# A systematic review of the effect of robot-mediated interventions in challenging behaviors of children with autism spectrum disorder

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**Abstract.** Autism Spectrum Disorder (ASD) is characterized by deficits in social and communication skills as well as restrictive and repetitive behavioral patterns. A variety of challenging behaviors in children with ASD and persistent non-compliance with daily requirements may be associated with delay in the development of social skills and impairing social relations, with an adverse effect on the educational process and on the self-esteem of individuals. To this aim, there is a need for appropriate interventions, targeted at reducing these behaviors. Robot-mediated interventions (ROMI) can be advantageous for children with ASD, who often show an increased interest in technology enhanced interventions. Research focusing on the effect of ROMI on challenging behaviors in children with ASD has been limited. For this purpose, it was conducted a review of studies that empirically tested the usefulness of ROMI in managing challenging behaviors in children with ASD. A literature search was made in five databases using keywords pertaining to robots, ASD, challenging behaviors, and interventions. Nine studies were reviewed which met the inclusion criteria. The findings of these studies indicate that ROMI show promise in reducing challenging behaviors such as tantrums, repetitive and stereotyped behaviors, inappropriate behaviors in transitions. In terms of non-compliance, mixed results were presented. Further research is needed to explore the usefulness of robots both in reducing challenging behaviors of children with ASD and in preventive exercises in early intervention programs for this population.

## 1 Introduction

Individuals with Autism Spectrum Disorder (ASD) display qualitative impairment in social communication and social interaction as well as restricted, repetitive, and stereotyped patterns of interests, behavior, and activities [1]. Delays in the development of these skills in children with ASD, may result in a variety of challenging behaviors such as aggression, self-injury, disruption, stereotypy, tantrums, destruction of objects [2-5], and persistent non-compliance with daily requirements that place them in demanding situations [5]. Such behaviors can cause difficulties for both the individuals with ASD and the people around them, including their parents, carers, health professionals, educators, and even members of the community [6, 4]. They may have an adverse effect on the development of social relations, the educational process of children with ASD, and on their self-esteem [7, 8]. They

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are likely to prevent the individual's independent living and generally impair their quality of life.

In addition, there is a positive correlation between challenging behaviors and anxiety, suggesting the association of higher levels of anxiety with higher levels of challenging behaviors [9]. School-age children with ASD present anxiety related to changes in daily routines. Routine requests can trigger attempts to escape. Behaviors associated with anxiety may worsen when demands increase and this sequence of behaviors is likely to lead to a vicious circle of interactions regarding daily routines that progressively erodes the parent-child relationship [5]. To this aim there is a need for appropriate intervention, targeted at the problems associated with challenging behaviors, including non-compliance [10].

Robot-mediated interventions (ROMI) can be advantageous for children with ASD, who demonstrate increased interest in technology enhanced interventions. Robots can act as simplified agents to enhance the interaction with the child with ASD. The environment of the reciprocal action with the robot is controlled and is more predictable than interaction with humans, and it gives children with ASD a sense of security, with the result that they experience less exasperation [11, 12]. Interaction with robots has been shown to help children with ASD to increase desirable behaviors such as joint attention, imitation, communication, turn taking, and triadic interactions.

Despite the positive effects observed with ROMI, robots cannot approximate the richness of human interaction. However, they can be as effective as the human partner at teaching specific skills such as imitation and social initiations [13]. Robots can be a useful tool in the hands of experts to achieve the desired goal. They can be adapted to meet the unique needs of each child [14]. Using a robot as a tool to improve the behavior of the child towards other people could potentially lead to positive results. Research interest focusing on the effect of ROMI on problem behaviors in children with ASD is currently scarce. For this reason, a review of studies was conducted that empirically tested the efficacy of ROMI in managing challenging behaviors in children with ASD.

Specifically, the research questions focused on the review were the following: 1) Are repetitive and stereotyped behaviors reduced in ROMI? 2) Are aggression and tantrums reduced in ROMI? 3) Is non-compliance reduced in ROMI?

## 2 Method

For the purposes of the review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement, was used [15]. A systematic review was chosen, as the purpose was to collect the currently available empirical data, in order to critically appraise and synthesize the research results, and to raise questions for future research [16].

### 2.1 Literature Search

A literature research was conducted for publications for the period from 2011 to 2021 in the databases of Scopus, PubMed, Web of Science, MEDLINE, and Google Scholar using a combination of the keywords "Autism or Autism Spectrum Disorder" and "Robots or Robotics" and terms referring to "Challenging behaviors" (e.g., aggression, self-injury, tantrums, disruption, stereotypy, repetitive behaviors, non-compliance), and "Interventions". The combination of the above keywords was applied to each database.

### 2.2 Eligibility criteria

To be included in the review the publication should: 1) be in English, 2) targets interventions with robots delivered explicitly to children with ASD, and 3) incorporates measurements of challenging behaviors in children with ASD. Publications were excluded that 1) constitute a technological description of the robot, 2) do not report on intervention, and 3) are not an empirical study.

### 2.3 Data Extraction

Data were extracted from the eligible papers, using data forms including key components of the study characteristics, methodology, and results. Outcome measures were recorded that assessed aspects of problem behaviors, including but not limited to measures of challenging behaviors of children with ASD. All the studies included in the review provided data on participants, the target behavior, the type of robot used in the intervention, the outcome measures, the research design, and the findings. Depending on the target behavior, some research questions were raised (3 in total).

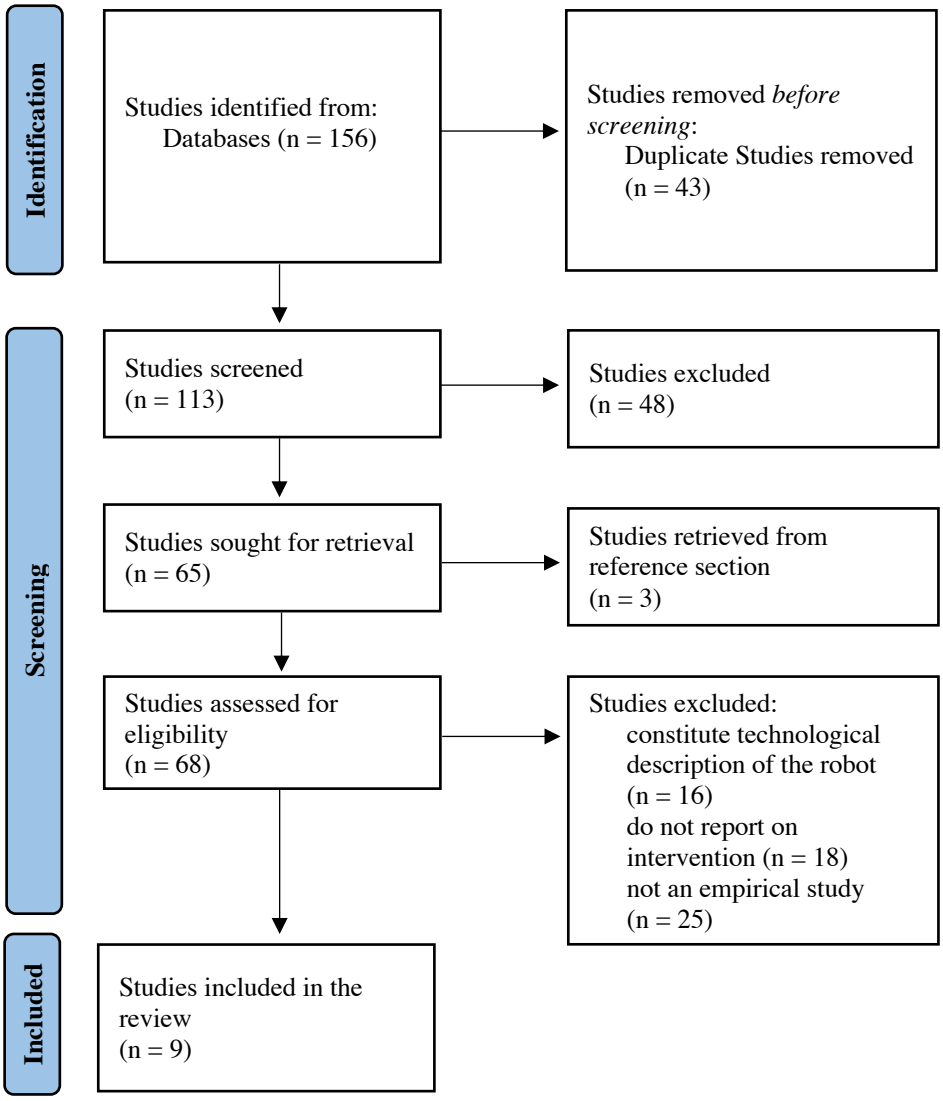

**Fig. 1.** PRISMA flowchart depicting the literature search and selection of studies included in the review of ROMI in children with ASD.

### 2.4 Search Results

The initial research has revealed 156 potentially relevant studies (Figure 1), of which 43 were duplicate. The title and abstract of the remaining studies were further evaluated for inclusion in the review and 48 studies were deemed ineligible and were excluded. The reference section of the remaining studies was investigated, resulting in 4 supplementary studies. The 65 initial and the 3 additional studies were reviewed taking into account the inclusion and exclusion criteria. Of those 68 studies, several were excluded because they constituted a technological description of the robot (n=16), did not report on intervention (n=18), or were not an empirical study (n=25), and finally 9 studies were included in the systematic review.

## 3 Results

### 3.1 Participant characteristics

Data on the number, gender, and age of the children participating in the studies were provided in all the 9 reports included in the review. The number of participants in the studies ranged from 2 to 36 and the total number was 88 of which most were boys and only 12 girls. The age of the children ranged from 3 to 14 years old, with a mean age of 6.99 years. Only one study did not state the mean age of the participants. The characteristics of the participants in the studies reviewed here are presented in Table 1.

### 3.2 Use of robots

Five different robots were used in the studies included in the review. The robot most commonly used was the humanoid robot NAO which was used in five of the nine studies. The robots QTrobot, RovioTM, and Zoomer were each used in one study and Troy in two. Most of the robots, were humanoid. Of the two non-humanoid robots, one was an animal-like robotic dog and the other a mobile robot. The choice of robot was determined by the activities that the researchers used to attain the defined behavioral goals. The teaching of skills that focus on simple interactions, imitation, and turn-taking is more easily achieved using robots with anthropomorphic shape [13, 17-19]. Their complex expressions manage to stimulate children's interest for longer periods of time on the activity and also facilitates the generalization of the behaviors that have been taught [13, 14, 17].

### 3.3 Intervention studies

#### *3.3.1 Repetitive and Stereotyped behaviors*

Repetitive and stereotyped behaviors (RSBs) are a characteristic feature of ASD and the term includes a range of behaviors such as stereotyped and/or repetitive motor movements, repetitive use of objects or speech, compulsive behavior, perseveration, obsessions, rituals, sameness, restricted behaviors, stereotyped use of language, and self-injury [20, 21]. RSBs affect the functioning of children with ASD, diverting them from flourishing interaction with their environment and impending their acquisition of social and academic skills [20, 22] and for this reason, interventions targeted at reducing RSBs in children with ASD are important.

In most studies that used ROMI it was observed that children engaged in fewer RSBs [18, 23, 24]. Only one study found that ROMI led to some increase in RSBs in the children with ASD [25] and one showed no training-related changes [26]. In three studies the interaction of the children with ASD with the robot was based on one session [18, 23, 24] while the other two utilized multiple sessions [25, 26]. Regarding the training, the researchers used rhythmic synchrony-based exercises and imitation games with movements of the lower and upper body of gradually increasing difficulty [23, 26]. It was shown that these activities help children with ASD to become aware of their bodies, to strengthen the sense of self, and to improve coordination. In this way, some of the unwanted RSBs can be restricted in a pleasant and playful way [23]. The researchers also used turn-taking games and simple modules of interaction with the robot [18, 24, 25]. Robots can be adapted to meet the unique needs of each child. Using a robot as a tool to improve the behavior of the child towards other people could potentially elicit positive results.

### *3.3.2 Tantrums and aggression*

Individuals with ASD often exhibit more than one challenging behavior and aggression, tantrums, and property destruction are among the most common [27]. The transition from one situation to another often impedes children with ASD and may provoke challenging behaviors such as tantrums. For example, children with ASD may cry when the bell rings and they have to go to the classroom for the lesson, or when they do not want to leave their toy at home, or when they are told to brush their teeth before going to bed. In addition, they may experience difficulty in following specific steps to complete an activity, resulting in inappropriate behavior. Tantrum behaviors include intense outbursts and lack of self-control, crying, screaming, shouting, hitting, breaking things, or running away. Tantrum behaviors and aggression towards others tend to be consistent with the age of the child [28, 29].

Whitmer [29] explored the effects of a ROMI on tantrum behaviors in 4 children with ASD. Each child participated in a multiple-baseline designed program with a variety of session types and follow-up sessions. Tantrum behaviors in ROMI decreased for 3 of the 4 children. The activities conducted during treatment with the robot consisted of a triadic interaction including the child's parent, a graduate student clinician, and the child, with the robot acting as another interactive partner. Triadic interactions help the children not only to learn the desired skill, but also to achieve generalization of what they have learned, when interacting with other people around them [14].

Beaudoin et al. [30] explored the feasibility of using two intervention technologies, the humanoid robot NAO and a wearable haptic device, separately, to facilitate transitions in occupational therapy sessions for children with ASD and as a method to document behavioral changes. They used a single case reversal (ABA) design with two participants. Each child participated in one of the two situations. The humanoid robot was used to facilitate transitions during the intervention sessions, e.g., to announce transitions in the activities. Only one refusal behavior was observed in transitions during the sessions. Because tantrum behaviors can occur during daily activities, and particularly during transitions between activities and events, the researchers used the robot as a warning signal to inform the children of the coming change. In this way they are made aware of what is to come and are given enough time to process the data and prepare for the upcoming changes [30]. Furthermore, David et al. [25] observed that ROMI led to some increases in aggression while at the same time to an improvement in adapted behaviors such as orienting behaviors and integration efforts.

### *3.3.3 Non-compliance*

Children with ASD may exhibit persistent non-compliance with daily requirements which place them in demanding situations [5]. In the study of Silva et al. [31], the goal was to explore whether dogs can help children with severe ASD in complying with challenging demands. They used a within-subject design, where the participants were exposed to three conditions (a preferred toy, a live dog, or a robotic dog) before facing a challenging situation. Compliance was observed to be higher with the live dog than with the robot. Free play interaction with the live dog included changes that facilitated emotion regulation and compliance with the demanding requirement.

Nelson [32] investigated the use of a humanoid robot to facilitate compliance with two types of directives in four children with ASD. Pre- and post-intervention assessment of compliant and non-compliant behavior was conducted. Two of the four children appeared to make gains in compliant behavior in response to physical manipulation from their mother. Of the two other participants, one showed no difference after the intervention and the other showed a decrease in compliance. The same result was observed for compliance with verbal directives; two of the four children manifested improvement in compliant behavior.

**Table 1.** Summary of the studies on robot mediated intervention in children with ASD included in the review.

| **Authors** | **Participants (number, gender age, diagnosis)** | **Target behavior** | **Robot** | **Outcome measures** | **Research Design** | **Results** |
|---|---|---|---|---|---|---|
| Shamsuddin et al., 2013 [18] | n=6 (5m, 1f) 5-13 years, LF-ASD | RSBs | H robot NAO | GARS-2 Subscale score | Single session | Reduced RSB in ROMI |
| Costa et al., 2018 [23] | n=15m 4-14 years, ASD | RSBs | H robot QTrobot | Number of chains of RSBs was counted | Single session | Reduced RSBs in ROMI |
| Ismail et al., 2012 [24] | n=6 (Nm) years=Nm, ASD | RSBs | H robot NAO | GARS-2 Subscale score | Single session | Reduced RSB in ROMI |
| David et al., 2020 [25] | n=5 (3m, 2f) 3-5 years, ASD | RSBs, Aggression | H robot NAO | Frequency of challenging behaviors | Single case alternative treatments design | ROMI led to some increases in RSBs and aggression |
| Srinivasan et al., 2015 [26] | n=36 (32m, 4f) 5-12 years, ASD | RSBs, Self-injury, Non-compliance | H robot NAO & mobile robot Rovio™ | Frequencies of challenging behaviors | RCT | No training-related changes in challenging behaviors |
| Whitmer, 2015 [29] | n=4 (2m, 2f) 4-9 years, ASD | Tantrums | H robot Troy | Presence of tantrum behaviors | Multiple-baseline design with various session types | Tantrums decreased in ROMI for 3/4 children |
| Beaudoin et al., 2021 [30] | n=2 (1m, 1f) 4-7 years, LF-ASD | Aggression, Tantrums, Self-injury, Rituals | H robot NAO | Frequency of refusal behavior | Single case reversal design | Only one refusal behavior was observed in |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | transitions during sessions |
| Silva et al., 2017 [31] | n=10m 6-9years, LF-ASD | Non-compliance | Robotic dog Zoomer | Presence or absence of non-compliance | Within-subject design | Compliance was higher with the live dog than with the robot |
| Nelson, 2013 [32] | n=4 (2m, 2f) 4-9 years, ASD | Non-compliance | H robot Troy | Child's responses to the directives given by their parent over the 5′ interaction | Single subject multiple baseline design | 2 out of the 4 children manifest improvement in compliant & decrease in non-compliant behavior |

n: number, m: male, f: female, ASD: autism spectrum disorder, LF: low functioning, ROMI: robot mediated interventions, RSBs: repetitive and stereotyped behaviors, RCT: randomized controlled trial, H robot: humanoid robot, GARS-2: Gilliam Autism Rating Scale-Second Edition; Subscale of Stereotyped Behavior, Nm: not mentioned

## 4 Discussion

The literature search produced 9 studies that met the inclusion criteria of this review. The studies differed in the number of children participating and their level of functionality. Five different robots were used in the 9 studies, most of which were humanoid, and the choice of the robot was determined by the activities that the researchers used to achieve their intended behavioral goals. Both group-based and single-subject designs were used in the studies. Group based designs can play a key role in determining the importance of an intervention, but single-subject design can add significant value to the research. Both types of design constitute a quantitative approach that aims to establish causal relationship by manipulating an independent variable, measuring a dependent variable, and controlling extraneous variables [33]. The two types of research design differ and the choice between the two depends on the number of participants, the nature of the intervention, and the specific research questions.

Depending on the target behavior, three research questions were raised in the studies reviewed. The first question was whether RSBs are reduced in ROMI. The study results indicated that ROMI shows promise in reducing RSBs in children with ASD. Three studies reported positive results [18, 23, 24] and only one an increase during the intervention [25]. Those studies differed in the research design, duration, and the number of participants who took place in the intervention. The differences in the results among the studies can be attributed to the duration of training. Brief interactions with the robot can lead to positive results [18, 23, 24] while the extended duration fails to maintain the desired behavioral results [25, 26]. In addition, the type of training chosen in each case affects the research results. Simple interactions with the robot, such as imitation games or turn-taking games can reduce RSBs. Conversely, when the intervention involves complex interactive skills, the robot may not be so appealing due to its technical limitations. Imitation games requiring rapid body movements that simulate natural movement permit greater effectiveness when presented by the human mediator due to the fact that the robot is much slower, and its responses are slightly delayed [26].

The second research question was if ROMI leads to a reduction in aggression and tantrum behaviors in children with ASD. It was observed that tantrum behaviors decreased when the robot interaction came at the beginning of the session [29]. During transition, which often disturb children with ASD, provoking challenging behaviors, only one refusal behavior was observed [30], indicating that the use of interactive humanoid robots can help reduce specific challenging behaviors in children with ASD during transition. Only in one study some increases in aggression were observed [25] while in one no training related changes were found [26].

The third research question focused on the ability of ROMI to reduce non-compliance in children with ASD. Three studies explored this dimension, and the results of intervention were mixed. In one study, the use of a live dog led to a reduction in non-compliance to a greater extent than the animal-like robotic dog [31]. In the other study, two of the four children demonstrated compliant behavior and decreased non-compliant behavior [32] while in the third no training related changes were observed. Further research should be conducted with a larger sample and more controlled conditions.

In closing, the role of the robot in the treatment of children with ASD needs to be discussed. A robotic facilitator appears capable of playing a mediating role in dealing with stressful situations and other difficulties experienced by children with ASD, resulting in challenging behaviors. It should be emphasized that the purpose of using the robot in interventions with children with ASD is not to replace human partners, but to facilitate and reinforce specific behaviors in children with ASD [34].

## 5 Limitations and future research

The objective of this review was to investigate the usefulness of ROMI in managing challenging behaviors in children with ASD. The review had a number of limitations, the most significant of which was the restricted quantity of available studies, based on the inclusion and exclusion criteria. Despite the small number of studies, this review presented a promising body of research concerning the usefulness of ROMI in the management of challenging behaviors in children with ASD, although methodological limitations precluded comparisons, as each study had a different research aim, design, sample size, sample characteristics, measurements and variables.

Data manifest beneficial outcomes in the behavior of participants when interacting with the robot. That fact highlights the need for further exploration of the usefulness of robots both in reducing challenging behaviors in children with ASD and of their utilization in early intervention programs with this population. More extensive research with larger samples of children will be needed for validation of the study results, including a follow-up period, as some of the studies did not include follow-up assessment. If consistent findings are confirmed by replication and follow-up, some conclusions could be drawn about the effectiveness of each intervention, providing better understanding of the usefulness of ROMI, both under clinical and experimental conditions and in routine practice.

## 6 Conclusions

This systematic review explored the usefulness of ROMI in managing challenging behaviors in children with ASD. Robots appear to be a useful tool in the hands of experts to achieve the desired goal of moderating challenging behavior that interferes with everyday activities. They can be adapted to meet the unique needs of each child. Using a robot as a tool to improve the behavior of children with ASD in their interaction with other people could potentially lead to positive results. The few relevant studies reviewed here, despite their methodological

diversity, demonstrate beneficial outcomes in modifying the behavior of children with ASD when interacting with a robot. These preliminary findings indicate the need for further exploration of the usefulness of robots, both in reducing the challenging behaviors of children with ASD and for preventive purposes in early intervention programs with this population.

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