Social Robots Design to improve Social Skills in Autism Spectrum Disorder

Francesca Perillo[1], Marco Romano[2] and Giuliana Vitiello[1]

[1] *Università degli Studi di Salerno – UNISA, Via Giovanni Paolo II, Fisciano, 84084, Italy*
[2] *Università degli Studi Internazionali di Roma – UNINT, Via delle Sette Chiese, 139, Roma, 00147, Italy*

Abstract

The incorporation of social robots signifies a notable advancement in the field of robotics, allowing machines to interact with humans not merely on a functional level, but also in emotional and social dimensions. Equipped with artificial intelligence, sensors, and communication capabilities, these robots possess the capacity to identify emotions, respond to social cues, and adjust their behavior accordingly. The advent of social robots marks a substantial transformation in human-robot interaction, emphasizing emotional connections and social engagement as mechanisms to bridge the gap between humans and machines.In this study, we demonstrate that within the domain of autism therapy, the integration of social robots—QTrobot, NAO, and Pepper—has yielded promising outcomes. Each robot exhibits distinctive features tailored to specific therapeutic requirements. Our conclusions offer guidelines for the selection of the most suitable robot, considering individual strengths and functionalities, within the context of autism therapy.It is important, however, to acknowledge that despite the potential therapeutic applications for individuals with autism, social robots do not constitute a comprehensive solution. Instead, they present supplementary avenues for engagement and learning, acting in tandem with the efforts of human therapists.

Keywords
Social Robotics, ASD, children

1. Introduction

In recent years, we have witnessed the pervasive integration of computer technologies into our daily lives, making them increasingly accessible to all. These technologies have found application in numerous sectors, with examples such as Virtual and Augmented Reality being employed not only for entertainment but also extensively utilized in educational [8][33][35] and clinical settings [5][34][36]. It is precisely in the realm of disability support that these technologies are yielding novel and compelling outcomes. For example, mobile technologies have been largely employed as aids for various disabilities [18], such as dyslexia [30] and visual impairment [31, 9]. The latest wave of technologies poised to profoundly impact our lives in the coming years is centered around Artificial Intelligence (AI) [32,19,39] and robotics. AI has already been experimented with and utilized as a tool to support individuals with disabilities, such as those who are deaf or mute [10]. Moreover, AI is playing a crucial role in propelling traditional robotics towards the realm of social robotics. The emergence of social robots represents a major progression in robotics, whereby machines are programmed to engage with humanity not only on a functional level but also socially and emotionally. Equipped with artificial intelligence, sensors, and communication abilities, social robots can detect human emotions, responding to social

Proceedings of the Digital Innovations for Learning and Neurodevelopmental Disorders, May24–25, 2024, Rome, Italy
fperillo@unisa.it (F. Perillo); marco.romano@unint.eu(M.Romano); gvitiello@unisa.it(G. Vitiello)
0009-0008-2302-3535 (F. Perillo); 0000-0002-8581-3160 (M. Romano); 0000-0001-7130-996X (G. Vitiello)

cues, and adapting their actions accordingly. The integration of social robots represents a paradigm shift in human-robot interaction. It emphasizes not only functionality, but also the development of emotional connections and social engagement. Social robots aim to bridge the gap between humans and machines through their human-like appearance, expressive features, and ability to comprehend and respond to human speech and gestures. Initially designed for industrial or repetitive functions, robots have now evolved to fulfil various social roles. Social robots can act as companions for the elderly, children, or people in need of social interaction. They can engage in conversation, play games, tell stories, or even provide emotional support [6]. A study adopts the "companionship as a secondary function" approach, whereby a non-humanoid robot is developed to fulfill a primary function those older adults view as suitable, with companionship serving as a secondary function [7]. Social robots are used also in therapeutic settings to assist people with autism, dementia, or mental health problems. They help develop social skills, provide routine reminders, and offer emotional support [13, 14]. Social robots can also distract children during painful medical procedures in the pediatric emergency department [11]. Moreover, social robots are used in educational settings to enhance the learning experience. They can act as tutors, helping children learn subjects such as math or languages in an interactive and engaging way [12]. Social robots can be a practical solution for children with dyslexia, assisting them in their learning [15]. Some companies are using social robots as customer service representatives, providing information, guiding customers through stores, or assisting with basic tasks [16]. Social robots are also being used in public spaces such as airports or hotels to assist visitors with directions, information, or general enquiries [17]. So far, these robots are being developed for use in a variety of settings, such as homes, hospitals, and public places, and are addressing a range of needs, including providing companionship for the elderly, educational support for children, assistance for people with special needs, and even customer service in business. The progress of social robots is constantly evolving with the ongoing advancement of artificial intelligence, machine learning, and robotics technology. As these machines become increasingly sophisticated, their roles, responsibilities, and the potential impact on society are subjects of ethical consideration being explored and debated.

2. Robots as a support tool for people with autism

Autism Spectrum Disorders (ASDs) are neurodevelopmental conditions characterized by persistent and significant impairments in social and communicative functioning and by restricted and repetitive patterns of behavior, interests, and activities [1, 37, 38]. Due to the large heterogeneity of the autism spectrum, a single approach is difficult to establish and to be proven as the best one [2].There is a growing interest in the scientific and therapeutic community in the use of robots in the context of autism [22, 23]. Social robots can provide predictable reactions, structured interaction, and a non-threatening presence that can stimulate interest in children with autism spectrum conditions [3, 4]. Social robots have shown enormous potential as support tools for children with ASD. These devices, characterized by a humanoid or semi-humanoid interface, are designed to interact with individuals in a similar way to human interactions. To date, several robots are being used in different studies: QTrobot, NAO and Pepper are some examples. We will focus mainly on long-term experiments conducted with social robots. The common goal of these projects was to provide children with SLD with an interactive and stimulating environment that can improve their quality of life and social skills.

QTrobot becomes a valuable resource by providing a safe and predictable environment within an autism center. One of the most striking features of QTrobot is its flexibility and adaptability. It can create targeted programs and activities to improve communication skills, social interaction, and emotion management to meet the specific needs of each child [24, 25]. Moreover, QTrobot acts as a diagnostic and monitoring tool, providing measurable data on the child's interactions and progress over time [26]. This allows the treatment to be further adapted and tailored to maximize the benefits for everyone. The use of robots NAO has highlighted the effectiveness of machine interaction in the context of children with autism spectrum disorders [27]. Interaction with robots has been shown to provide children with a different perspective by removing the social pressure to respond correctly or conform immediately to social norms [28, 29]. This significantly reduces anxiety and tension levels in children. By providing accurate data through structured and measurable interactions, robots can assist in early diagnosis and assessment of social skills [21]. Social robots can act as play partners or interlocutors to encourage and improve social interactions in children with ASD. They can enable children to practice social skills such as eye contact, conversation and managing social interactions [20]. Their ability to record and recognize behaviors can help professionals diagnose and monitor a child's responses to specific social stimuli. Social robots are also used to understand and manage emotions. They can be programmed to express and recognize emotions, providing a visual and interactive model for the child to learn how to recognize and respond to emotions.

3. Guidelines and conclusions

In the context of autism therapy, the utilization of social robots has demonstrated promising outcomes, with QTrobot, NAO, and Pepper emerging as prominent choices. Each of these robots possesses unique features that cater to specific therapeutic needs. Our conclusions offer guidelines for selecting the most appropriate robot based on distinct therapeutic requirements, considering their individual strengths and functionalities.

3.1 Emotional Expression and Recognition: QTrobot stands out as the sole robot among the three capable of expressing emotions through facial expressions. Equipped with cameras and an integrated system for human emotion recognition, QTrobot is particularly effective for training children in recognizing and expressing emotions. Its proficiency in motor skills, especially in arm movements for drawing activities, facilitates collaborative therapeutic exercises.

3.2 Child-Friendly Interaction and Mobility: NAO's compact size makes it appealing to children. Its functional legs enable movement and engagement in activities such as playing with a ball. Although NAO's arm movements are limited, its size and mobility make it a suitable choice for activities requiring physical interaction, despite constraints on carrying weights or precise movements.

3.3 Stability, Mobility, and Therapeutic Interactivity: Pepper, lacking legs, compensates with wheel-based mobility, offering enhanced stability. It can carry some weights and execute comprehensive gestures with its hands. Notably, Pepper incorporates an integrated tablet for proposing therapeutic games and interacting with children. The ability to practice complete gestures, along with stable mobility, renders Pepper suitable for a variety of therapeutic scenarios.

In addition to the above guidelines, it is crucial to highlight that all three robots can engage with children through speech synthesis. Notably, QTrobot has recently integrated speech synthesis with the ChatGPT service, enabling more comprehensive verbal communication.

This advancement enhances the communicative capabilities of QTrobot, potentially providing a richer therapeutic experience.

However, the employment of robots in therapy, particularly for individuals with autism, is not a comprehensive remedy. It is crucial to note that despite the potential for positive outcomes, robotic therapy cannot replace the vital role of human therapists. Rather, it serves as a complement to their work, assisting in forming relationships with autistic individuals and enhancing the access and engagement of therapy. The incorporation of social robots in therapy highlights the need to view them as tools rather than replacements for human interaction. Their facilitating role enhances the therapeutic process by offering further avenues for learning and interaction. Furthermore, the use of social robots in specialized care for autistic children is transforming environments into inclusive spaces that promote holistic development. It is not just about providing targeted assistance; it is about transforming disabilities into opportunities for education and development. We are promoting an innovative approach that emphasizes inclusion and progress for all using these technologies.

References

[1] American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders: DSM-5. Washington, DC: American Psychiatric Association.

[2] Pennisi, P., Tonacci, A., Tartarisco, G., Billeci, L., Ruta, L., Gangemi, S. and Pioggia, G. (2016), Autism and social robotics: A systematic review. AutismResearch, 9: 165-183. https://doi.org/10.1002/aur.1527

[3] Baron-Cohen, S. (2002). The extreme male brain theory of autism. Trends in Cognitive Sciences, 6, 248–254.

[4] Baron-Cohen, S. (2006). The hyper-systemizing, assortative mating theory of autism. Progress in Neuro-Psychopharmacology and BiologicalPsychiatry, 30, 865–872.

[5] Frolli, A.; Savarese, G.; Di Carmine, F.; Bosco, A.; Saviano, E.; Rega, A.; Carotenuto, M.; Ricci, M.C. Children on the Autism Spectrum and the Use of Virtual Reality for Supporting Social Skills. Children 2022, 9, 181. https://doi.org/10.3390/children9020181.

[6] Hoffman, G., Bauman, S., & Vanunu, K. (2016). Robotic experience companionship in music listening and video watching. Personal and Ubiquitous Computing, 20, 51-63. https://doi.org/10.1007/s00779-015-0897-1.

[7] Erel, H., Dado, O., Manor, A., & Zuckerman, O. (2021). The Multifaceted Nature of Robotic Companionship when Presented as a Secondary Function. Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems. https://doi.org/10.1145/3411763.3451582.

[8] Romano, M., Frolli, A., Aloisio, A., Russello, C., Rega, A., Cerciello, F., & Bisogni, F. (2023). Exploring the Potential of Immersive Virtual Reality in Italian Schools: A Practical Workshop with High School Teachers. Multimodal Technologies and Interaction, 7(12), 111.

[9] Romano, M., Bellucci, A., & Aedo, I. (2015). Understanding touch and motion gestures for blind people on mobile devices. In Human-Computer Interaction–INTERACT 2015: 15th IFIP TC 13 International Conference, Bamberg, Germany, September 14-18, 2015, Proceedings, Part I 15 (pp. 38-46). Springer International Publishing.

[10] Battistoni, P., Di Gregorio, M., Romano, M., Sebillo, M., Vitiello, G., & Solimando, G. (2020). Sign language interactive learning-measuring the user

engagement. In Learning and Collaboration Technologies. Human and Technology Ecosystems: 7th International Conference, LCT 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part II 22 (pp. 3-12). Springer International Publishing.

[11] Foster, M., Candelaria, P., Dwyer, L., Hudson, S., Lindsay, A., Nishat, F., Pacquing, M., Petrick, R., Ramírez-Duque, A., Stinson, J., Zeller, F., & Ali, S. (2023). Co-design of a Social Robot for Distraction in the Paediatric Emergency Department. Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction. https://doi.org/10.1145/3568294.3580127.

[12] Papadopoulos, K., Velentza, A., Christodoulou, P., &Fachantidis, N. (2022). Social Educational Robotics Application: Architecture and Interconnectivity. 2022 13th International Conference on Information, Intelligence, Systems & Applications (IISA), 1-4. https://doi.org/10.1109/IISA56318.2022.9904372.

[13] Cantone, A. A., Esposito, M., Perillo, F. P., Romano, M., Sebillo, M., & Vitiello, G. (2023). Enhancing Elderly Health Monitoring: Achieving Autonomous and Secure Living through the Integration of Artificial Intelligence, Autonomous Robots, and Sensors. Electronics, 12(18), 3918, https://doi.org/10.3390/electronics12183918.

[14] Battistoni, P., Cantone, A. A., Esposito, M., Francese, R., Perillo, F. P., Romano, M., ... &Vitiello, G. (2023, July). Using Artificial Intelligence and Companion Robots to Improve Home Healthcare for the Elderly. In International Conference on Human-Computer Interaction (pp. 3-17). Cham: Springer Nature Switzerland.

[15] Barra, P., Cantone, A. A., Francese, R., Perillo, F., Tortora, G., &Vitiello, G. Bridging the gap: Exploring Robotic solutions for Children with Dyslexia.

[16] Ernens, S., Delcourt, C., Dessart, L., &Baiwir, L. (2022). Frontline Employees' Attitude Toward Embodied Social Robots In Customer Service: An Integrative Framework And Empirical Test. Journal of Service Management Research. https://doi.org/10.5771/2511-8676-2022-4-262.

[17] Kamino, W., &Šabanović, S. (2023). Coffee, Tea, Robots?: The Performative Staging of Service Robots in 'Robot Cafes' in Japan. Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction. https://doi.org/10.1145/3568162.3576967.

[18] Battistoni, P., Sebillo, M., Di Gregorio, M., Vitiello, G., & Romano, M. (2020, January). ProSign+ a cloud-based platform supporting inclusiveness in public communication. In 2020 IEEE 17th Annual Consumer Communications & Networking Conference (CCNC) (pp. 1-5). IEEE.

[19] Battistoni, P., Romano, M., Sebillo, M., & Vitiello, G. (2021, July). A Change in Perspective About Artificial Intelligence Interactive Systems Design: Human Centric, Yes, But Not Limited to. In International Conference on Human-Computer Interaction (pp. 381-390). Cham: Springer International Publishing.

[20] Thanopoulou, A. (2022). Technical elements of social assistance robots that enhance the therapeutic or supportive effectiveness of the cooperative and communicative behavior of children with autism. EDMETIC. https://doi.org/10.21071/edmetic.v11i2.14341.

[21] Puglisi, A., Caprì, T., Pignolo, L., Gismondo, S., Chilà, P., Minutoli, R., Marino, F., Failla, C., Arnao, A., Tartarisco, G., Cerasa, A., & Pioggia, G. (2022). Social Humanoid Robots for Children with Autism Spectrum Disorders: A Review of Modalities, Indications, and Pitfalls. Children, 9. https://doi.org/10.3390/children9070953.

[22] Lin, J., Li, J., She, Y., Lin, L., Wu, H., Zhang, E., Lei, J., Huang, W., & Li, J. (2022). Using a social robot for children with autism: A therapist-robot interactive

model. Computer Animation and Virtual Worlds, 33. https://doi.org/10.1002/cav.2109.

[23] Gaitán-Padilla, M., Cifuentes, C., &Munera, M. (2022). Three Study Cases of Social Robotics in Autism Spectrum Disorder Treatment: Personalization and Usability of CASTOR Robot. 2022 International Conference on Rehabilitation Robotics (ICORR), 1-6. https://doi.org/10.1109/ICORR55369.2022.9896590.

[24] Tartarisco, G., Bruschetta, R., Marino, F., Caprì, T., Minutoli, R., Chilà, P., Failla, C., Puglisi, A., Arnao, A., Cerasa, A., & Pioggia, G. (2022). Exploring behavioural and physiological interactions in a group-based emotional skill social robotic training for autism spectrum disorders. 2022 International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME), 1-4. https://doi.org/10.1109/ICECCME55909.2022.9988169.

[25] El-Muhammady, M. F., Zabidi, S. A. M., Yusof, H. M., Rashidan, M. A., Sidek, S. N. I., & Ghazali, A. S. (2022, December). Initial Response in HRI: A Pilot Study on Autism Spectrum Disorder Children Interacting with a Humanoid QTrobot. In International Conference on Robot Intelligence Technology and Applications (pp. 393-406). Cham: Springer International Publishing.

[26] Nazari, A., Höhn, S., Paikan, A., &Ziafati, P. (2023, September). Receptive Language Development Diagnosis and Tracking in Conversational Interactions with QTrobot for Autism. In Proceedings of the First Workshop on Connecting Multiple Disciplines to AI Techniques in Interaction-centric Autism Research and Diagnosis (ICARD 2023) (pp. 12-16).

[27] Chevalier, P., Isableu, B., Martin, J. C., &Tapus, A. (2016). Individuals with autism: Analysis of the first interaction with nao robot based on their proprioceptive and kinematic profiles. In Advances in Robot Design and Intelligent Control: Proceedings of the 24th International Conference on Robotics in Alpe-Adria-Danube Region (RAAD) (pp. 225-233). Springer International Publishing.

[28] Lytridis, C., Vrochidou, E., Chatzistamatis, S., &Kaburlasos, V. (2019). Social engagement interaction games between children with Autism and humanoid robot NAO. In International Joint Conference SOCO'18-CISIS'18-ICEUTE'18: San Sebastián, Spain, June 6-8, 2018 Proceedings 13 (pp. 562-570). Springer International Publishing.

[29] Brienza, M., Laus, F., Guglielmi, V., Carriero, G., Sileo, M., Grisolia, M., ... &Muratori, F. HRI-based Gaze-contingent Eye Tracking for Autism Spectrum Disorder Treatment: A preliminary study using a NAO robot.

[30] Di Gregorio, M., Romano, M., Sebillo, M., & Vitiello, G. (2022, January). Dyslexeasy-App to Improve Readability through the Extracted Summary for Dyslexic Users. In CCNC (pp. 1-6).

[31] Di Chiara, G., Paolino, L., Romano, M., Sebillo, M., Tortora, G., Vitiello, G., &Ginige, A. (2011, September). The framy user interface for visually-impaired users. In 2011 Sixth International Conference on Digital Information Management (pp. 36-41). IEEE.

[32] Battistoni, P., Di Gregorio, M., Romano, M., Sebillo, M., & Vitiello, G. (2023). Can AI-Oriented Requirements Enhance Human-Centered Design of Intelligent Interactive Systems? Results from a Workshop with Young HCI Designers. Multimodal Technologies and Interaction, 7(3), 24.

[33] Romano, M., Díaz, P., & Aedo, I. (2023). Empowering teachers to create augmented reality experiences: the effects on the educational experience. Interactive Learning Environments, 31(3), 1546-1563.

[34] Frolli, A., Bosco, A., Lombardi, A., Di Carmine, F., Marzo, S., Rega, A., & Ricci, M. C. (2021). Asperger's and virtual reality. Proceedings http://ceur-ws. org ISSN, 1613, 0073.

[35] Bisogni, F., Laccone, R. P., Esposito, C., Frolli, A., & Romano, M. (2023). VIRTUAL REALITY AND FOREIGN LANGUAGE LEARNING. In ICERI2023 Proceedings (pp. 9201-9207). IATED.
[36] Frolli, A., Ricci, M., Di Carmine, F., Savarese, G., Siciliano, M., Carotenuto, M., & Rega, A. (2022). Using virtual reality to improve learning in children with ADHD. CURRENT PEDIATRIC RESEARCH, 26, 1244-1249.
[37] Piedimonte, A., Conson, M., Frolli, A., Bari, S., Della Gatta, F., Rabuffetti, M., Keller, R., Berti, A., & Garbarini, F. (2018). Dissociation between executed and imagined bimanual movements in autism spectrum conditions. Autism research : official journal of the International Society for Autism Research, 11(2), 376–384. https://doi.org/10.1002/aur.1902
[38] Caliendo, M., Di Sessa, A., D'Alterio, E., Frolli, A., Verde, D., Iacono, D., Romano, P., Vetri, L., & Carotenuto, M. (2021). Efficacy of Neuro-Psychomotor Approach in Children Affected by Autism Spectrum Disorders: A Multicenter Study in Italian Pediatric Population. Brain sciences, 11(9), 1210. https://doi.org/10.3390/brainsci11091210
[39] Rega, A., Mennitto, A., Vita, S., &Iovino, L. (2018). New technologies and autism: Can augmented reality (ar) increase the motivation in children with autism? 12th International Technology, Education and Development Conference, V-262–2018, 4904–4910.