# Using Robots to Augment (not Replace) People in Therapeutic Settings

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***Abstract*—The use of robots to assist people presents a wide range of potential benefits. Specifically, therapeutic robots can provide assistance in companionship, education, and health-care domains. However, there are also costs and a potential for harm associated with this prospect. A significant risk of therapeutic robots is that the use of a robot could reduce the amount of human contact a user might receive. This is particularly troubling for populations at risk for social isolation, such as the elderly in nursing homes and children with developmental disorders, two of the most widely-studied populations for robot-assisted therapies. We examine the use of robots to augment rather than replace humans in therapeutic settings.**

## I. INTRODUCTION

Robots are being considered for therapeutic applications in several domains where they can interacts with users through non-contact assistive social interaction. This area of research, called socially assistive robotics (SAR) [2], presents opportunities for improving the standard of care in elder-care, post-stroke rehabilitation, and social interaction for children with autism spectrum disorders (ASD), among other domains of application. As SAR systems are being developed for therapeutic applications, we must consider both how the robot performs and how such uses will impact care. In the ideal case, users will receive a greater therapeutic benefit when a robot is involved and will also enjoy the interaction. In fact, a sign of success of such applications is the user's willingness to interact with the robot as much as possible, but such attachment could result in the user experiencing less social interaction with people.

## II. RELATED WORK

SAR is a very new field and thus few socially assistive robots are currently deployed in non-experimental therapeutic settings. This section overviews existing SAR systems designed for therapeutic purposes and typically evaluated for technology development and feasibility only. It is difficult, therefore, to evaluate such systems for therapeutic potential, yet the proposed systems do give a guide as to where current research is aimed. We emphasize the ASD and elder-care domains, as there is a high potential for social isolation, the focus topic of the paper, in those domains and with their user populations.

In ASD, play is the most common scenario for therapeutic child-robot interaction considered to date. Salter et al. [12] used a Roball, an actuated ball robot to examine proprioceptive interaction between human and robot. The robot could self-propel to move toward/away from a child as well as react to the child pushing, spinning or otherwise moving it. Robots have been used for rhythmic play such as dance using the Keepon robot [7] or mediated social interaction through drumming with the Kaspar robot [11]. Robots have also been used in much more clinical settings, to provoke joint attention using the DOMER [17] or mediated social interaction using Kaspar [10] and CosmoBot [8].

In elder-care settings, socially assistive robots have been used as companions and exercise coaches. A consumer robot, Paro [18], has been deployed in nursing homes to provide companionship. Paro is a stuffed animal robot in the shape of a baby seal, commonly deployed in the common areas of nursing homes to provide pet-like interaction for communities that do not allow pets. Similar work has employed pet robots such as NeCoRo [9], a cat-like robot, and Aibo [6], a dog-like robot for similar companionship tasks. Fasola and Matarić [1] present a system for providing exercise coaching for elders in nursing home settings through an imitation game. Both of these robots are used to address both the isolation and the inactivity that is typical of elders in nursing homes. Robots are also used in intelligent homes for the elderly [5].

Robot performance in a therapeutic context should ultimately be evaluated in terms of the longer-term effect on the target health outcomes, but at this stage of the field, immediately observable behavior effects are usually used as a metric. For example, if the robot is designed to support compliance with an exercise regimen, then compliance and performance during the exercise session is an obvious performance metric, along with safety. For a detailed examination of performance metrics by task domain, consult Tsui et al. [15].

As assistive technologies begin to flourish, so do their ethical appraisals. Among those are vocal critiques that typically garner more attention than supportive views. In particular, Turkle [16] presents technology as an isolating factor, and states that assistive robotics in particular can pose isolation problems with populations such as the elderly. The key aspect of this argument is that time spent interacting with robots will leave less opportunity for interacting with people, and that using robots for artificial social interaction is disingenuous and emotionally harmful to the user. Sharkey and Sharkey [13] present a similar argument for robots used with children. Both opinions applied to the current work with SAR can be seen as hyperbolic since most of this work is still in design and development stages and is specifically aimed at complementing rather than replacing human care, in order to address the lack of available, trained, and affordable human caregivers. Nonetheless, they bring up concerns worth considering and keeping in mind during SAR system design and use.

## III. DESCRIPTION OF ROBOT-AUGMENTED THERAPY

In this section we examine robot-augmented therapy systems designed specifically with the goal of enhancing human care, and discuss how they would be used and evaluated.

### A. *Social Role of the Robot*

While not directly replacing a human therapist, the role of the SAR system can take many forms, as follows:

- **Therapist/coach:** The robot acts as an expert or adviser, directly giving instruction and/or feedback. It is endowed with some authority over the therapeutic task. An example of this would be a post-stroke rehabilitation robot that encourages and coaches in-home rehabilitation exercises [14] or an exercise robot that motivates the user to stay physically active [1].
- **Mediator:** The robot facilitates communication or other types of interaction between the user and another individual (a therapist/coach, peer, etc.). This role is intended for contexts wherein the user would feel more comfortable interacting with a robot than with a person. The robot has some limited authority in this role. Autism intervention and therapy is the most obvious use for such robots [7], though other types of socialization may also be relevant, such as adapting to a new/foreign culture.
- **Partner/companion:** The robot here serves to mitigate isolation, loneliness, and depression. It has no authority as it acts neither as an expert or as an intermediary. In fact, the robot is not explicitly carrying out a therapeutic task, but its presence and interaction is itself intended as therapeutic. The robot's role is meant to be soothing and comforting, and in some contexts also encouraging of interaction with others (e.g., family and friends) [18]. Companion robots for the elderly are the most obvious example, but other domains are also relevant, such as anxiety, stress, and depression treatment. Objects are used in therapies such as the DIR/Floortime approach [19]. Examples, such as a jack-in-the-box, a bubble-blower, or a doll are used by a therapist to guide a therapeutic interaction. A robot companion can act in place of such an object, behaving in a social manner or otherwise used to provoke specific scenarios related to therapeutic goals [3].

Fig. 1. The humanoid robot used in the experiment (shown with an experimenter).

In practice, a robot may take on more than one of the above roles, concurrently or sequentially, as relevant for the given therapy context. There are also other social roles SAR systems may take, and most have not been explored yet.

It is important to note the role of people in each of the robot roles listed above. For the mediator or partner/companion roles, another individual is required for the therapeutic scenario to be established. In the case of a therapist/coach role, a co-present human therapist is not needed, but one is required in the planning and proscribing of the therapeutic regimen and in the evaluation of a user's progress. The requirement that a person be involved in the therapeutic scenario should allay concerns about social isolation.

## IV. METHODOLOGY EXAMPLE FROM ASD STUDIES

Children with ASD are prone to social isolation due to deficiencies in social skills. While it may seem counter-intuitive to use robots to socially interact with such children, anecdotal evidence shows that children with ASD interact socially with robots. Therefore, using a social robot with children with ASD could lead to increased social behavior, a benefit for therapeutic goals. However, children with ASD are also prone to fixated interests on objects, so such robots could also lead to human-robot interaction to the detriment of human-human interaction. Such behavior can, and should, be monitored, even outside of a clinical setting.

We are currently running a series of feasibility studies which examine autonomous robot behavior, and how a child reacts to such behavior. In these studies, we have a child interacting with a robot in a clinic setting. While we feel that teleoperated or puppeteered robots can have a beneficial role as part of larger therapeutic interventions for children with ASD, there are several possible confounds which arise with the use of puppeteered robots. For example, if a positive therapeutic effect was observed with the use of a puppeteered robot, was this effect due to the robot or instead to a proficient puppeteer? Can these puppeteering skills be taught? And, does this potentially reduce the total human social contact which the child might experience, since the robot would be standing between the therapist and child? Using an autonomous robot which would not require a person in full control could avoid some of these confounds.

Our experimental methodology for these studies focused on three goals:

1) To monitor both human-robot and human-human interaction which occurs during and experiment session. To this end, we always have a family member (usually a parent) present during the session, along with the participating child and the robot. We do this so that we can monitor any changes, both positive and negative, to human-human interactive behavior. The presence of the parent in these interaction provides us with an opportunity to observe how the robot can provoke and encourage, or might in fact discourage, both human-human and human-robot interaction.
2) To observe comparative reactions to different robot behavior, morphology, and function. For example, does a robot's contingency affect a child's response to the robot? If not, would a robot behaving randomly with no regard to appropriate social behavior provide a similar benefit? Does a humanoid robot evoke a different response to a less socially capable, and possibly less intimidating robot? Finally, what does a robot need to do in order to engage the child?
3) To collect and annotate social behavior of children with ASD as they socially interact with a robot. Ongoing work uses these collected data to model observed social behavior and to determine what appropriate responses would be.

To serve these goals, we equipped our experimental space with several eye-level cameras and microphones for audio and video recording. We also used an overhead camera (along with markers work by child, parent, and robot) to track the positions of the child, robot, and parent along with the orientation of the robot. These data were used for the autonomous social behavior used in the experiment as well as for the data collection for our ongoing modeling work. The robot was able to use these overhead data to navigate autonomously in addition to understanding rudimentary interaction behavior of the child (approaching the robot, moving away, staying still, or moving behind the robot). The robot could then respond to such cues with actions such as waving, nodding or shaking its head, moving toward or away from the child, and non-verbal vocalizations ("uh-huh", "awwww", "woo-hoo", among others). We instructed the parent participating in the experiment session to stand aside (giving them a chair in the corner of the room) unless their child involves them in the interaction (either by inviting the parent over, or engaging the parent socially in some other way).

Fig. 2. The humanoid robot used in the experiment (shown with an experimenter).

Following the experiments, the recorded data are analyzed by human coders, in order to create a ground truth of what social behavior occurred during the session. This serves the goal of studying the quantity and quality of resulting human-human and human-robot interaction. Additionally, this coding ser

Our first study [3] compared a bubble-blowing robot which blew bubbles contingent to the child's actions to one that blew bubbles randomly. We observed an increased amount interaction behavior on the part of the child toward the robot in the contingent condition than the random condition, matching our hypothesis. We also discovered that not only did the child interact with the parent when the robot was present, the child interacted with the parent more in the contingent condition. This demonstrates that the robot did not negatively impact interaction with a parent. A follow-up study [4] compared a humanoid robot with a non-robotic toy with similar functionality. Again, we observed an increased amount of social behavior with the robot condition than with the toy condition, matching our hypothesis, and an increase in the interaction between the child and parent was higher in the robot condition than the toy condition, demonstrating that interaction with a robot does not have to negatively impact social interaction with a parent. Both of these studies used a randomly assigned condition order along with an orientation period to counteract any effects due to novelty.

Both of these studies used a very small sample size ($n = 5$, $n = 8$), and cannot be considered conclusive results. However, they do suggest that we can observe changes in human-human interaction behavior between experimental conditions. Such changes can indicate whether or not the presence of a robot would have a net positive or negative effect on social interaction.

## V. SUMMARY AND ONGOING WORK

We described how the use of robots to augment humans in therapeutic settings rather than replace them may allay concerns of social isolation. This could benefit populations prone to social isolation, such as elders in nursing homes and children with ASD. Such an augmentation can lead to challenges of its own, such as how to assess the value of a robot added to a therapeutic regimen. Most of the roles used for therapeutic applications of SAR require a person to be in the scenario available to interact with a user. As such, we feel that this is an attractive model for addressing the needs of populations vulnerable to social isolation.

Ongoing work is focusing on enabling the recognition and exhibition of more complex human-robot interactive behavior using spatial features. We are using a spatio-temporal model of social behavior over distance-based features such as: distances between child and robot; child and parent; and child and wall can recognize positive vs. negative reactions to the robot. We are also examining how similar distance-based features can be used for autonomous robot behavior which conforms to such spatial models of social interaction between human and robot. Finally, we are exploring how spatial and temporal models of social interaction can be used to model social behavior for a turn-taking imitation game in order to provide intelligent feedback. The focus of this ongoing work is to enable autonomous behavior so that the robot can act as an effective augmentation for a human therapist in clinical settings with children with ASD.

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## REFERENCES

[1] J. Fasola and M. J. Matarić. Robot exercise instructor: A socially assistive robot system to monitor and encourage physical exercise for the elderly. In *IEEE International Symposium in Robot and Human Interactive Communication*, pages 416–421, Viareggio, Italy, Sep 2010.

[2] D. Feil-Seifer and M. Matarić. Defining socially assistive robotics. In *Proceedings of the International Conference on Rehabilitation Robotics*, pages 465–468, Chicago, Il, Jul 2005.

[3] D. J. Feil-Seifer and M. J. Matarić. Toward socially assistive robotics for augmenting interventions for children with autism spectrum disorders. In *11th International Symposium on Experimental Robotics 2008*, volume 54, pages 201–210, Athens, Greece, Jul 2008. Springer.

[4] D. J. Feil-Seifer, M. P. Black, E. Flores, A. B. S. Clair, E. K. Mower, C.-C. Lee, M. J. Matarić, S. Narayanan, C. Lajonchere, P. Mundy, and M. Williams. Development of socially assistive robots for children with autism spectrum disorders. Technical report, USC Interaction Lab Technical Report CRES-09-001, Los Angeles, CA, Oct 2009.

[5] J. Jung, J. Do, Y. Kim, K. Suh, D. Kim, and Z. Bien. Advanced robotic residence for the elderly/the handicapped : Realization and user evaluation. In *Proceedings of the International Conference on Rehabilitation Robotics*, pages 492–495, Chicago, Il, Jun-Jul 2005.

[6] M. Kanamori, M. Suzuki, and M. Tanaka. Maintenance and improvement of quality of life among elderly patients using a pet-type robot]. *Nippon Ronen Igakkai zasshi. Japanese journal of geriatrics*, 39(2):214, 2002.

[7] H. Kozima, Y. Yasuda, and C. Nakagawa. Social interaction facilitated by a minimally-designed robot: Finding from longitudinal therapeutic practices for autistic children. In *Proceedings of the International Conference on Robot and Human Interactive Communication*, pages 599–604, August 2007.

[8] C. Lathan, K. Boser, C. Safos, C. Frentz, and K. Powers. Using cosmo's learning system (CLS) with children with autism. In *Proceedings of the International Conference on Technology-Based Learning with Disabilities*, pages 37–47, Dayton, OH, July 2007.

[9] T. Nakashima, G. Fukutome, and N. Ishii. Healing Effects of Pet Robots at an Elderly-Care Facility. In *International Conference on Computer and Information Science*, pages 407–412. IEEE, 2010.

[10] B. Robins, K. Dautenhahn, and J. Dubowski. Robots as isolators or mediators for children with autism? A cautionary tale. In *Proc. Convention on Social Intelligent and Interaction in Animals, Robots and Agents*, pages 12–15, Hatfield, UK, 2005.

[11] B. Robins, K. Dautenhahn, R. te Boekhorst, and C. Nehaniv. Behaviour delay and robot expressiveness in child-robot interactions: a user study on interaction kinesics. In *Proceedings of the International Conference on Human-Robot Interaction (HRI)*, pages 17–24, Amsterdam, The Netherlands, March 2008. ACM New York, NY, USA.

[12] T. Salter, F. Michaud, D. Létourneau, D. Lee, and I. Werry. Using proprioceptive sensors for categorizing interactions. In *Proc. Human-Robot Interaction*, Washington, D.C., March 2007.

[13] N. Sharkey and A. Sharkey. The crying shame of robot nannies: an ethical appraisal. *Interaction Studies: Social Behaviour and Communication in Biological and Artificial Systems*, 11, 2010.

[14] A. Tapus, C. Tapus, and M. J. Matarić. User-robot personality matching and assistive robot behavior adaptation for post-stroke rehabilitation therapy. *Intelligent Service*

*Robotics: Multidisciplinary Collaboration for Socially Assistive Robotics*, 1:169–183, Apr 2008.

[15] K. Tsui, D. J. Feil-Seifer, H. Yanco, and M. J. Matarić. Methods for evaluating assistive robotic technology. In R. Madhavan, E. Tunstel, , and E. Messina, editors, *Performance Evaluation and Benchmarking of Intelligent Systems*, chapter 3, pages 41–66. Springer, 2009.

[16] S. Turkle. *Alone Together: Why We Expect More from Technology and Less from Each Other*. Basic Books, 2010.

[17] M. Villano, C. Crowell, K. Wier, K. Tang, B. Thomas, N. Shea, L. Schmitt, and J. Diehl. DOMER: a wizard of oz interface for using interactive robots to scaffold social skills for children with autism spectrum disorders. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 279–280, Lausanne, Switzerland, Mar 2011. ACM.

[18] K. Wada, T. Shibata, T. Saito, K. Sakamoto, and K. Tanie. Psychological and Social Effects of One Year Robot Assisted Activity on Elderly People at a Health Service Facility for the Aged. In *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*, pages 2785–2790, Taipei, Taiwan, September 2003.

[19] S. Wieder, S. Greenspan, and B. Kalmanson. Autism Assessment and Intervention: The Developmental Individual-Difference, Relationship-Based (DIR [R])/Floortime [TM] Model. *Zero to Three*, 28(4): 7, 2008.