Robotic Tool to Improve Skills in Children with ASD: A Preliminary Study

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Abstract- **Children with autism spectrum disorders (ASD) may present some difficulties in developing social behaviours, communicating with others and acquiring cognitive skills. In this study, we test the introduction of a robot Lego Mindstorms NXT as a mediator and/or positive reinforcement in the intervention of children with ASD in triadic interventions. The goal was to improve their academic skills and to transfer the acquired skills to their daily lives. Three case studies with 8-13 years old children are presented and discussed. The explored target skills were the concept of quantity, colour awareness and a gesture to make a request. Parents had an active participatory role in this study, especially in the Skill Transfer Phase.**

Keywords- Autism Spectrum Disorders; Assistive Robotics; Social Interaction; Lego Mindstorms NXT

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is characterized by behavioural changes and can be diagnosed with multiple degrees of severity in the early years of life. This disorder affects the way individuals interact with others and with their environment. Difficulties in social communication and cognitive skills as well as repetitive, restricted and stereotyped behaviours, activities and interests are some of the characteristics of this spectrum [1, 2, 3, 4].

The National Autism Society (NAS) presents the Triad of Impairments. This triad divides the impairments of people with ASD into three groups: 1) social interaction – they have difficulties in maintaining adequate behaviour in society leading to social isolation; 2) social communication – they have some difficulties in establishing contact with others, experience difficulties in verbal and non-verbal communication; and 3) social imagination – they tend to be unable to engage in simple games and have difficulties in generalized learning [2, 5].

The origin of ASD is not completely clear. However, recent studies indicate that a person with ASD is genetically predisposed at birth to the disorder [5, 6]. At the moment, there is no cure for ASD, but there exist many methods for intervention in people with ASD such as Treatment and Education of Autistic and Related Communications Handicapped Children Method (TEACCH), Applied Behaviour Analysis (ABA), Picture Exchange Communication System (PECS), and the Developmental, Individual Difference, Relationship-based (DIR®/Floortime™) [7].

The core ideas of TEACCH are based on: 1) finding a pronounced adaptation at home by setting the environment to allow for the sharing of activities, and including parents in the intervention; 2) elaborating a personalized intervention program which permits an individual evaluation and intervention; and 3) structuring the learning environment through the daily routines shown in frames, agendas or posted on walls [7].

ABA method consists of applying methods of behavioural analysis to correct actions. Thus, the skill is individually taught and the success of the answer is positively reinforced. However, if the child manifests inappropriate behaviour, positive reinforcement must not be given [7].

PECS method aims to encourage children with ASD to initiate an activity by a figure and persist in the communication until the peer answers. This method may be an alternative to verbal communication. It has a very clear and detailed manual treatment which allows for the simplification of the learning process [6].

The Floortime method is based on affective relationships. The professionals or parents sit on the floor with the child. During the interaction it is important to maintain mutual attention engagement and encouragement. Challenges will then be purposed to the child. The advantage of this model is to direct the child to resolve the challenges in a friendly way. As a result, many skills may be developed with the child during this intervention [8].

Professionals and parents are encouraged to promote and engage the children in the interventions. However, the disorder may complicate the intervention as the children have difficulties in concentration, have a gap in motivation and attention and, present disabilities in cognitive skills and as a result are often distracted [9].

Robotics is a multidisciplinary area, having several applications namely, in the biomedical area. Research has highlighted the importance of the use of robots in the development of competences namely, their use in areas such as a learning and

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practicing tool in the development of skills and, in the provision of feedback or encouragement. This area has also created new opportunities to innovate support mechanisms for children with ASD [10, 11].

Research carried out with interactive robots and individuals with ASD has demonstrated a high level of response and interest when electronic and robotic components are applied [12].

Following this trend, this study focused on exploring the use of a robotic platform to improve some academic skills in children with ASD. In particular, the explored target skills were the concept of quantity; colour awareness and a gesture to make a request, exploring also these skills in order to transfer them to the family's daily life. The robot assumed the role of mediator and provided feedback or encouragement.

II. PURPOSE OF STUDY

This study is included in the Robótica-Autismo project developed at University of Minho in collaboration with the Special Education Unit of a group of schools in the north-west of Portugal.

The aim of this study was to evaluate the effect of introducing a robotic platform in the intervention of children with ASD, promoting the learning of new skills as academic or cognitive abilities. The robot must be a complement to the daily intervention. Therefore, the interaction must be performed between the investigator, the child with ASD and the robot, encouraging a triadic relationship.

Thus, the expected changes in children's behaviour are: autonomy, communication and interaction skills, attention and eye contact and the learning of academic and cognitive skills.

The core of this study is how the robot can support the learning of skills and promote interaction and communication skills in children with ASD. As a result, the robot has a role of positive reward, as the children can explore and manipulate the robot only when they have successfully performed the activity.

III. STATE OF THE ART

Today, there are new technologies that appear as a complement to the intervention in ASD. Robots are one of these new technologies that allow for the support of intervention mechanisms of children with ASD, improving several skills like communication, cognitive development and interaction. Below are some papers that have been developed in the past years.

The project AuRoRa (AUtonomous RObotic platform as a Remedial tool for children with Autism) has been developing some robots with the aim of studying the effect of using autonomous robots to engage children with ASD in several tasks. This may allow for the development of social skills like eye contact and joint attention [13]. The work developed allowed for the understanding that the robot was safe and that the children were not afraid. Thus, the robot motivated the children to interact with it [2, 13]. In this project some robots like Robota and KASPAR were built.

The humanoid robot Robota has more complex activities and interactions than the previous robots, being able to describe sequences and make combinations of actions. The main role is to engage children with ASD in imitation games. This doll-shaped robot can evaluate the answers of the children to basic human characteristics, such as eye gaze, expressiveness of the face, and basic social interaction [13]. One of the studies performed with Robota analysed the effect of the exposure to a humanoid robot on children with ASD. Thus, the children showed interest in the robot and after continued exposition, they considered the robot as a mediator between them and the investigator [15].

Another robot built for this investigation group in the AuRoRa project was KASPAR (Kinesics and Synchronisation in Personal Assistant Robotics). It is a humanoid robot able to express emotions with less complexity than a human face [16]. KASPAR was specially developed as a social robot to improve and promote the communication and interaction skills in children with ASD. KASPAR can express emotions, such as happiness, neutral, sadness and surprise [17]. This robot was built to promote social skills in children with ASD, such as imitation, turn taking, and join attention. In the interaction with KASPAR, the children can also learn or improve body awareness [16].

The Interactive Robotic Social Mediators as Companions (IROMEC) project started in 2006. This research group studied the way in which a robotic toy can be used as a social mediator, encouraging children with special needs to play several games. These games can be played either alone or in cooperative play [16]. The game scenarios were developed bearing in mind the needs of the children. The main areas that these games intend to help are sensorial and cognitive development, communication and interaction skills, motor development, and emotional and social development. Thus, the IROMEC robot allows for several scenarios which permit different experiences to develop particular skills. All scenarios were developed considering the competences that each child needs to improve and also, several areas of development: sensorial and cognition development, communication, interaction, motor, emotional and social development [18].

Keepon is a simple robot with a snowman-like body able to interact with verbal language, direct its gaze and to express emotions like pleasure and excitement [19]. Keepon can be controlled by a remote control and so it can direct its gaze to the children or to an object promoting joint attention. It can also react emotionally when the child performs an important social

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interaction. Thus, when the child looks at the same object that Keepon is looking at, it can jump and dance to express its excitement. This reaction can encourage the child to maintain attention. Keepon can also encourage the child to interact with peers, promoting triadic interactions [16].

At University of Minho in 2009, the research project Robótica-Autismo (www.robotica-autismo.com) was launched which involves robots and ASD. In this project, the robot Lego Mindstorms NXT was used. The aim was to improve the social life of individuals with cognitive impairments like ASD. The robot was used as a mediator of activities to improve the interaction and communication skills of people with special needs [20, 21, 22].

IV. METHODOLOGY

This paper aims to apply a robotic platform in the intervention of children with ASD by encouraging them to learn skills. Therefore, we intend to verify if the robot is a suitable promoter in the child learning process. Thus, there are some questions that need to be answered, namely: “Can a robot promote the academic learning skills in children with ASD?”; “Can a robot be an appropriate tool to maintain child’s attention?”. Below, the methodology used to answer these questions is described.

This work was developed in five stages. In the first, a protocol was established with a group of schools in the north-west of Portugal. A target group was then selected and the informed consents were signed. The activities for each child were defined and the experiments were performed. Finally, the results were analysed.

A. The Robot

The robot used in the experiments was a Lego Mindstorms NXT (www.lego.com). It is a modular, and low cost robot which can be activated using different types of sensors such as touch, sonar, light and sound. It can be built in several forms, for example in a human-like or a non-human-like shape. In this work, the robot shown in Fig. 1 was used.

Fig. 1 The Lego Mindstorms NXT Robot

It is possible to program the robot using the LEGO MINDSTORMS Education NXT Software which is released in robotics kit Lego. This software is simple, and permits the programming of the Lego robot by dragging and dropping blocks. When the program is concluded, it can be sent to the NXT brick by a wireless bluetooth connection or a USB cable.

The Lego robot is suitable for children with ASD because it allows for several forms; children with ASD can freely handle the robot without the risk of breaking components; the robot attracts their attention due to its repetitive and mechanical movements; and the robot holds the attention of children as they can explore and manipulate it during the experiments [19, 20, 21].

B. Environment

The experiments were performed in two classrooms of the Special Education Unit at an elementary and secondary school in the north-west of Portugal (Fig. 2).

Fig. 2 Classrooms where experiments took place

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In each room, three cameras were placed in order to obtain as much information as possible during the experiments. All experiments were set up in the same way and recorded on video. The alignment of the cameras was carried out in the following manner: the main camera was placed in such a way as to record the face of the child to see where he/she was looking; the second camera was placed to capture the entire experiment; and a third camera was used to follow the movements of the lower members performed by the child. The child sat in front of his/her partner (researcher, parents or unknown person to the child), at the other end of the table.

The elements of each experiment were: the child, the partner, the robot, a rail, different colored balls (two blue balls, two red ones and an orange one) depending on the chosen activity, a bag where the balls were placed and colourful cards.

C. Target Group

Initially, a protocol between the Rector of University of Minho and the director of a group of schools was established. The group of schools informed those legally responsible (parents) about this work and about the inclusion criterion of the study participants and obtained the signed consent. These criterions were: children with ASD diagnosis with moderate severity levels; children included simultaneously in a regular class and in structured learning units regulated by a decree of law 3/2008 and, children supported by a team of professionals in the area of Special Education.

The team which selected the children was constituted by parents, teachers specialized in ASD and psychologists and speech therapists. 14 children with ASD aged between 6 to 16 years who attend elementary and secondary school were selected as part of the study group.

These 14 children represent different levels of interests and competences in the areas of verbal and non-verbal communication, social interaction, independence and academic skills which were encountered in the analyses of the individual process of each child, namely in the Individualized Education Program.

The team selected some of the competences for each child which could be developed with the support of the Robot. This selection was completed by way of individualized analyses of the objectives of the Individualized Education Program. Simultaneously, the objectives emerged from the answers obtained from parents and the case coordinator professional in the evaluation questionnaire regarding the competencies and interests of the children.

The questionnaire intended for the parents included a group of questions related to the activities carried out, the different ways the child uses to communicate and the child’s level of response to the activity. These responses were given according to the Likert scale with response levels of 1 to 5 namely: never (1), rarely (2), occasionally (3), frequently (4) and always (5). In some situations, parents could choose “not applicable”.

The professional’s questionnaire was composed of a conjunction of open-ended questions which attempted to characterize the competence levels in different areas of development of the child, interests, learning styles and effective learning strategies.

The participants in this study were constituted by fourteen children with ASD between the ages of six and sixteen years. Eight children were in elementary school and six in secondary School.

The study intended to adapt the activities to each child, promoting specific competences that children were lacking of. After six experiments, it was possible to observe that not all children had the same motivation and due to the low complexity of activities allowed by the Lego robot, some of the high-performance children successfully accomplished all the activities. Therefore, it was necessary to adjust the methodology of the study by selecting the target children and specifying the particular activity for each child. As a result, it was necessary to adjust the number of participants, reducing the sample size from 14 to 3 children. Thus, this final target group was considered a more homogeneous sample (Table 1).

TABLE I CHARACTERIZATION OF THE TARGET GROUP

Child	Gender	Age	Characteristics	Goal
A	Female	8	She does not possess verbal language, She does not know how to count.	Concept of quantity
B	Male	10	He does not possess verbal language. He is not aware of colours.	Colour awareness
C	Male	13	He does not possess verbal language. Language by images. Mental retardation.	Gestures to make a request.

D. Activities

The experiments consisted of 10 to 12 sessions of 10 minutes each in the classroom.

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In all the activities described below, the robot had the role of mediator/positive reinforcement. On the one hand, it is a mediator because it maintains the attention of the child engaged in the activity. On the other hand, it is the positive reinforcement because when the child performs the activity successfully, she/he has the possibility to manipulate the robot before returning to the task.

There were three prepared activities to perform:

1- Gesture to make a request (Fig. 3). The aim of the activity is to teach the child to ask for something he/she wants. In this way the interaction between the child and the partner is also developed. Thus, in this activity each child has to use a gesture to ask for the ball with the robot being the mediator/positive reinforcement for this activity. In the end, we want the child to be able to use the gesture to ask for any object of daily life. If the child is successful in the performance of the activity, he/she is rewarded with the robot.

Fig. 3 Experiment of the activity Gesture to make a request

2- Concept of quantity (Fig. 4). The researcher asks the child for a given number of balls (one to three). Initially, the investigator shows the number of balls (modeling) and then the child must give the researcher the same number of balls as in the model. In the end, we wanted the child to be able to give the right quantity by using objects found in daily life without any model. If the child is successful in the performance of the activity, he/she is rewarded with the robot.

Fig. 4 Experiment of the activity: Concept of quantity

3- Colour awareness (Fig. 5). The goal is to introduce the colour concept, namely blue, red, yellow and green colours. The researcher shows the colour (model) and then the child must throw the ball of the same colour asked for. If the child is successful in the performance of the activity, he/she is rewarded with the robot.

Fig. 5 Experiment of the activity: Colour awareness

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E. Project ́s Phases

The project methodology was divided into five different phases: Definition of Methodology, Pre-test, Practice, Re-test and Transfer of Skill. Table 2 details and explains each phase.

TABLE II PHASES OF THE PROJECT

Phase	Description
1) Definition of Methodology	Initially, there was a meeting held between the researchers, psychologists and professionals, in order to define the strategies of the study and methodologies to apply during the experiments. Then, each child was analysed according to the skills to be developed and defined and the activity was then planned. A questionnaire was delivered to parents and professionals, with the purpose of knowing the skills of the children.
2) Pre-test	This was the first contact between the researcher, the child and the robot. The robot was used as a positive reinforcement to perform the task and acted as a mediator.
3) Practice	The activity was then introduced in the individual routine of the child and the experiment was performed twice a week, for three weeks.
4) Re-test	Re-test allows for the evaluation of the consistency of learning. After three weeks of practice, a Re-test was performed. This involved one session and was performed within the same parameters of the previous sessions.
5) Transfer of Skill	The evaluation of the transfer of skill was divided into two experiments of this phase which were similar to the last experiments, except that the robot was removed, the partners were changed and the activity was performed with objects in daily life of the children. Thus, the first experiment was performed with the child with ASD and an unknown person in the classroom. The second experiment took place with the child and a known person (mother or father of child), but in this case, the experiment was performed in a familiar context. Thus, the parents had an active role in this proceeding. In addition to this evaluation the professionals and the parents were given a final assessment questionnaire in order to monitor the progress of the child's skill.

Table 3 characterizes each phase in terms of participants, number of performed sessions, their duration and frequency. The experiments ran for two months.

TABLE III PHASES CHARACTERIZATION

Phase	Participants	Number of sessions	Session Duration (min)	Frequency (day)
Pre-Test	Investigator, Child and Robot	1	10	1
Practice	Investigator, Child and Robot	6	10	2 (3 weeks)
Re-Test	Investigator, Child and Robot	1	10	1 day
Transfer of Skill	Parents and Child Unknown person and Child	2	10	2

V. ACTIVITIES ANALYSES (INDICATORS)

As previously mentioned, the experiments were recorded on video. In order to analyze the videos regarding children's behaviour, a coding scheme was created. This scheme allowed us to quantify the success of the experiments and the influence of the robot.

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These indicators were included in three different categories (Table 4): reaction to the robot (Reaction), spontaneous interactions with the robot (Action) and interaction time in minutes (Time).

TABLE IV INDICATORS TO ACTIVITY ANALYSES

Reaction	**Action (freely)**	**Time**
1.Ignores the robot (Ignore)	1. Indicates intention to the manipulation of the robot (Manipulate)	1- Interaction Time
2. Demonstrates typical manifestations (Manifest)	2.Answers the task (Response)	
3. Focuses on some detail (Fixed)		

The first category presented in Table 4 includes some common behaviour patterns found in children with ASD: ignoring the activity, namely the robot and the partner, no eye contact which corresponds to the Ignore indicator. The Manifest indicator, which refers to the stereotyped manners of the child as: hand-flapping or body rocking. The indicator that counts the number of times that the child focuses on a particular detail is the Fixed indicator. The second category includes free interaction with the robot (Manipulated indicator) and response to the proposed activity (Response indicator). The last category quantifies the time of interaction between the child, the researcher and the robot in 10 minutes (Interaction Time indicator).

The indicators of the first and second columns are counted according to the number of occurrences; the indicator of the third column refers to the time that the child keeps interacting with the researcher. In the end, it is possible to draw a graph of the child's performance during the experiments.

After five seconds of the occurrence of the indicators Ignore, Manifest, Fixed, if they are still active they are counted again; otherwise, they maintain the same value until another occurrence is detected.

VI. RESULTS

Only the results of the target group (three children after the readjust) will be presented below.

In Fig. 6 and Fig. 7 it is possible to see the obtained results for the activity concept of quantity performed with child A in terms of response indicator and interaction time, respectively. The number of responses of the child was almost the same as the orders given by the researcher. In the first experiment, the child could not manipulate the robot; she could only observe the robot moving as it was only activated by the researcher. In the following experiments, the child could freely manipulate the robot. Therefore, the interaction time increased, although the time devoted to the order/answer activity was lower (the number of order and responses decreased). In the seventh experiment, the colour of the balls was changed which could have influenced the decrease in the number of responses given by the child as well as in the interaction time. After the seventh experiment, the number of responses increased and the child performed the activity successfully. Except for Experiment 7, the interaction time was around 8-9 minutes.

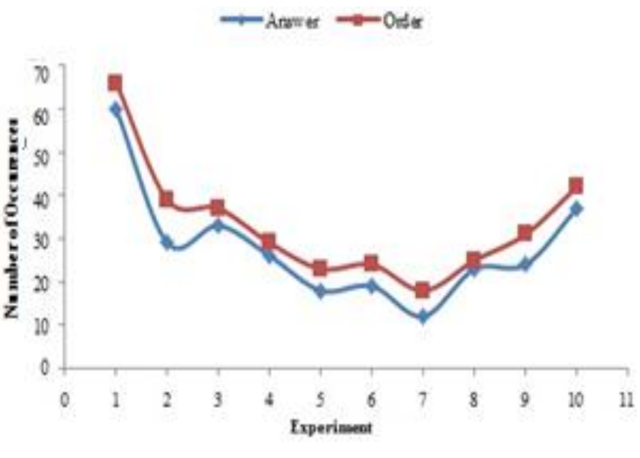

Fig. 6 Response indicator: Number of Order and Answer occurrences for child A – activity concept of quantity

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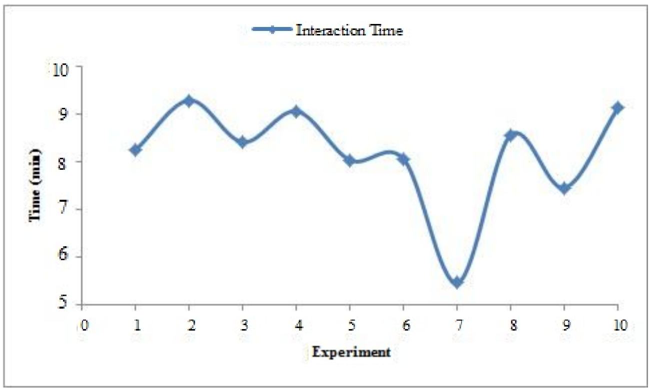

Fig. 7 Interaction time indicator for child A– activity concept of quantity

In Fig. 8 and Fig. 9 it is possible to see the obtained results with child B with whom the colour awareness concept was encouraged. In the second experiment, the number of orders and the number of responses were similar. However, the interaction time decreased abruptly possibly because the child was very restless. The interaction time increased to a stable value in the next experiment. In the last two experiments, the balls were replaced by objects of the children's daily lives, namely pencils, spoons, toys, bread, among others. In the tenth experiment, the activity was performed without the robot and the partner was an unknown person. This may have had an influence on the number of responses and on the interaction time. These two indicators had a strong decrease indicating that the child was not engaged in the activity. Experiment 11 was performed at home with the children's mother and without the robot. As indicated in the graph, the interaction time increased to a stable value and the order/answer indicators matched.

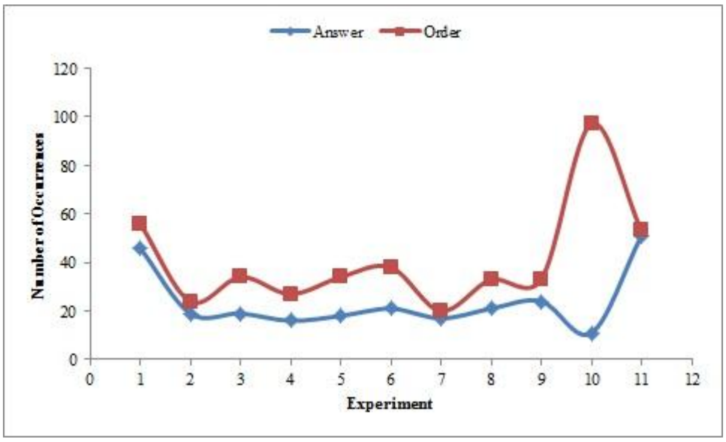

Fig. 8 Response indicator: Number of Order and Answer occurrences for child B – activity colour awareness

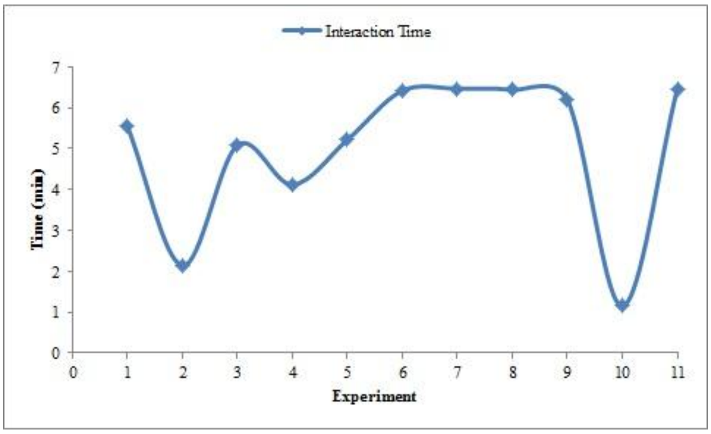

Fig. 9 Interaction time indicator for child B– activity colour awareness

Finally, the results of the third child are shown in Fig. 10 and Fig. 11. This activity developed the skill gesture to make a request. This child is low-functioning, so during the experiments the number of responses was very low. In the last experiment the child answered more effectively and the number of responses was approximately the same as the number of orders. The interaction time was unstable but in last experiment, this indicator gradually increased. With either the unknown person or with the parents, the child answered very well.

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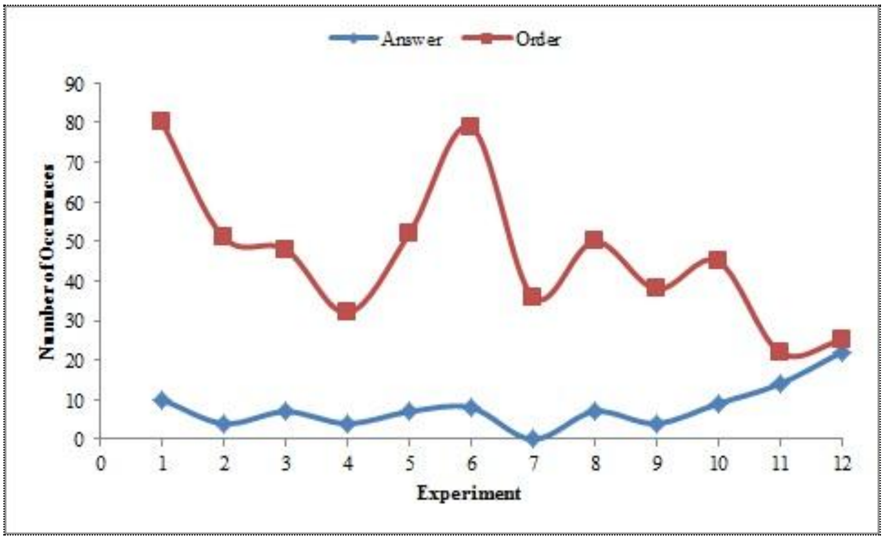

Fig. 10 Response indicator: Number of Order and Answer occurrences for child C – activity Gesture to make a request

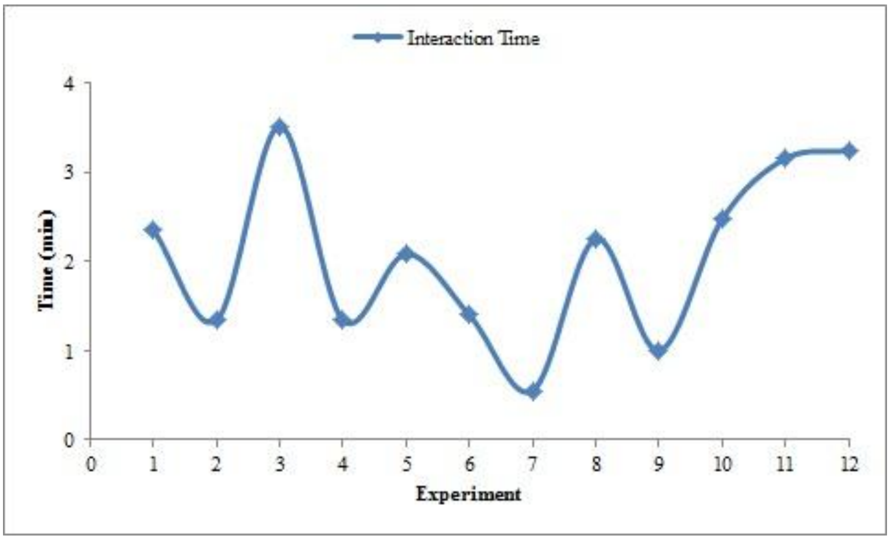

Fig. 11 Interaction time indicator for child C– activity Gesture to make a request

VII. LIMITATIONS AND FUTURE WORK

The preliminary work presented focuses on the use of robotic platform, in particular, Lego robot, to promote the interaction and communication with ASD children.

There are some aspects that may affect this intervention such as the state of mind of the children and the subjectivity of the analysis of social behaviour of children with ASD. Another point in this study is the reduced dimension of the target group. This limitation is referred in various studies [10]. A larger sample size will permit to increase the validity, and the possibility to generalise these results.

Child A learned the concept of quantity. Before the experiments, the child could only associate equal quantities when the model was shown. After all experiments were completed, the child was able to give the correct quantity to the partner. The success of this experiment was also observed in the skill transfer phase, where the child was able to use the new skill in his/her daily life with objects, such as pencils, spoons and toys. Therefore, parents' feedback in the final assessment questionnaire was very positive and motivating.

Regarding the second child (child B), he was inconsistent in performing the activity of colour awareness. However, the child increased the interaction time and the attention span in the activity. Yet, not all the responses were correct. Also, parent's feedback was very positive and they believed that the behaviour of their child had improved his eye contact and the attention time.

Finally, in the activity performed with the third child (child C) it is possible to conclude that the activity was accomplished with success. In the final experiments the child was able to ask for objects found in his daily life with a gesture.

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In this preliminary study, the children revealed behavioural changes and acquired new skills, which can be seen in the analyses of the results, together with the final evaluation carried out by parents and professionals in a final questionnaire which indicated the competencies and current behaviour of the child in school and at home context at the end of the intervention.

The reports provided by parents and professionals demonstrate the importance of using the robot in acquiring competencies in children, as shown by the analysis of the strata presented. Teachers referred that: “The robot motivated the child to learn with great success in such a way that he/she had never done before”; “This was advantageous because it was more of a training exercise to increase the time which the child spent on the task and the amount of attention that was focused”; “The notions were acquired in a playful manner, which contributed to the success in the acquisition of new knowledge”.

Parents also stressed the advantages of using the Robot referring that: “I had a greater notion in terms of……”; “My child demonstrated more attention and eye contact”; “I was able to use the advice provided regarding food”, among others.

The robot may have been an attractive and important tool due to its repetitive and mechanical movements in the learning process which highlighted competencies and promoted enjoyment experiences. These results were possible due to the collaboration of families and professionals.

We would also like to underline the importance of parental involvement in the entire planning and intervention process, which permitted us to carry out the final investigation session in a family context. In this way, the child had the opportunity to transfer the acquired competencies in the school environment to the real and functional life situations of the family.

Although it is considered that the transfer of competencies is one of the most important aspects of this study, in future studies it is necessary to determine whether this transfer of competencies is maintained throughout time, in different locations and contexts.

Therefore, can the robot in fact attract children's attention while supporting learning? As a result, further studies are being designed in order to validate this type of intervention in children with ASD.

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