

Robots in clinical settings for therapy of individuals with autism: Are we there yet?

Momotaz Begum and Holly Yanco
Department of Computer Science
University of Massachusetts Lowell
Email: {mbegum,holly}@cs.uml.edu

Richard Serna
Department of Psychology
University of Massachusetts Lowell
Email: Richard_Serna@uml.edu

David Kontak
Crotched Mountain
Rehabilitation Center
Email: David.Kontak@crotchedmountain.org

Abstract—The huge potential that robots offer in the therapy of individuals with autism spectrum disorders (ASD) is well known in the robotics community, thanks to over a decade of research involving individuals with ASD and different types of robots. The clinical community, however, is not equally aware or convinced about the efficacy of robots in ASD therapy, mostly because a vast majority of research in this direction does not maintain necessary clinical standards. The time has come to gather the pieces of learned knowledge and direct the research in a direction where robots can prove their efficacy and can actually be used in the therapy of individuals with ASD. In this paper we introduce our ongoing study to investigate the feasibility of using a robot to teach new skills to individuals with ASD. We also report a set of design criteria necessary to prove the efficacy of a robot for ASD therapy in clinical settings.

I. INTRODUCTION

Mounting anecdotal evidence collected through numerous studies have established the fact that many individuals with Autism Spectrum Disorders (ASD) can connect noticeably better with robots than with people. Two recent surveys covering almost all of such studies involving different kinds of robots and individuals with ASD (IwASDs) in varying contexts are presented in [1], [2]. The majority of these studies report that many IwASDs show some increase in joint attention, eye-contact, verbal activity, social engagement, etc. in the presence of a robot. These evidences suggest that IwASDs may have cognitive and/or biological bias toward robots over the human [3]. A number of recent studies show neurobiological evidences in favor of such a claim. For example, an fMRI study suggests that adults with ASD may perceive a humanoid robot as a social interaction partner the same way a typically developing adult perceives a fellow human being [4]. Another study shows that robotic movements elicit visuomotor priming in children with ASD (visual priming is a precondition for automatic imitation, a behavior generally absent in children with ASD) [5]. Despite showing promise, none of these reports proves the efficacy of a robot in therapeutic applications in clinical settings. The necessity of robotics research in this direction to meet the clinical standard and the inadequacy of current research to prove the efficacy of robots in ASD therapy has been discussed thoroughly in [6], [3], [7]. Recently, a number of systematic reviews and meta-analyses of the technology-based interventions for IwASDs have concluded that the robot based studies with IwASDs reported before

December 2011 fail to meet a set of criteria commonly observed to assess the outcome of an ASD therapy [8], [9]. We conducted a survey of literature reported until January 2014 and observed that recent robotics research (e.g. [10], [11], [12], [13]) has started to focus on aspects in research design required to prove the efficacy of robot in ASD therapy, e.g. use of control(comparison)-treatment group, reporting participants' diagnostic condition, use of established outcome measures, etc. We, however, identified only one study (reported in [14]) which performed assessment of the therapy in a standard manner.

Although the whole purpose of research in this direction is to design robots which can either replace or augment people in the therapy of IwASDs, to the best of our knowledge, no research shows enough clinical evidence to claim that teaching a new skill to IwASDs is possible through robot-based or robot-augmented therapy. In this abstract we describe our ongoing research which aims to contribute in that sector by investigating the feasibility of a robot-mediated therapy to teach a new skill to IwASDs.

II. PROVING EFFICACY OF ROBOTS IN ASD THERAPY: NECESSARY ASPECTS OF RESEARCH DESIGN

Recent literature suggests that group-based design, although considered as the gold-standard in clinical research, might not be the only choice to prove the efficacy of ASD therapies [15], [16]. Single-subject research design has unique value in autism research [17]. Clinical literature on ASD therapy discuss about the criteria that should be observed in order to prove effectiveness of a new therapeutic method [18], [19], [20]. This paper summarizes the criteria, applicable to single-subject design of robot-based studies with IwASDs, that should be considered in order to prove the efficacy of robots in ASD therapy.

- Goal of therapy: Every ASD therapy generally aims to teach a new behavior or eliminate a problem behavior and the effect is expected to last long, if not forever [21]. Accordingly, a robot-based therapy needs to identify in the first place that what it wants to achieve. The skill or behavior to be taught through the therapy largely dictates the robot's hardware and software design.
- Participants' characteristics: Every participant's age, gender, diagnostic conditions (expressed using standard di-

agnostic instruments) should be reported [18]. This facilitates to identify any correlation, if exist, between the demographics of participants and efficacy of robots.

- Baseline measurement: It is extremely important to assess the participants, prior to the study, with respect to the goal of the therapy. It plays a key role to assess the role of robot in the therapy. Standard measurement tools should be used for baseline measurement [19].
- Method of therapy: A wide range of evidence-based interventions are well known to produce positive therapeutic outcomes in IwASDs [19]. A robot-based therapy should also be designed following any (or combination) of the standard approaches for ASD therapy. The choice of an approach also determines the design of a robot's software.
- Progress monitoring: Progress monitoring is pivotal to assess the success of any ASD therapy [20]. This is also a core component to assess the efficacy of robot as a new therapeutic tool. Unfortunately, almost all of the existing robot-based studies fail to accommodate a progress monitoring phase. Standard measurements should be followed to assess the progress.
- Programming for generalization: Programming for generalization is a pressing need for robot-based therapies. A known concern about robot-mediated therapy is that IwASDs may fail to execute a skill learned through robots with the human [6].

III. A ROBOT-MEDIATED THERAPY DESIGN FOR ASD

We are currently conducting a study at Crotched Mountain Rehabilitation Center (CMRC), NH, USA to investigate the feasibility of teaching a skill to IwASDs through a robot. The detailed results from the study will be available in future publications. This section describes the way our study has been designed to prove the efficacy of a robot in clinical settings.

- Goal of therapy: The goal of the study is to teach a basic skill of social greetings to a group of IwASDs. Based on a discussion with the clinicians at CMRC, lack of social greetings has been identified as a common social deficit among the IwASDs served by the CMRC. Accordingly, a therapy is designed to teach the skill of saying 'Hi' or 'Hello' voluntarily or in response to a social greeting. The study is of multiple baseline type and follows a reversal design.
- Participants' characteristics: Inclusion criteria for the study are: 1. Individuals diagnosed with any form of ASD and 2. An individual with ASD who, according to his/her therapists, have one or more of the pre-requisite abilities to initiate/respond to social greetings but does not generally do so. The ability to imitate, verbal ability, the physical ability of waving hands, etc. are considered a few of the pre-requisites to teach the skill of initiating/responding to social greetings. The IwASDs served at CMRC are within the age group 8 – 20 years and are low-functioning ($IQ < 80$).
- Baseline measurement: Prior to the study, the frequency at which the participating IwASDs respond to an external

social greeting (initiated by a familiar and an unfamiliar person) or initiate a greeting when they see a familiar person is measured. Baseline measurement continues until a stable pattern is observed with a minimum of three measurement points.

- Method of therapy: The therapy is designed following the basic structure of applied behavior analysis (ABA), a widely accepted method for behavioral intervention [22]. The therapy is delivered through a humanoid robot named 'Blue' (Aldebaran Robotics Inc.) (Fig. 1(a)). A user-interface is designed for the therapists (or the wizard, for a Wizard-of-Oz control) following the basic principles of ABA (i.e. Discriminative stimulus (S^D) \implies Prompts (P) (if necessary) \implies Reinforcement/Reward (R)). Prompts are delivered according to a delayed cue schedule. Two different types of prompts are used to evoke the correct behavior in the participant. The first type of prompt is modeling (i.e. the robot models the target behavior with the caregiver of the participant) and the second type is verbal instruction (i.e., the robot directly informs the participant the correct way to respond to the discriminative stimulus). Discriminative stimulus and prompts are chosen to be simple and easily understandable by the target population. An example of discriminative stimulus is the robot saying "Hi [name of the participant]" as soon as the participant enters the therapy room. Similarly, an example of verbal instruction prompt is the robot saying "[name of the participant], say 'Hi' to me". The duration between the appearance of S^D and P is increased gradually if the participant starts to show positive responses to the therapy, until the P is no longer necessary. The basic form of reinforcement/reward is the robot 'appreciating' the IwASD for his/her correct behavior. Fig. 1(b) shows the user-interface.
- Progress monitoring: After the therapy is stopped, the frequency at which participants respond to social greetings will be measured over one week. A consistent success of 90% or above in responding to greetings will be considered as an improvement of the behavior.
- Programming for generalization: If a participant makes considerable progress, we expect to take the therapy outside of a "within room" scenario to facilitate generalization. For example, social interactions in open spaces will be designed by placing the robot in a hallway/library where the robot will deliver the greeting command (and the corresponding therapy, if needed) to a participant as (s)he passes-by the robot. This will help to generalize the skill in regular day-to-day life settings. Gradually the robot will be removed from the scene in order to help the participant to practice the learned skill even without the presence of the robot.

IV. CONCLUSION

This abstract discusses how to prove the efficacy of robots for ASD therapy in clinical settings. It reports a number of aspects of single subject research design which should

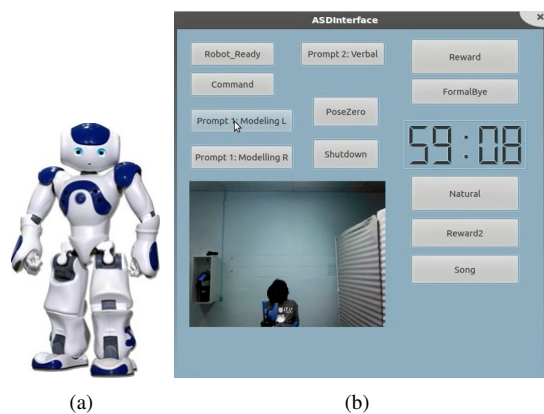


Fig. 1. (a) The humanoid robot 'Blue' (Aldebaran Robotics Inc.) (b) The robot-control interface. The face of the participant is made blurred to comply with the IRB protocol

be considered while designing robot-based studies on ASD therapy. Finally, the abstract briefly describes our ongoing study to investigate the feasibility of teaching a skill to a group of low-functioning ASD through a humanoid robot.

REFERENCES

- [1] J.-J. Cabibihan, H. Javed, M. A. Jr., and S. M. Aljunied, "Why robots? a survey on the roles and benefits of social robots in the therapy of children with autism," *International Journal of Social Robotics*, vol. 5, pp. 593–618, 2013.
- [2] B. Scassellati, H. Admoni, and M. Mataric, "Robots for use in autism research," *Annual Review of Biomedical Engineering*, vol. 14, pp. 275–294, 2012.
- [3] J. Diehl, C. R. Crowell, M. Villano, K. Wier, K. Tang, and L. Riek, *Clinical Applications of Robots in Autism Spectrum Disorder Diagnosis and Treatment (in A comprehensive guide to autism)*. Springer Publishing, 2014, pp. 411–422.
- [4] T. Chaminade, D. D. Fonseca, D. Rosset, E. Lutscher, G. Cheng, and C. Deruelle, "fMRI study of young adults with autism interacting with a humanoid robot," in *Proc. IEEE International Symposium on Robot and Human Interactive Communications (RO-MAN)*, 2012, pp. 380–385.
- [5] A. Pierno, M. Mari, D. Lusher, and U. Castiello, "Robotic movement elicits visuomotor priming in children with autism," *Neuropsychologia*, vol. 31, pp. 448–454, 2008.
- [6] J. Diehl, L. Schmitt, C. R. Crowell, and M. Villano, "The clinical use of robots for children with autism spectrum disorders: A critical review," *Research in Autism Spectrum Disorders*, vol. 6, pp. 249–262, 2012.
- [7] E. S. Kim and B. Scassellati, "Bridging the research gap: Making hri useful to individuals with autism," *Journal of Human Robot Interaction*, vol. 1, p. 2654, 2012.
- [8] O. Grzynszpan, P. L. Weiss, F. Perez-Diaz, and E. Gal, "Innovative technology-based interventions for autism spectrum disorders: A meta-analysis," *Autism*, vol. 18, pp. 346–361, 2014.
- [9] F. D. D. Reed, S. R. Hyman, and J. M. Hirst, "Applications of technology to teach social skills to children with autism," *Developmental Neurorehabilitation*, vol. 5, pp. 1003–1010, 2011.
- [10] B. Vanderborght, R. Simut, J. Saldien, C. Pop, A. S. Rusu, S. P. abdDirk Lefeber, and D. O. David, "Using the social robot probo as a social story telling agent for children with asd," *Interaction Studies*, vol. 13, pp. 348 – 372, 2012.
- [11] E. Bekele, J. A. Crittendon, A. Swanson, N. Sarkar, and Z. E. Warren, "Pilot clinical application of an adaptive robotic system for young children with autism," *Autism*, vol. 18, pp. 598–608, 2014.
- [12] A. Tapus, A. Peca, A. Aly, C. Pop, L. Jisa, S. Pintea, A. S. Rusu, and D. O. David, "Children with autism social engagement in interaction with nao, an imitative robot," *Interaction Studies*, vol. 13, p. 315347, 2012.
- [13] C. A. Pop, R. E. Simut, S. Pintea, J. Saldien, A. S. Rusu, J. Vanderfaillie, D. O. David, D. Lefeber, and B. Vanderborght, "Social robots vs. computer display: Does the way social stories are delivered make a difference for their effectiveness on asd children?" *Journal of Educational Computing Research*, vol. 49, pp. 381–401, 2013.
- [14] B. Huskens, R. Verschuur, J. Gillesen, R. Didden, and E. Barakova, "Promoting question-asking in school-aged children with autism spectrum disorders: effectiveness of a robot intervention compared to a human-trainer intervention," *Developmental Neurorehabilitation*, vol. 16, pp. 345–356, 2013.
- [15] R. H. Horner, E. G. Carr, J. Halle, G. McGee, S. Odom, and M. Wolery, "The use of single-subject research to identify evidence-based practice in special education," *Exceptional Children*, vol. 71, pp. 165 – 179, 2005.
- [16] A. E. Kazdin, "Evidence-based treatment and practice: New opportunities to bridge clinical research and practice, enhance the knowledge base, and improve patient care," *American Psychologist*, vol. 63, pp. 146– 159, 2008.
- [17] G. Mesibov and V. Shea, "Evidence-based practices and autism," *Autism*, vol. 15, pp. 114–133, 2011.
- [18] B. Reichow, F. R. Volkmar, and D. V. Cicchetti, "Method for evaluating and determining evidence-based practices in autism," *Journal of Autism and Developmental Disorders*, vol. 38, pp. 1311–1319, 2008.
- [19] "Autism spectrum disorders: Guide to evidence based interventions," Missouri Autism Guidelines Initiative, Tech. Rep., 2012.
- [20] "Best practices for designing and delivering effective programs for individuals with autistic spectrum disorders," California Departments of Education and Developmental Services, Tech. Rep., 1997.
- [21] Z. Warren, J. Veenstra-VanderWeele, W. Stone, J. L. Bruzek, A. S. Nahmias, J. H. Foss-Feig, R. N. Jerome, and S. K. et al., "Therapies for children with autism spectrum disorders," Vanderbilt Evidence-based Practice Center: Agency for Healthcare Research and Quality (US), Tech. Rep. 11-EHC029-EF, Apr. 2011.
- [22] J. Virus-Ortega, "Applied behavior analytic intervention for autism in early childhood: meta-analysis, meta-regression and dose-response meta-analysis of multiple outcomes," *Clinical Psychology Review*, vol. 30, pp. 387–399, 2010.