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Use of the PARO robot as a social mediator in a sample of children with neurodevelopmental disorders and typical development

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Abstract

*Background.*Social robotics is a research field aimed at providing robots with skills related to social behavior and natural human interaction. Many studies have demonstrated the efficacy of these robots as socio-communicative mediators. Others have used them to create a new communication channel and promote social interaction in children with autism spectrum disorder (ASD). For children with ASD prolonged interpersonal interaction can sometimes generate extreme frustration. They may find it difficult to focus their attention and learn social skills. The robot may therefore become a reliable and more predictable technological intermediary for the child.

Methods. Our study involved the use of the PARO seal robot as a social mediator in groups of children with neurodevelopmental disorders. We aimed to investigate whether the social robot could facilitate relationships with adults in children with neurodevelopmental disorders by comparing their interactions with those of typically developing children.

Results. The results of our research partially confirm what has been reported in the existing literature, while introducing some innovations that could be addressed by future research. The results of the statistical analysis show a positive correlation in the 'interaction' dimension and the presence of the PARO seal in subjects diagnosed with autism without intellectual impairment. These data highlight the PARO robot's ability to facilitate communication and social skills in children with autism without intellectual impairment.

Conclusions. The results of the present study confirm that social robotics can be a valid tool to improve socio-communication skills in clinical samples of children with autism without intellectual impairment. ***Clin Ter 2023; 174 (2):132-138 doi: 10.7417/CT.2023.2509***

Key words: *Autism, Children, PARO robot, social mediator, communication, neurodevelopmental disorders*

Introduction

In the last 20 years, growth and development in the field of robotics and artificial intelligence have favored the creation of potentially revolutionary devices in almost every area of life. Social robotics is a research field aimed at providing robots with a series of skills specifically related to social behavior and natural human interaction. The study of social robots (or socially assistive robots, SARs) focuses on human-robot social interaction (1). SARs are an emerging form of assistive technology that includes all robotic systems capable of providing user assistance through social interaction (2, 3, 4).

There are many types of social mediator robots. Some have humanoid features, while others have animal shapes or mixed traits. Many studies have demonstrated the efficacy of these robots as socio-communicative mediators (5, 6), and other studies have used them to create a new communication channel and facilitate social interaction in children with autism spectrum disorder (ASD) (7). ASD is an early-onset neurodevelopmental disorder characterized by difficulties in social interaction and communication and the presence of restricted interests and repetitive and stereotyped behaviors (8). The term "spectrum" was included to emphasize the heterogeneity of the disorder and indicate a continuum within which everyone has their own specificity.

For children with ASD prolonged interpersonal interaction can sometimes generate extreme frustration. They may find it difficult to focus their attention on social stimuli and learn social skills. The robot may therefore become a reliable and more predictable technological intermediary for the child. Some research has highlighted how the use of social mediator robots can bring benefits, such as an increase in children's initiatives while interacting with therapists and a decrease in discomfort during sessions. Furthermore, some children appear to be particularly comfortable with robots (9). In several studies using different types of social mediator robots, participants with ASD showed better social performance when interacting with robots than humans did.

Sperati et al. (10) tested *me+*, i.e. experimental interactive soft toy that looks like a panda, on two small groups of children aged 30–48 months: one group diagnosed with ASD and the other with Communication Disorder (CD). The proposed play activities aimed to foster simple imitative behaviors and stimulate child engagement. When compared with the results of a previous study on children with typical development (TD), findings of this study suggested that, on

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average, *+me* was able to encourage positive engagement and that different groups tended to manifest some different behaviors. Children with ASD and CD showed a higher tendency to occasionally move away from the setting and to move around within the room compared with children with TD. For children with neurodevelopmental disorders, these results suggest that the use of personal space may be a potential transdiagnostic feature as well as a potential specific behavioral feature characterizing subjects with ASD, which may be useful in supporting traditional diagnosis from the first years of life. Furthermore, some subjects showed a reduction in stereotyped behaviors during the session with robots (11).

Even though social robots have been much more investigated in ASD, it can be hypothesized that also children with other neurodevelopmental disorders, e.g. communication disorder, may take advantage of this innovative, therapeutic approach. Recent studies have shown that social robots are very well accepted by children and their parents (12,13). The main reasons for which social robots are particularly interesting interaction partners for children lie in their toy-like appearance, their several interactive abilities (sounds, lights, movements), their patience in teaching children through many repetitions without getting tired and their ability of remaining emotionally and behaviorally stable in their interactions (14).

Our study involved the use of the PARO seal robot as a social mediator in groups of children with neurodevelopmental disorders. We aimed to investigate whether the social robot could facilitate relationships with adults in children with neurodevelopmental disorders by comparing their interactions with those of children with TD. The answer to this question could have important implications for the use of robotic social mediators within the rehabilitation setting. The results of previous exploratory studies (15-18) carried out at the rehabilitation unit of Le Scotte Hospital in Siena and the Albesani Clinic in Castel San Giovanni have demonstrated that the PARO robot can be a powerful social mediator since it is not designed to help the user to perform tasks, but can be involved in personal experiences thanks to its specific physical, emotional, and behavioral characteristics (19).

Several studies in the literature have used the PARO robot with elderly patients diagnosed with dementia (20, 21). PARO provides indirect benefits for users by increasing their activity, their modalities of social interaction, including visual, verbal, and physical interaction, which vary between primary and non-primary interactors. Moreover, the positive effects of the PARO robot on older adults' activity levels have shown steady growth, suggesting they are not due to short-term "novelty effects". Finally, using the PARO robot has shown positive effects in therapy and a reduction in the use of antipsychotic medications.

A 2020 review of eight studies on older adults with dementia demonstrated that interventions using the PARO robot can be beneficial in improving the quality of life (QOL), affection, and social interaction, while reducing neuropsychiatric symptoms and psychotropic or pain medication use. This study identified three domains of outcome measures used to assess the effects of interventions using the PARO robot: QOL, biological and physiological conditions, and medical treatment (22).

However, only few studies have been conducted with the specific aim of evaluating the PARO robot effectiveness in improving ASD symptoms. For this reason, we aimed to investigate the effects of using a social robot in the treatment of children with ASD.

The PARO robot is an interactive robot created by Shibata and collaborators (23) that is modeled after an Arctic seal pup. The robot has a length of about 57 cm and a weight of approximately 2.8 kg. It is covered with soft fur (pink in our case). The robot can autonomously perform different types of movements (eyes, up-down and right-left head movements, front and lower fins) and is equipped with several sensors that make it sensitive to light and touch all over its body, allowing it to control its posture and body temperature and to recognize human voice and localize sounds coming from the surrounding environment. The PARO robot can exhibit three different types of behavior: reactive, proactive, and physiological. Reactive behavior is related to response to external stimuli. Proactive behavior determines the character of the robot and the need to sleep or to be stimulated and develops during interactions thanks to a neural network. Finally, physiological behavior is based on the sleep/wake rhythm and on the long-term memory that records different kinds of previous interactions. The state of the internal batteries also affects this third type of behavior (e.g., the PARO robot seems more tired when batteries are low) (23, 24).

However, the fact that the number of basic behaviors exhibited by the robot is finite allows the generation of a potentially infinite number of behaviors due to variation in the parameters of the neural network. This makes the PARO robot's behavior difficult to predict (24).

Methods

Experimental protocol

The sample consisted of 40 children aged between 3 and 5 years old (28 males and 12 females, mean age in months = 46; standard deviation (SD) = 7.87), divided into 4 groups: 10 children diagnosed with autism without intellectual impairment (7 males and 3 females, mean age in months = 44), 11 children diagnosed with autism with intellectual impairment (7 males and 4 females, mean age in months = 46), 10 children with expressive language disorder (8 males and 2 females, mean age in months = 44), and 9 with typical development (TD) (6 males and 3 females, mean age in months = 41). Participants were recruited from two different centers, respectively the "CRC Centro Ricerca e Cura" in Rome and the "Department of Human Neuroscience section of Child Neuropsychiatry of the Policlinico Umberto I" in Rome.

Participants were diagnosed with ASD after a comprehensive multi-disciplinary assessment with a child psychiatrist and psychologist, in accordance with international diagnostic criteria (DSM-5): the assessment included evaluation with ADI-R and ADOS-2, a validated test to define the level of development or cognitive level according to each patient's (e.g., Griffiths III, Leiter-3, WPPSI-IV). Children who received ASD diagnosis were also investigated for genetic screening (Fragile X, Array CGH) and EEG test.

The ASD group included patients with an ADOS-2 score higher than 8, an ADI-R scores higher than the cut offs for each area (10 as cut-off for social interaction, 8 for communication and language, 3 for repeated and stereotyped behavior area).

Patients with scores in the normal range in the developmental or cognitive test were included in the "autism without intellectual impairment" group.

Patients with cognitive or developmental impairment were included in the group "autism with intellectual impairment", according to the scores in the developmental or cognitive test,

About 30% of ASD patients showed aspecific abnormal waveforms in the EEG recording, with no clinical correlation that will be monitored in time. No ASD patients with diagnosis of epilepsy were included in the study.

About 10% of ASD patients showed genetic polymorphism, form parental segregation, not etiologically related to the neurodevelopmental disorder, according to genetic consultation. No ASD patients with syndromic genetic disorders were included in the study.

In our study a 15-minute videotaped play session was recorded for each child. Observations were performed in a room devoid of distracting stimuli. The room contained a large, padded carpet and a standard set of toys, including a ball, two cups, two saucers, two teaspoons, a toy car, a top, a cotton blanket, and a doll (Fig. 1).

Videos were recorded between October and December 2019 at the CRC and the Department of Child Neuropsychiatry at Policlinico Umberto I in Rome.

Each play session was divided into 3 phases:

- Phase 1: 5 minutes in which the child had the opportunity to freely play with the set of toys together with his/her mother and in the absence of the PARO seal. The operator was present but did not participate;
- Phase 2: 5 minutes in which the child had the opportunity to freely play with the set of toys and with the PARO seal on, in the absence of his/her mother. The operator was present and interacted with both the child and the seal;
- Phase 3: 5 minutes in which the child had the opportunity to freely play with the set of toys and with the PARO seal on, together with his/her mother. The operator was present but did not participate.

Between phases 1 and 2, both the child and his/her mother were asked to take a short break outside the playroom, during which the child had a short snack and did not have access to other playful stimuli. During this break, the operator inserted the PARO seal into the play setting.

The videotaped sessions were coded using some items of the "basic function assessment scheme" (25), by examining attentional skills, association skills, imitation, and interaction (Table 1). Coders were trained on the specific observational

Table 1. Observation grid items upon which the video encoding was based (25)

Category	Item
Attention – *focus interest on a stimulus or event*	Ability to orient the gaze; Ability to keep attention on an object; Ability to keep attention on an action; Ability to complete what begins; Too rapid changes from one activity to another; Excessive attention to detail.
Association - *ability to coordinate and perform two actions simultaneously*	Ability to watch and do; Ability to watch and listen; Ability to listen and do (execute instructions); Ability to speak and do (describe what you do); Motor response to sound, sight, voice; Non-linguistic responses to sound and sight; Verbal responses to sound, sight, voice.
Imitation - *reproduction of a behavioral model*	Imitation of gestures; Imitation of simple actions; Imitation of mimicry (smiles, grimaces, etc.); Imitation of sounds; Imitation of words.
Interaction - *mutual relationship between people*	Ability to share the gaze; Ability to share attention; Ability to share an action (or play); Ability to respect the alternation of shifts.

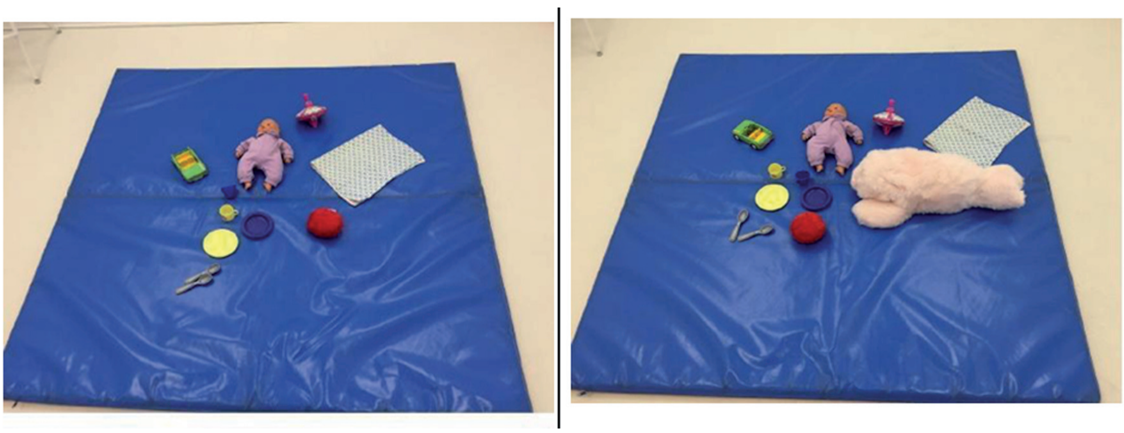

Fig. 1. Videotaped play session environment

scheme by an independent expert coder from Venuti's team, with whom they selected the areas of observation most pertinent to the study objectives.

Each item was allocated a score from 1 to 5 based on the child's ability level, where 1 corresponded to the absence of a behavior and 5 to very frequent and intense behavior, except for the 'too rapid changes from one activity to another' and 'excessive attention to detail' items, for which the absence of behavior corresponded to a score of 5.

In order to avoid any agreements due to chance and to detect the phenomenon under analysis, 30% of the sessions were analyzed by two independent observers whose encodings had to reach 75% agreement as calculated by a confusion matrix (26) adjusted according to Cohen's kappa (27). The agreement reached was 86%. The software used for the analysis was IBM SPSS Statistics version 25.

Results

Two types of statistical analyses were carried out:

- The Friedman test in order to observe variations in the same variables at different times (in our case between phases 1, 2, and 3).
- The Kruskal-Wallis test in order to ascertain the presence of a statistically significant difference in the distribution of variable scores between phases 1, 2, and 3 in the subgroups identified by the 'diagnosis' variable.

From the Friedman test, we observed significant differences in the 'interaction' dimension between phases 1 and 3 in the autism without intellectual impairment group ($p = 0.014$) and in the expressive language disorder group ($p = 0.006$), demonstrating an improvement in the quality of social exchanges due to the presence of the PARO seal (Fig. 2).

As regards the 'association' dimension, significant differences in scores emerged in the TD group between phases 2 and 3 ($p = 0.007$), showing an improvement in performance in this dimension with the insertion of the PARO seal and the mother (Fig. 3).

In the other dimensions, no significant differences in scores were detected (Fig. 4, 5).

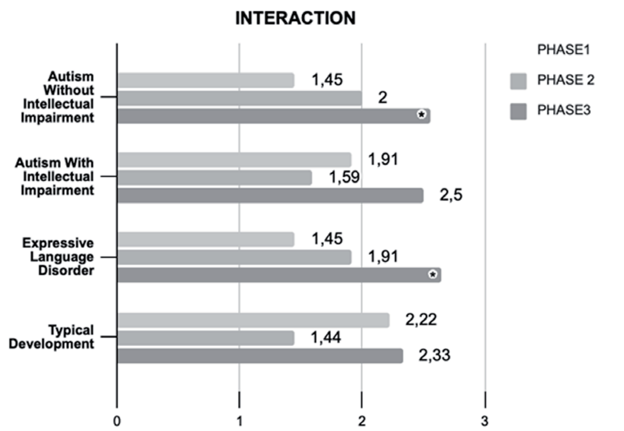

Fig. 2 Significant differences between phases in the 'interaction' dimension

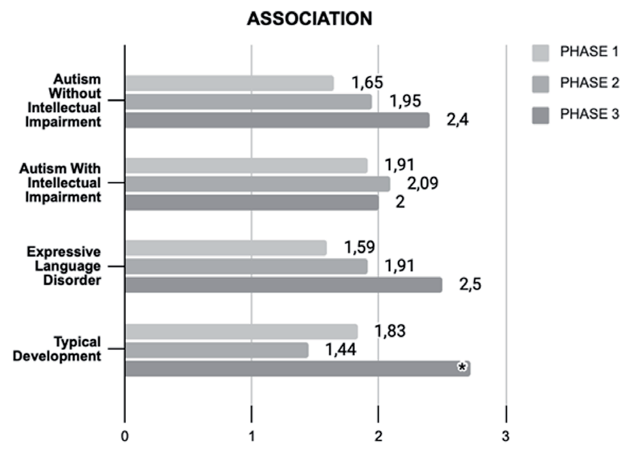

Fig. 3. Significant differences between phases in the 'association' dimension

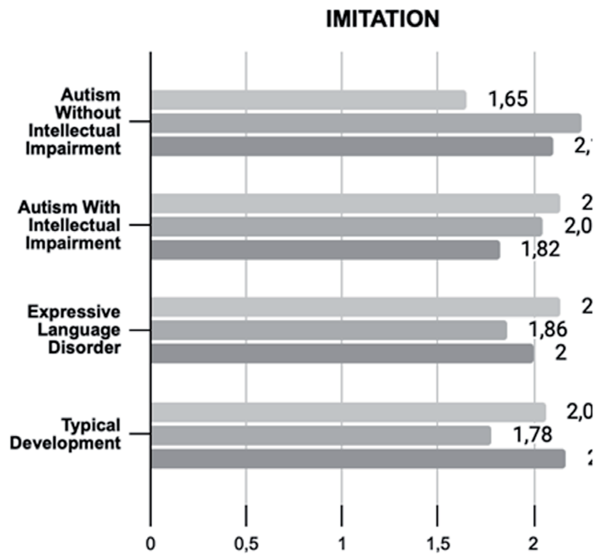

Fig. 4 Differences between phases in the 'imitation' dimension

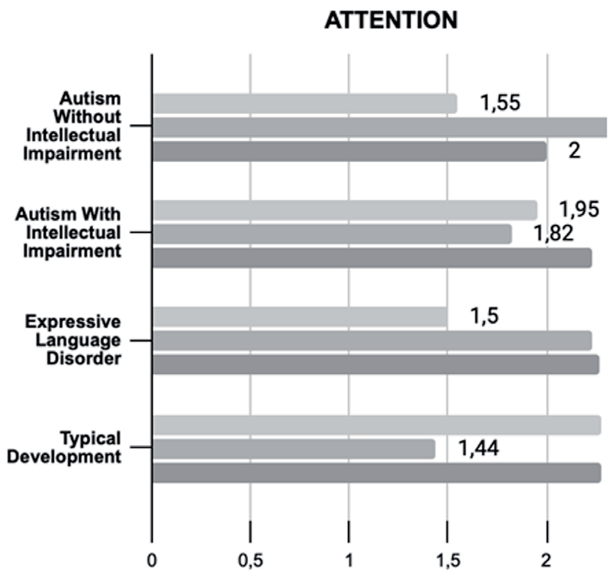

Fig. 5 Differences between phases in the 'attention' dimension

In phase 1, where only the mother and child were present, score distributions for the 'association' dimension differed significantly between the autism with intellectual impairment and expressive language disorder groups, the autism with intellectual impairment and autism without intellectual impairment groups, and the autism with intellectual impairment and TD groups, pointing to statistically significant differences between the autism with intellectual impairment group and the TD and expressive language disorder groups. In phases 2 and 3, score distributions differed significantly between the autism with intellectual impairment and expressive language disorder groups, the autism with intellectual impairment and TD groups, and the autism with intellectual impairment and autism without intellectual impairment groups, indicating statistically significant differences between the autism with intellectual impairment and TD, the expressive language disorder and the autism without intellectual impairment groups.

As concerns the 'attention' dimension, in all three phases and regardless of the PARO seal presence, score distributions differed significantly between the autism with intellectual impairment and expressive language disorder groups, the autism with intellectual impairment and the autism without intellectual impairment groups, and the autism with intellectual impairment and TD groups, indicating statistically significant differences between the autism with intellectual impairment and the expressive language disorder groups, the autism without intellectual impairment and the TD groups.

In phase 1, score distributions for the 'imitation' dimension differed significantly between the autism with intellectual impairment and expressive language disorder groups and the autism with intellectual impairment and TD groups, indicating statistically significant differences between the autism with intellectual impairment group and expressive language disorder and TD groups. Conversely, in phases 2 and 3, score distributions differed significantly between the autism with intellectual impairment and expressive language disorder groups, the autism with intellectual impairment and TD groups, and the autism with intellectual impairment and autism without intellectual impairment groups, indicating statistically significant differences between the Autism with intellectual impairment group and expressive language disorder, TD, and autism without intellectual impairment groups.

Finally, score distributions for the 'interaction' dimension differed significantly between the autism with intellec-

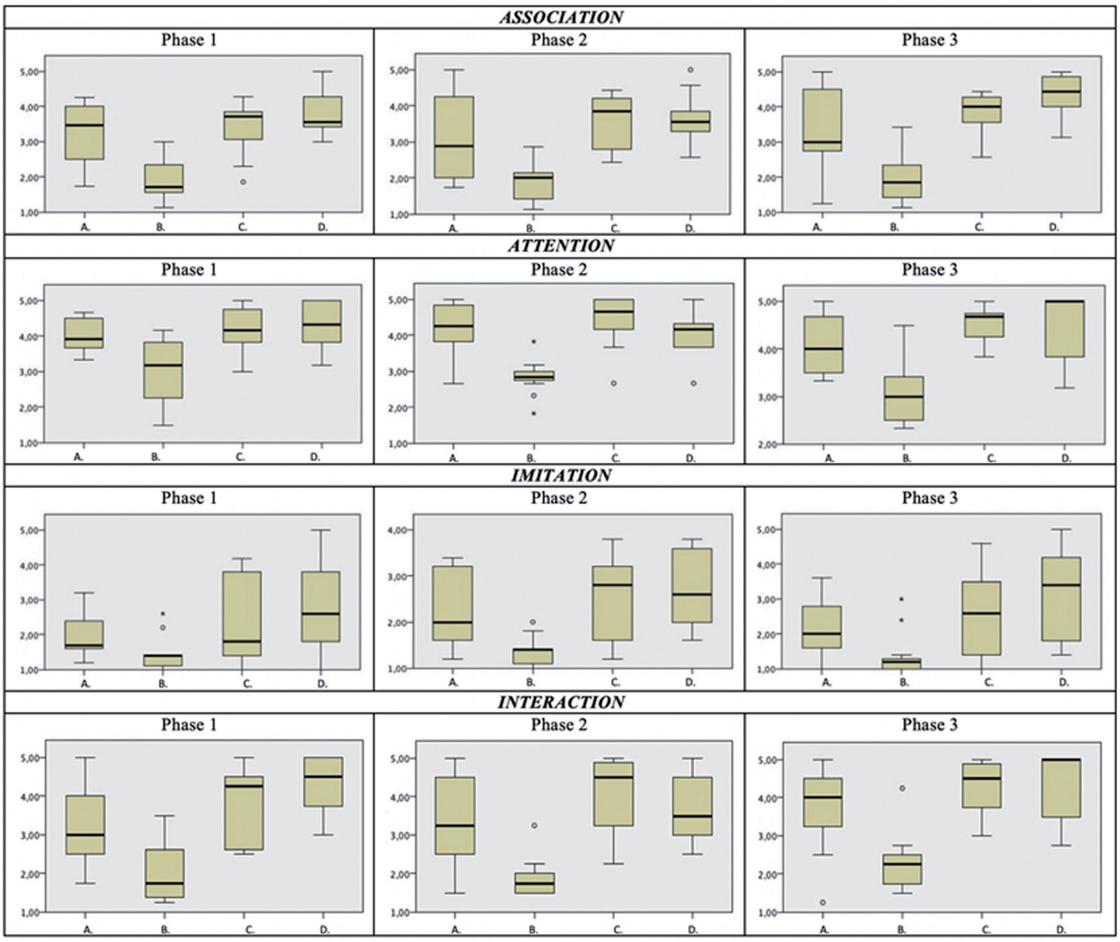

Fig. 6 Differences between groups in phases 1, 2, and 3

A: Autism without intellectual impairment
B: Autism with intellectual impairment
C: Expressive language disorder
D: Typical Development

tual impairment and expressive language disorder groups, the autism with intellectual impairment and autism without intellectual impairment groups, and the autism with intellectual impairment and TD groups, pointing to statistically significant differences between the autism with intellectual impairment group and expressive language disorder, autism without intellectual impairment, and TD groups.

Discussion

The results of our research partially confirm what has been reported in the existing literature, while introducing some innovations that could be addressed by future research. Regarding the ‘interaction’ dimension, the results of the statistical analysis showed a positive correlation between the presence of the PARO seal and performance in this area in subjects diagnosed with autism without intellectual impairment. These data highlight the PARO robot’s ability to facilitate communication and social skills in children with autism without intellectual impairment. Our analysis therefore seems to confirm the hypothesis that the use of social mediating robots can improve social skills for children with ASD. In fact, previous studies using different types of social mediating robots observed that participants with ASD showed better social performance when interacting with robots as compared to humans (28, 29, 10).

However, our data appear to contradict literature findings regarding autism with intellectual impairment children. We did not find any significant differences in the ‘interaction’ dimension with the introduction of the PARO seal (9), thus suggesting that its use may not be indicated for children with a diagnosis of that kind. Furthermore, this group showed significantly lower performance in all areas as compared to all other groups. These findings offer an interesting starting point for further studies, which are particularly needed considering the scarcity of studies conducted with the specific purpose of evaluating the effectiveness of social robots in improving ASD symptoms.

Further noteworthy findings concern children with expressive language disorders, who seem to show similar performance to those with autism without intellectual impairment in the ‘interaction’ dimension – a finding that is consistent with existing literature (10). Statistical analysis showed a positive correlation between the presence of the PARO seal and performance in this area in the expressive language disorder sample, indicating an improvement in socio-communication skills when children were playing with their mother and the PARO seal, as compared to when the PARO seal was absent. This finding is significant especially when considering the substantial difficulties these children have in language and communication, and could represent a focus for future research.

Finally, the normative sample represented by children with TD showed performance worsening in the ‘association’ dimension when the PARO seal was introduced, and no significant differences were found for children with TD in any other area. This could be because children with TD are more reassured by the presence of their mother, rather than by the PARO seal, and are able to carry out association skills requiring the combination of more than one single skill.

Limitations and Conclusions

Our study has some limitations that need to be mentioned. One concerns the small sample size, the other regards gender distribution: the number of males (29) was quantitatively higher than females (12). While this distribution is in line with the higher frequency of all neurodevelopmental disorders in males, it may not guarantee sufficient heterogeneity.

Several operators have been involved in the protocol administration and the videorecording activities, and this may have played a part in creating uncontrollable differences.

To conclude, the results of the present study confirm the fact that social robotics can represent a valid tool to improve socio-communication skills in clinical samples of children with autism without intellectual impairment and expressive language disorder. Future research should focus on this area in order to offer new knowledge within the scientific and rehabilitative domains.

Statements and Declarations

The authors have no competing interests to declare that are relevant to the content of this article.

The study was approved by the ethics committee of Sapienza University of Rome and performed in compliance with the Declaration of Helsinki (2000). Written informed consent was obtained from the participants’ parents.

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