Brief review of robotics in low-functioning autism therapy

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Brief Review of Robotics in Low-Functioning Autism Therapy

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Abstract. In the last decade, numerous research studies showed that robots can be suitable assistants in the care and treatment of children with Autism Spectrum Disorder (ASD). Still, more investigation is required to fully assess the introduction of robotics assistants, as the majority of the studies was limited in numbers of participants and scope, e.g. by considering stand-alone interventions, High Functioning Autism (HFA) individuals only, and provided limited objective results, i.e. usually the success is evaluated via qualitative analysis of videos recorded during the interaction.
In this paper, we present a brief review of the experience on integrating robot-assisted therapy also in the treatment of children with Low-Functioning Autism (LFA) which is the most common case (>70%). Studies described here investigated the integration of a robot-assisted intervention in the training, and the results encourage the use of a robotic assistant also in LFA. Based on this experience, we suggest that current robotic technology is still at an experimental stage and require to actively involve all stakeholders in design of new robotic systems that can successfully account for the peculiar characteristics of ASD individuals.

Keywords: Socially Assistive Robotics, Low-Functioning Autism, Intellectual disability, Autism therapy.

1 Introduction

Intellectual Disability (ID) and Autism Spectrum Disorders (ASD) are main neuro-developmental disorders with a frequency of 2-3% in western countries [1]. ASD is a

general term for a "spectrum" of behavioural phenotypes including deficits in communication and social interaction, and restricted and repetitive behaviours, interests and activities [2, 3], and it usually manifests in the first three years of the developmental period. ASD can often comorbid with some level of ID [4], in fact it has been reported that 70% of children with ASD have an Intellectual Quotient (IQ) below 70 [5], which encompasses four ID levels: "mild", "moderate", "severe" and "profound", characterized by significant limitations in both intellectual function and in adaptive behavior before the age of 18 [5]. This condition is often referred to as Low-Functioning Autism (LFA - IQ lower than 70), in contrast to High Functioning Autism (HFA - IQ higher than 70) [6]. Specifically, LFA individuals are characterised by significant limitations in both intellectual functions and adaptive behaviour i.e. in problems with reasoning, learning or problem-solving as well as communication and social skills difficulties [7]. This mixture of conditions requires therapeutic interventions more challenging and, therefore, technological aids could be useful to help therapeutic work aiming at obtaining an adequate quality of life [8].

2 Socially Assistive Robotics and Low-Functioning Autism

Considering the complexity of LFA it is appropriate to use a multi-modal therapeutic intervention that can be adapted to the individual's needs to obtain the best benefits from the treatment [9]. Researchers have shown that some individuals with ASD prefer robots to humans and that robots generate a high degree of motivation and engagement in individuals who are unlikely or unwilling to interact socially with human therapists [10].

It has been shown that the persons with ASD are attracted to mechanical and electronic devices [11]. Consequently, it would seem that a robotic device could be a useful tool when a therapist is trying to help, teach, communicate, or interact with persons with this neurodevelopmental disorder. Also, in children with ASD, the complexity of emotions expressed by persons may be the reason why they experience difficulty understanding gestures or facial expressions, resulting with them shying away from friends and the world around them [12]. The robotics, especially humanoid robots, in children with ASD can be used to invoke interest and engagement [13] or as a diagnostic tool [14], that should always be included in the therapeutic plans [15]. Duquette et al. [16] showed improvements in affective behavior and attention-sharing with co-participating human partners during an imitation task solicited by a robotic doll. Furthermore, the simplified social behaviour of robots may be especially beneficial for individuals with ASD who face difficulty in perceiving and expressing emotions, understanding gestures or facial expressions, because practicing communication can be less intimidating with a robot than with a human [17, 18].

2.1 Applications of robotics in the treatment of children with LFA

Current social projects increasingly show robots as an instrument for the enhancement of the care already in place, rather than a replacement of the human caregiver, showing numerous benefits of robot assistants in the treatment of children with LFA

[19–21]. The aim of using robots in clinical practice is to reduce the therapists' workload by allowing the robot to take care of some parts of the intervention. This includes monitoring and recording the behaviour of the children, engaging them when they are disinterested, and adapting the appropriate levels of treatment [21] while allowing the therapist to plan the required intervention for every child [22].

However, as most of the studies focused on ASD individuals without ID ignored to analyse comorbidities, using this approach we could possibly address one of the current gaps between scientific research and clinical application [23]. While qualitative analysis is frequently considered in previous research (e.g. via analysis of video-recorded human-robot interaction), the quantitative analysis that can be made through the use of standardized psycho-diagnostic tools is often missing [23, 24].

In a recent study with five children with LFA the NAO robot was able to attract the children's attention, keep each child engaged during interaction and hence give positive impact to the children's communication behavior. Specifically, children with ASD and moderately impaired IQ (from 40 to 54) are receptive to robot-based intervention [12].

A study with three children with ASD and ID suggests that the robot can be effectively integrated in the ASD therapies currently used in the treatment. The results encourages the development of effective protocols in which the robot acts as a mediator between the child with ASD and humans and suggests some research avenues for focus in the future [25].

In a recent study with six male children with LFA (Fig.1), the robot-assisted therapy was included in the TEACCH (*Treatment and Education of Autistic and related Communication handicapped CHildren*) method among the standard activities, which are identified via a specific visual schedule [15]. The TEACCH approach is based upon cognitive-behavioral and social learning principles and aims to design environments that meet the unique learning style needs and preferences of the ASD population [26].

Fig. 1. Example of session with the NAO robot in LFA.

Research suggests that children with LFA and moderately impaired intelligence show good response to robot-based intervention [12]. However, while other studies with children with LFA "mild", "moderate", and "severe" levels confirm a~~n~~ significantly increased imitative level of the children while acquired the capability to perform new tasks, this does not happen with "profound" level of ID in LFA. In this level, although the participants did not learn any tasks and show a modest (5%) increase in the gross motor imitation of the robot. In this regard, their behavior with the robot was comparable to that performed with other human beings [15].

3 Conclusion

Clinical studies show that the robotic-assisted therapy can be successfully integrated into the standard treatment of children with LFA when the interaction is adapted to the specific individual level. Results confirm that the robotic-assisted therapy can be successfully integrated into the standard treatment of children with LFA.

Indeed, various studies suggest that care and treatment should be tailored to the needs of the patient. It is well known that, with the same diagnosis, each condition is unique and therefore should be treated in a personalized way. The principles of rehabilitation indicate how important it is for the therapists to consider the patient's strengths and weaknesses to achieve the best results in therapy [9]. Experimental results indicate that the personalization of intervention can significantly improve the utility of an educational or assistive human-robot interaction [27].

In conclusion, children with LFA are often difficult to treat because they need constant support to carry out usual activities [28], and current robotic technology is still at an experimental stage and may require complex systems to be deployed [29]. Therefore, explorative studies of new therapeutic approaches involving robotics are generally focusing on a small number of cases easier to manage, e.g. without comorbidities (see [30] for a survey). These limitations have generated doubts and scepticism among the practitioners about the actual applicability of the robotic-assisted therapy in the standard treatment [19, 31]. The research findings based on quantitative assessment and monitoring are crucial to establish a solid ground for the utilization of the humanoid robot as a mediator with the caregiver, also in the treatment of children with LFA.

References

1. Bourke, J., De Klerk, N., Smith, T., Leonard, H.: Population-based prevalence of intellectual disability and autism spectrum disorders in Western Australia. Medicine (United States). 95, 1–8 (2016). https://doi.org/10.1097/MD.0000000000003737.
2. Oeseburg, B., Dijkstra, G.J., Groothoff, J.W., Reijneveld, S.A., Jansen, D.E.M.C.: Prevalence of chronic health conditions in children with intellectual disability: a systematic literature review. Intellectual and developmental disabilities. 49, 59–85 (2011).
3. Schwartz, C.E., Neri, G.: Autism and intellectual disability: two sides of the same coin. In: American Journal of Medical Genetics Part C: Seminars in Medical Genetics. pp. 89–90. Wiley Online Library (2012).
4. Underwood, L., McCarthy, J., Tsakanikos, E.: Mental health of adults with autism spectrum disorders and intellectual disability. Current Opinion in Psychiatry. 23, 421–426 (2010).
5. Ropers, H.H.: Genetics of early onset cognitive impairment. Annual review of genomics and human genetics. 11, 161–187 (2010).
6. de Giambattista, C., Ventura, P., Trerotoli, P., Margari, M., Palumbi, R., Margari, L.:

Subtyping the autism spectrum disorder: comparison of children with high functioning autism and Asperger syndrome. Journal of autism and developmental disorders. 49, 138–150 (2019).
7. American Psychiatric Association: DSM 5. (2013).
8. Goldsmith, T.R., LeBlanc, L.A.: Use of technology in interventions for children with autism. Journal of Early and Intensive Behavior Intervention. 1, 166 (2004).
9. Dawson, G., Rogers, S., Munson, J., Smith, M., Winter, J., Greenson, J., Donaldson, A., Varley, J.: Randomized, controlled trial of an intervention for toddlers with autism: the Early Start Denver Model. Pediatrics. 125, e17–e23 (2010).
10. Rabbitt, S.M., Kazdin, A.E., Scassellati, B.: Integrating Socially Assistive Robotics into Mental Healthcare Interventions: Applications and Recommendations for Expanded Use. Clinical Psychology Review. 35, 35–46 (2015). https://doi.org/10.1016/j.cpr.2014.07.001.
11. Robins, B., Dautenhahn, K.: Interacting with robots: can we encourage social interaction skills in children with autism? ACM SIGACCESS Accessibility and Computing. 6 (2004). https://doi.org/10.1145/1055680.1055682.
12. Shamsuddin, S., Yussof, H., Ismail, L.I., Mohamed, S., Hanapiah, F.A., Zahari, N.I.: Humanoid Robot NAO interacting with autistic children of moderately impaired intelligence to augment communication skills. Procedia Engineering. 41, 1533–1538 (2012).
13. Robins, B., Dickerson, P., Stribling, P., Dautenhahn, K.: Robot-mediated joint attention in children with autism: A case study in robot-human interaction. Interaction studies. 5, 161–198 (2004).
14. Scassellati, B.: How social robots will help us to diagnose , treat , and understand autism. Robotics research. 552–563 (2007). https://doi.org/10.1007/978-3-540-48113-3_47.
15. Conti, D., Trubia, G., Buono, S., Di Nuovo, S., Di Nuovo, A.: Evaluation of a Robot-Assisted Therapy for Children with Autism and Intellectual Disability. In: Lecture notes in computer science - Towards Autonomous Robotic Systems, Giuliani M., Assaf T. e Giannaccini M. (eds). pp. 405–415. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-96728-8_34.
16. Duquette, A., Michaud, F., Mercier, H.: Exploring the use of a mobile robot as an imitation agent with children with low-functioning autism. Autonomous Robots. 24, 147–157 (2008). https://doi.org/10.1007/s10514-007-9056-5.
17. Alemi, M., Meghdari, A., Basiri, N.M., Taheri, A.: The effect of applying humanoid robots as teacher assistants to help iranian autistic pupils learn english as a foreign language. In: International Conference on Social Robotics. pp. 1–10. Springer (2015).
18. Conti, D., Trubia, G., Buono, S., Di Nuovo, S., Di Nuovo, A.: Affect Recognition in Autism: a single case study on integrating a humanoid robot in a standard therapy. QWERTY. 14, 66–87 (2019).
19. Conti, D., Di Nuovo, S., Buono, S., Di Nuovo, A.: Robots in education and care of children with developmental disabilities: a study on acceptance by experienced and future professionals. International Journal of Social Robotics. 9, 51–62 (2017). https://doi.org/10.1007/s12369-016-0359-6.
20. Robins, B., Dautenhahn, K., Ferrari, E., Kronreif, G., Prazak-Aram, B., Marti, P., Iacono, I., Gelderblom, G.J., Bernd, T., Caprino, F., Laudanna, E.: Scenarios of robot-

assisted play for children with cognitive and physical disabilities. Interaction Studies. 13, 189–234 (2012). https://doi.org/10.1075/is.13.2.03rob.

21. Conti, D., Trubia, G., Buono, S., Nuovo, S. Di, Nuovo, A. Di: Social robots to support practitioners in the education and clinical care of children : The CARER-AID project. Life Span and Disability. 1, 17–30 (2020).
22. Esteban, P.G., Baxter, P., Belpaeme, T., Billing, E., Cai, H., Cao, H.-L., Coeckelbergh, M., Costescu, C., David, D., De Beir, A.: How to build a supervised autonomous system for robot-enhanced therapy for children with autism spectrum disorder. Paladyn, Journal of Behavioral Robotics. 8, 18–38 (2017).
23. Diehl, J.J., Schmitt, L.M., Villano, M., Crowell, C.R.: The Clinical Use of Robots for Individuals with Autism Spectrum Disorders: A Critical Review. Research in autism spectrum disorders. 6, 249–262 (2012).
24. Kim, E., Paul, R., Shic, F., Scassellati, B.: Bridging the Research Gap: Making HRI Useful to Individuals with Autism, (2012). https://doi.org/10.5898/JHRI.1.1.Kim.
25. Conti, D., Di Nuovo, S., Buono, S., Trubia, G., Di Nuovo, A.: Use of Robotics to Stimulate Imitation in Children with Autism Spectrum Disorder: A Pilot Study in a Clinical Setting. In: Proceedings of the 24th IEEE International Symposium on Robot and Human Interactive Communication, ROMAN. pp. 1–6 (2015). https://doi.org/10.1109/ROMAN.2015.7333589.
26. Mesibov, G.B., Shea, V.: The TEACCH program in the era of evidence-based practice. Journal of autism and developmental disorders. 40, 570–579 (2010).
27. Leyzberg, D., Spaulding, S., Scassellati, B.: Personalizing robot tutors to individuals' learning differences. In: Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction. pp. 423–430. ACM (2014).
28. Wong, C., Odom, S.L., Hume, K.A., Cox, A.W., Fettig, A., Kucharczyk, S., Brock, M.E., Plavnick, J.B., Fleury, V.P., Schultz, T.R.: Evidence-based practices for children, youth, and young adults with autism spectrum disorder: A comprehensive review. Journal of autism and developmental disorders. 45, 1951–1966 (2015).
29. Cao, H.L., Esteban, P., Bartlett, M., Baxter, P.E., Belpaeme, T., Billing, E., Cai, H., Coeckelbergh, M., Costescu, C., David, D.: Robot-enhanced therapy: development and validation of a supervised autonomous robotic system for autism spectrum disorders therapy. IEEE Robotics and Automation Magazine. (2019).
30. DiPietro, J., Kelemen, A., Liang, Y., Sik-Lanyi, C.: Computer-and Robot-Assisted Therapies to Aid Social and Intellectual Functioning of Children with Autism Spectrum Disorder. Medicina. 55, 440 (2019).
31. Conti, D., Cattani, A., Di Nuovo, S., Di Nuovo, A.: Are Future Psychologists Willing to Accept and Use a Humanoid Robot in Their Practice? Italian and English Students' Perspective. Frontiers in psychology. 10, 1–13 (2019). https://doi.org/10.3389/fpsyg.2019.02138.