, social robots could run population-based analytics to identify population-level trends, learn what works for similar patients within the social network, share this information with its user, and help connect its user to others with similar conditions.

VI. Conclusion

In this short paper, we discussed three significant societal challenges (global aging, chronic disease, and children with neurodevelopmental disorders) where socially assistive robots have the potential to make positive impact. We highlighted three categories of interaction (medium, agent, network) where social robotic technologies could play an innovative role. What makes social robots particularly interesting over other technologies and approaches is the ability to engage people along social and emotional dimensions – whether that is to enable people to connect more richly and meaningfully over distance, to enable people to engage with one another in ways that might not be possible otherwise due to impairments or disabilities, or to engage patients in a always-available high-touch experience that is deeply personalized to their health needs and goals. . The promise of this technology is to augment human care professionals and networks, potentially serving a wide variety of roles, that are cost-effective and scale to a large population of diverse users over the long term.

There is much that still needs to be understood and evaluated, but the possibilities could be transformative. Below is a short list of some of the research challenges for socially assistive robots to realize their full promise:

1. How to design robots that can effectively communicate with and understand the intent, needs, and state of its user in the context of daily life?

2. How to design robots that can successfully engage its user over longitudinal time scales, beyond weeks to years and even a lifetime?

2. How to design robots that can continue to adapt to its user as he or she changes to provide a high-touch, personalized, and optimal healthcare experience?

3. How to design robots that engender appropriate trust and ethics?

4. How to design robots that successfully support a wide diversity of users across demographic differences or special needs?

5. How to design robots that support and integrate effectively into extended human care networks?

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