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Using a humanoid robot to promote inclusion of children with Autism Spectrum Disorders in mainstream classrooms: An overview of the *RoBò* service delivery approach

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Abstract

In this contribution we present RoBò, a multidisciplinary service delivery approach developed to support teachers in the use of social robots to promote inclusion of children with Autism Spectrum Disorders (ASD) in school settings. RoBò is composed of four steps which are briefly illustrated by reporting on the case of Alice, a six-year-old girl with a diagnosis of ASD without intellectual disability. Although RoBò is in its experimental stage, preliminary results are encouraging and show that it may be helpful in increasing opportunities for social interaction and inclusion of children with ASD in non-controlled environments. Research is underway to prove its effectiveness in supporting teaching practices targeting children with special educational needs.

Keywords: Autism spectrum disorders; Social robotics; Special educational needs; Assistive technology.

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1. Introduction

Children with Autism Spectrum Disorders (ASD) have persistent difficulties in social communication and interaction across multiple contexts (American Psychiatric Association, 2013). Such difficulties may include, for instance, communicating appropriately with others, initiating and sustaining social relationships, and participating in new environments (Lord, Elsabbagh, Baird, & Veenstra-Vanderweele, 2018). Given the importance of social skills to successful social, emotional, and cognitive development, a variety of programs have been developed to promote inclusion of students with ASD in school settings with a view to fostering the development of their social competences through active participation in social and communication activities (Bellini, Peters, Benner, & Hopf, 2007; Ke, Whalon, & Yun, 2018).

Recent literature routinely reports that children with ASD appear to have a special interest in computerized activities (Grynszpan, Weiss, Perez-Diaz, & Gal, 2014). This has stimulated researchers as well as educational professionals to develop inclusive teaching programs employing digital technologies to foster social competency and communication skills in children with ASD (e.g. Lindsay, Hounsell, & Cassiani, 2017; Fage, Consel, Balland, Etchegoyhen, Amestoy, Bouvard *et al.*, 2018).

Social robots – i.e. artificial agents created to assist people with everyday tasks and provide entertainment through simple forms of verbal and behavioral communication – are examples of such technologies used to promote social skills in children with ASD (Pennisi, Tonacci, Tartarisco, Billeci, Ruta, Gangemi *et al.*, 2016). Recent evidence has documented the increased use of social robots involving students with ASD in educational scenarios (for a recent review, see Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018), with encouraging results regarding their effectiveness in increasing the engagement of children with ASD in social activities (Wainer, Ferrari, Dautenhahn, & Robins, 2010; Hughes-Roberts, Brown, Standen, Desideri, Negrini, Rouame *et al.*, 2019).

Despite their great promise, concerns however remain regarding the potential of social robots in educational settings, as they are not yet considered usable outside of controlled settings or isolated structured interactions (Clabaugh & Matarić, 2019). As a consequence, educators' interest in adopting potentially useful robotic applications is challenged by the difficulties they face in integrating such innovative platforms within their everyday school practices.

2. The *RoBò* service delivery approach

To overcome the aforementioned challenges and allow school professionals to develop effective robot-based interventions, we present a service delivery approach which can be applied to any educational context aimed at supporting teachers as well as other school-related stakeholders in the implementation of educational activities performed with the use of a humanoid robot. The decision to use a humanoid robot was taken on the basis of current evidence suggesting that robots resembling human appearance and having moving limbs are more effective in eliciting social responses in children with ASD (Desideri, Negrini, Malavasi, Tanzini, Rouame, Cutrone *et al.*, 2018). The humanoid robot used is a NAO (Version 6), produced by Aldebaran Robotics. NAO is 57.4 centimeters (22.5 inches) tall and weighs 5.4 kilograms (about 11.4 lb.). It has 25 degrees of freedom and a humanoid shape, which enable it to move and produce gestures and grasps small objects. It can also recognize and produce sounds and convert text files into speech outputs in order to engage in basic conversation.

Named *RoBò*, the service delivery approach was developed by the WeCareMore Centre for Research and Innovation of AIAS Bologna and has recently been embedded within the activities of the assistive technology team at the Regional Centre for Assistive Technology (CRA) in Bologna, Italy. It is the result of a European project conducted between the years 2014 and 2016 aimed at evaluating the effectiveness of social robotics to promote engagement of ASD children in treatment activities performed by the health professionals working in ASD specialized services of the Bologna Local Health Authority (Desideri *et al.*, 2018; Desideri, Ottaviani, Malavasi, di Marzio, & Bonifacci, 2019a; Hughes-Roberts *et al.*, 2019; Desideri, Bonifacci, Croati, Dalena, Gesualdo, Molinario *et al.*, 2020). As such, *RoBò* may be seen as a move away from documenting efficacy of robot-based interventions conducted in controlled settings toward assessing their effectiveness in less structured environments where specific treatment or rehabilitation interventions are not possible. Specifically, the aim of *RoBò* is to provide a co-development platform where teachers, educators and researchers can meet and develop robot-based activities that fit with the needs of individual students. During the process, data on robot effectiveness are collected with and as well as information to develop best practices for robot use.

The co-development process of the robot-based activities is composed of four consecutive steps: Goal-setting; Activity identification and development; Trial and implementation; and, Follow-up. In this contribution, we provide a brief description of each step by reporting on the case of Alice, a six-year-old student with a diagnosis of ASD without intellectual disability. Alice attends a state primary school in the Bologna municipal area. Diagnosis of ASD was performed by the multidisciplinary specialized ASD service of Bologna Local Health Authority.

2.1. Step 1: Goal-setting

In the first step, the school teachers – in collaboration with the local multidisciplinary specialized ASD service – contact the *RoBò* team to explore the possibility of using a robot in their educational activities. On this occasion, clear objectives for robot use are identified and reported using a modified version of the Individually Prioritized Problem Assessment (IPPA). With this tool, an individual respondent (usually the teacher responsible for the student) is asked to list up to seven problems he/she wants to respond to through the robot, and to rate each of them on a 5-point scale both in relation to the importance of the problem and in relation to the difficulty experienced in addressing it. Importance scores and difficulty scores are then multiplied, resulting in a baseline score between 1 and 25 for each problem. In a follow-up interview, respondents are asked to repeat the IPPA rating only in relation to the difficulty experienced in addressing the problems listed in the baseline interview. The perceived effectiveness of the intervention is calculated by subtracting the follow-up score from the baseline score, thus resulting in a change score (Desideri *et al.*, 2016; Desideri, Salatino, Pigini, Andrich, Cristofani, Bravi *et al.*, 2019b). In the case of Alice, three problems were identified, namely (a) lack of social interaction opportunities with her peers and the adults (IPPA score = 15); (b) reduced receptive/productive vocabulary (IPPA score = 20), and (c) poor sustained attention (IPPA score = 20).

2.2. Step 2: Activity identification and development

In the second step, the *RoBò* team develops the robot-based activities in close collaboration with the school team. Based on the discussions between all stakeholders, and considering Alice's interest in engaging in play activities, it was decided that the focus would be placed on the first problem (i.e. increasing social interaction opportunities with her peers). To this end, play scenarios were developed in which the teacher, together with the robot, engaged small groups of four to six children in question-answer exchanges. Alice was always present in these small groups. The aim of these small groups was to motivate Alice to give her attention to (e.g. orient toward) both the robot and her peers. These play scenarios were also functional for stimulating children within the small groups to give Alice their attention and interact with her.

Alice's teachers were taught to control the robot by means of a dedicated application running on a iPad and specifically developed by the *RoBò* team. Through the application, the teacher could move the robot and let it speak pre-recorded sentences and questions (e.g. "I'm happy to see you all", "I'm happy to see you again, Alice. How are you doing?", "Would you like me to change the color of my eyes? What color would you prefer?").

2.3. Step 3: Trial and Implementation

In the third step, the robot is brought to the school and the planned robot-based activities are performed for the time necessary to ascertain that they are appropriate for the student and the educational objectives. In the case of Alice, the aim of this step was to ensure that (1) she was not reluctant to take part in the robot-based activities and (2) she enjoyed the small-group activities. To this end, an ABAB single-case design was used.

Each of the four study conditions lasted one week. Baseline (A) and Robot (B) sessions included the same small-group question-answer activities. In the baseline phase, Alice attended four consecutive sessions, each lasting approximately 10 minutes. Similarly, in the Robot phase (B), Alice attended three sessions (10 min) of small-group activities during which the teacher used the humanoid robot. All the sessions were conducted by the same teacher, who was also in charge of controlling the robot.

Table 1 – *Observational system used in Step 3 to assess appropriateness of robot-based activities*

Indicator	Observed behaviors[a]
Nonverbal dyadic orienting	Child engages in eye contact with peers or the adult during interactions initiated by the adult, peers or robot.
Self-initiated social engagement	Child is physically oriented toward the adult or peers and/or directs affect (smiled, laughed) toward the adult or peers.
Social initiations	Any appropriate vocal or gestural behavior directed toward the adult or peers who attempts to evoke a peer response.

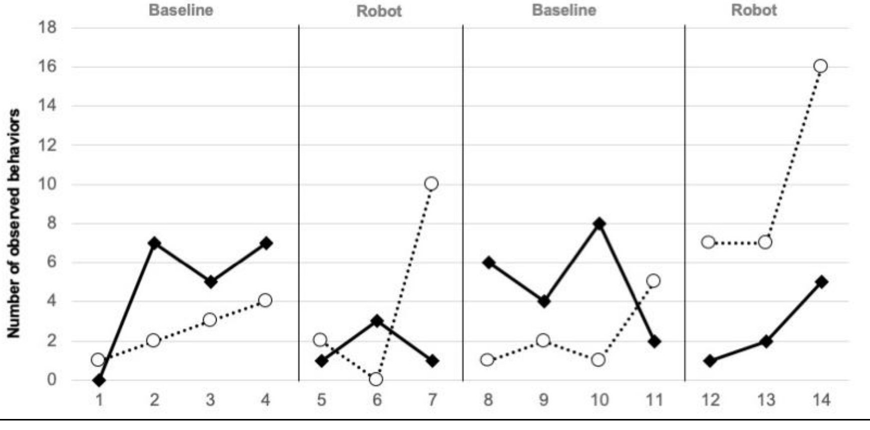
Disinterest	Child looks bored, uninvolved, not curious or uneager to continue activity. May yawn or try to avoid the situation. Spends much time looking around and not attending to task. If child does respond, may be long response latency. She is unhappy. Cries, pouts, has tantrums, appears to be sad, angry or frustrated. Child seems not to be enjoying self.
Happiness	Child smiles, laughs appropriately, seems to be enjoying self.

[a]Adapted from Boyd *et al*. (2011) and Koegel *et al*. (2009).

A descriptive observation system was developed for the purpose of examining activity appropriateness and Alice's reactions when interacting with the robot in comparison with a similar interaction scenario without the humanoid robot (see Tab.1). The system includes five observational variables (i.e. Nonverbal dyadic orienting; Self-initiated social engagement; Social initiations; Disinterest; Happiness) of which only Disinterest and Happiness were of interest for the current step. Prior to data collection, two observers were trained on the coding system using videos of children with ASD interacting with a humanoid robot in an educational setting and which had been recorded during a previous research study.

Analysis of the videos (see Fig.1) showed that, on average, Alice displayed more signs of happiness with the robot compared to baseline ($M_{Baseline}$ = 2.35; M_{Robot} = 7). In addition, she was also less disinterested when involved in interaction sessions with the robot ($M_{Baseline}$ = 4.8; M_{Robot} = 2.1).

Figure 1 – *Data regarding Alice during Step 3 and the sessions throughout the different phases of the study*



Note: The white circles represent the mean number of observed behaviors related to Happiness. The black squares represent the mean number of observed behaviors related to Disinterest.

Video analysis was supplemented with the Robot Predisposition Questionnaire (RPQ), which was administered to the teacher (Hughes-Roberts *et al.*, 2019). This questionnaire addresses seven dimensions that are assumed to form the user's attitude toward a social robot: goals, effectiveness, understanding, safety, ease of use, support, and transferability. Each dimension was rated on a 5-point Likert scale [1 (No) to 5 (Yes)], with lower scores indicating a more negative attitude, and a score of 3 (Possibly) considered as a threshold, below which the scores should be considered as an indicator of a negative attitude (Hughes-Roberts *et al.*, 2019). Overall, the RPQ results were highly positive in that the teacher gave a score of 5 to all dimensions. Based on the results from the video analysis and the teacher's positive attitude toward the potential usefulness of the robot-based activities to achieve Alice's educational objectives, it was agreed that the small-group activities would be implemented twice a week for three months (12 weeks in total).

2.4. Step 4: Follow-up

At the end of the planned robot-based activities, the teacher is requested to complete the IPPA follow-up interview. IPPA results may be supplemented by video analysis following the same observational procedure described in Step 3, depending on the resources available.

In the case of Alice, due to the measures to reduce the spread of the Covid-19 virus, it was only possible to conduct the small-group activities for two of the 12 weeks planned. Nevertheless, the IPPA follow-up interview was completed for the first problem (i.e. lack of social interaction opportunities) right after interruption of the activities, in order to document the closing of the service delivery process. It resulted in an IPPA follow-up score of 5, indicating a notable reduction in the teacher's perceived difficulty in involving Alice in social interactions compared to the baseline score (IPPA change score = 10). However positive, this result is only indicative of the potential effectiveness of the robot-based activities planned for Alice as they were interrupted well before their completion.

3. Discussion and Conclusion

This contribution was aimed at providing an overview of *RoBò*, a service delivery process to facilitate the inclusion of social robots in mainstream classrooms with a view to improving social interaction opportunities for children with ASD. Interventions that target core symptoms (i.e. social communication difficulties, imitation, emotion recognition) in children with ASD are increasingly being reported with overall positive results (Robinson, Cottier, & Kavanagh, 2019). Less attention, however, has been paid by the robotic and clinical fields to the importance of ensuring the proper introduction of robotic platforms also in those contexts where the delivery of specific structured interventions are not feasible due to a lack of resources (e.g. time) as well as clinical and technical competences. The aim of *RoBò* is thus to bring the opportunities for social engagement offered by social robotics also to non-rehabilitation settings and to unstructured educational activities. As such, *RoBò* may be seen as a complement to more focused and intensive treatment interventions conducted by specialized professionals.

As a service delivery approach, it involves the main characteristics needed to facilitate the planning of appropriate robot-based educational activities for children with ASD (van den Berk-Smeekens, Dongen-Boomsma, De Korte, Den Boer, Oosterling, Peters-Scheffer *et al.*, 2020): (a) it adopts a co-creation protocol between teachers, researchers, clinicians and engineers for the development of educational scenarios (Huijnen, Lexis, Jansens, & de Witte, 2016); (b) it uses a robot that resembles a human being but with clear mechanical features (Cabibihan, Javed, Ang, & Aljunied, 2013); (c) robot-based activities are highly adaptable to the child's characteristics and interests (Huijnen *et al.*, 2016).

To conclude, *RoBò* is a potentially useful service delivery approach to promote the use of social robots in school settings. In addition, it may further represent a useful platform where research and education can meet to develop best robot-based educational practices. Research is currently ongoing to document its effectiveness in improving (a) social interaction opportunities for children with ASD as well as (b) teachers' educational practices.

References

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders (5th ed.)*. Arlington, VA: American Psychiatric Publishing.

Bellini, S., Peters, J. K., Benner, L., & Hopf, A. (2007). A meta-analysis of school-based social skills interventions for children with autism spectrum disorders. *Remedial and Special Education, 28* (3), 153-162. https://doi.org/10.1177/07419325070280030401.

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018). Social robots for education: A review. *Science Robotics, 3* (21): eaat5954. https://doi.org/10.1126/scirobotics.aat5954.

Boyd, B. A., Conroy, M. A., Asmus, J., & McKenney, E. (2011). Direct observation of peer-related social interaction: Outcomes for young children with autism spectrum disorders. *Exceptionality*, *19* (2), 94-108. https://doi.org/10.1080/09362835.2011.565724.

Cabibihan, J. J., Javed, H., Ang, M., & Aljunied, S. M. (2013). Why robots? A survey on the roles and benefits of social robots in the therapy of children with autism. *International Journal of Social Robotics, 5* (4), 593-618. https://doi.org/10.1007/s12369-013-0202-2.

Clabaugh, C., & Matarić, M. (2019). Escaping oz: Autonomy in socially assistive robotics. *Annual Review of Control, Robotics, and Autonomous Systems*, *2*, 33-61. https://doi.org/10.1146/annurev-control-060117-104911.

Desideri, L., Negrini, M., Malavasi, M., Tanzini, D., Rouame, A., Cutrone, M. C., Bonifacci, P., & Hoogerwerf, E. J. (2018). Using a humanoid robot as a complement to interventions for children with autism spectrum disorder: A pilot study. *Advances in Neurodevelopmental Disorders, 2* (3), 273-285. https://doi.org/10.1007/s41252-018-0066-4.

Desideri, L., Ottaviani, C., Malavasi, M., di Marzio, R., & Bonifacci, P. (2019a). Emotional processes in human-robot interaction during brief cognitive testing. *Computers in Human Behavior, 90,* 331-342. https://doi.org/10.1016/j.chb.2018.08.013.

Desideri, L., Salatino, C., Pigini, L., Andrich, R., Cristofani, R., Bravi, S., Marchetti, G., Martocchi, V., Riccio, A., Mattia, D., Zanfardino, F., Brusa, F., Magni, R., Guerreschi, M., Bitelli, C., & Hoogerwerf., E. J. (2019b). Using a standard procedure to assess assistive technology service delivery outcomes: A proposal from the Italian Network of Independent Assistive Technology Centres. *Global Perspectives on Assistive Technology*, *269*. Available online: https://apps.who.int/iris/bitstream/handle/10665/330371/9789241516853-eng.pdf#page=278 [accessed 19th February 2020].

Desideri, L., Bonifacci, P., Croati, G., Dalena, A., Gesualdo, M., Molinario, G., Gherardini, A., Cesario, L., & Ottaviani, C. (2020). The Mind in the Machine: Mind Perception Modulates Gaze Aversion During Child-Robot Interaction. *International Journal of Social Robotics*. https://doi.org/10.1007/s12369-020-00656-7.

Fage, C., Consel, C. Y., Balland, E., Etchegoyhen, K., Amestoy, A., Bouvard, M., & Sauzéon, H. (2018). Tablet Apps to Support First School Inclusion of Children With Autism Spectrum Disorders (ASD) in Mainstream Classrooms: A Pilot Study. *Frontiers in Psychology*, *9*: 2020. https://doi.org/10.3389/fpsyg.2018.02020.

Grynszpan, O., Weiss, P. L., Perez-Diaz, F., & Gal, E. (2014). Innovative technology-based interventions for autism spectrum disorders: a meta-analysis. *Autism*, *18* (4), 346-361. https://doi.org/10.1177/1362361313476767.

Hughes-Roberts, T., Brown, D., Standen, P., Desideri, L., Negrini, M., Rouame, A., Malavasi, M., Wager, G., & Hasson, C. (2019). Examining engagement and achievement in learners with individual needs through robotic-based teaching sessions. *British Journal of Educational Technology*, *50* (5), 2736-2750. https://doi.org/10.1111/bjet.12722.

Huijnen, C. A., Lexis, M. A., Jansens, R., & de Witte, L. P. (2016). Mapping robots to therapy and educational objectives for children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *46* (6), 2100-2114. https://doi.org/10.1007/s10803-016-2740-6.

Ke, F., Whalon, K., & Yun, J. (2018). Social skill interventions for youth and adults with autism spectrum disorder: a systematic review. *Review of Educational Research*, *88* (1), 3-42. https://doi.org/10.3102/003465431774 0334.

Koegel, R. L., Vernon, T. W., & Koegel, L. K. (2009). Improving social initiations in young children with autism using reinforcers with embedded social interactions. *Journal of Autism and Developmental Disorders*, *39* (9), 1240-1251. https://doi.org/10.1007/s10803-009-0732-5.

Lindsay, S., Hounsell, K. G., & Cassiani, C. (2017). A scoping review of the role of LEGO® therapy for improving inclusion and social skills among children and youth with autism. *Disability and Health Journal*, *10* (2), 173-182. https://doi.org/10.1016/j.dhjo.2016.10.010.

Lord, C., Elsabbagh, M., Baird, G., & Veenstra-Vanderweele, J. (2018). Autismspectrum disorder. *The Lancet*, *392* (10146), 508-520. https://doi.org/10.1016/S0140-6736(18)31129-2.

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

Robinson, N. L., Cottier, T. V., & Kavanagh, D. J. (2019). Psychosocial health interventions by social robots: systematic review of randomized controlled trials. *Journal of Medical Internet Research*, *21* (5): e13203. https://doi.org/10.2196/13203.

van den Berk-Smeekens, I., van Dongen-Boomsma, M., De Korte, M. W., Den Boer, J. C., Oosterling, I. J., Peters-Scheffer, N. C., Buitelaar, J. K., Barakova, E. I., Lourens, T., Staal, W. G., & Glennon, J. C. (2020). Adherence and acceptability of a robot-assisted Pivotal Response Treatment protocol for children with autism spectrum disorder. *Scientific Reports*, *10* (1), 1-11. https://doi.org/10.1038/s41598-020-65048-3.

Wainer, J., Ferrari, E., Dautenhahn, K., & Robins, B. (2010). The effectiveness of using a robotics class to foster collaboration among groups of children with autism in an exploratory study. *Personal and Ubiquitous Computing*, *14* (5), 445-455. https://doi.org/10.1007/s00779-009-0266-z.