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Evaluation of a Robot-Assisted Therapy for Children with Autism and Intellectual Disability

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Abstract. It is well established that robots can be suitable assistants in the care and treatment of children with Autism Spectrum Disorder (ASD). However, the majority of the research focuses on stand-alone interventions, high-functioning individuals and the success is evaluated via qualitative analysis of videos recorded during the interaction.

In this paper, we present a preliminary evaluation of our on-going research on integrating robot-assisted therapy in the treatment of children with ASD and Intellectual Disability (ID), which is the most common case. The experiment described here integrates a robot-assisted imitation training in the standard treatment of six hospitalised children with various level of ID, who were engaged by a robot on imitative tasks and their progress assessed via a quantitative psychodiagnostic tool. Results show success in the training and encourage the use of a robotic assistant in the care of children with ASD and ID with the exception of those with profound ID, who may need a different approach.

Keywords: Autism Spectrum Disorder, Intellectual Disability, Socially Assistive Robotics, TEACCH, VB-MAPP.

1 Introduction

Autism Spectrum Disorder (ASD) can often comorbid with some level of Intellectual Disability (ID) [20], in fact it has been reported that 54% of children with ASD have an Intellectual Quotient (IQ) below 85 [3], which encompasses four ID levels: “mild”, “moderate”, “severe” and “profound”, characterised by significant limitations in both intellectual function and in adaptive behaviour. These limitations result in problems with reasoning, learning or problem-solving as well as communication and social skills difficulties. Imitative deficits are very often observed in children with ASD [9, 23]. The presence of ID makes therapeutic interventions more difficult and, therefore, there is need of the technological aid [7].

Considered the complexity and the wide amplitude of this “spectrum”, which encompasses different disabilities and severity levels, it is appropriate the use of a multimodal intervention that can be adapted to the individual’s needs in order to obtain the best benefits from the therapy. As the same medicine cannot be offered to all types of patients, similarly robot interactions need to be customized as per the state and conditions of the individual patients [18]. Therefore, the controllable autonomy of robots has been exploited to provide acceptable social partners for these children [1]. Indeed, several studies have shown that some individuals with ASD prefer robots to humans and that robots generate a high degree of motivation and engagement in individuals who are unlikely or unwilling to interact socially with human therapists (see [16] for a review). Recent studies have successfully presented robots as mediators between humans and individuals with ASD [10]. For instance, Duquette et al. [8] show improvements in affective behaviour and attention sharing with co-participating human partners during an imitation task solicited by a simple robotic doll.

Furthermore, social robots may be especially beneficial for individuals with ASD who face communication difficulties because practicing communication can be less intimidating with a robot than with another person [2, 12].

For this reasons, robotics research has shown numerous benefits of robot assistants in the treatment of children with ASD [5, 17, 22] however, most of the studies focused on ASD individuals without ID or neglected to analyse comorbidity. In fact, very little has been done in this area and it could be considered as one of the current gaps between the scientific research and the clinical application [4]. The aim to use robots in a clinical setting is to reduce the therapist’s workload by allowing the robot to take over some parts of the intervention. This includes, monitoring and recording the behaviour of the child, engaging the child when they are disinterested, and adapting between levels of intervention. This enables the therapist to oversee different children and plan the required intervention for every child on an individual basis [10].

However, while a qualitative analysis is usually considered by the previous research, e.g. via analysis of video-recorded human-robot interaction, the quantitative analysis that can be made through the use of standardized psycho-diagnostic tools is often lacking [7, 11].

The work presented here is part of the ongoing EU H2020 MSCA-IF CARER-AID project, which aims to fully integrate a robot-assistant within a standard treatment of hospitalised children with ASD and ID, i.e. the TEACCH (Treatment and Education of Autistic and related Communication Handicapped Children) approach [13].

The main aim of the present study was to verify the applicability of the robot-assisted therapy to lower ID levels, which are the most difficult to treat as support for a psycho-diagnostic and training tool previously standardized and validated in the psychological field. To this end, we introduced in the therapy a robot-assisted intervention, in which the rehabilitation tasks were developed and adapted to the children level according to a psycho-diagnostic instrument: Verbal Behaviour Milestones Assessment and Placement Program (VB-MAPP) [19], which is a standardised tool designed for children with ASD. In fact, the tool was used at the beginning (Ex-Ante) to identify the tasks to implement on the robot, and at the end (Ex-Post) of the training to quantitatively assess the result of the robot-assisted therapy.

2 Materials and Method

2.1 Participants

Six children (n=6, Males=6, *M*-chronological age=104.3 months, range= 66-121, *SD*=18.6), all males, were selected among patients diagnosed with ASD and ID. Specifically two participants were diagnosed with profound ID level, two severe ID level, one moderate ID level and one with mild ID level, as shown in Table 1.

Table 1. Participants description (Age in months)

P	CA	Leiter IQ	AE	ID Level
01	103	22	22	Profound
02	121	22	22	Profound
03	118	27	29	Severe
04	116	38	31	Severe
05	66	53	26	Moderate
06	102	56	35	Mild

For each child, Table 1 presents the Age Equivalent (AE) expressed in months, which is calculated as the average of the *Growth Scores* (GS) associated to the different Chronological Age (CA) groups. These are based on the performance of typically developed children in the test manual [19].

All the participants are currently receiving treatment at the IRCCS Oasi Maria SS of Troina (Italy), a specialized institution for the rehabilitation and care of intellectual disabilities. Participants' ASD and ID levels have been diagnosed before the beginning the study with the standard psycho-diagnostic instruments: Leiter-R, WISC, PEP-3, VABS, ADI-R, and CARS-2. For more details and explanation see [6]. All children had verbal language absent or limited exclusively to verbal stereotypes.

All children follow a clinical daily program of training using the TEACCH approach with psychologists and highly specialized personnel. The core of TEACCH is that structured teaching can effectively work with children with autism.

Ethical approval was obtained, all the parents signed consent forms before their children were included in the study. The robot-assisted therapy could be discontinued at any time if the therapeutic team believed it was appropriate for the child.

2.2 Verbal Behaviour Milestones Assessment and Placement Program (VB-MAPP)

Gross motor imitation abilities of the participants were evaluated using the Verbal Behaviour Milestones Assessment and Placement Program (VB-MAPP) [19]. The VB-MAPP is a criterion-referenced assessment tool, curriculum guide, and skill tracking system that is designed for children with developmental disabilities. VB-MAPP considers skills that are balanced and sequenced along three different levels of child development (1=0-18 months, 2=18-30 months, and 3=30-48 months).

We administered the VB-MAPP in the standard form to each participant to evaluate the level of the participants in order to identify the starting level and program the robot training accordingly. The VB-MAPP protocol evaluates each milestone score by giving 1 for the correct fully execution of the task, 0.5 a partial execution, 0 for error or no imitation.

2.3 The Robot and the Experimental Procedure

The robot used for experimenting the robot-assisted therapy was the Softbank Robotics Nao, which is a small toy-like humanoid robot, very popular for child-robot interaction studies [5], [7]. Nao is 58 cm high, weights 4.3 kg and can produce very expressive gestures with 25 degrees of freedom (DoF) (4 joints for each arm; 2 for each hand; 5 for each leg; 2 for the head and one to control the hips). Nao can detect faces and mimic eye contact moving the head accordingly, it can also vary the colour of LEDs in eyes' contour to simulate emotions, and it can capture a lot of information about the environment using sensors and microphones. Nao is programmed with a graphical programming tool, named *Choregraphe* [15].

The robot was programmed to implement the VB-MAPP tasks of levels 1 (Fig.1), which were then adapted and applied to match the specific level of the participants.

Gross Motor Imitation			
Stomp one foot		Left/hold 1 leg (bent at knee)	
Kick		Stomp both feet together	
Lift foot/point toes up & down		Squat	
Shake foot		Cross legs standing	
Place feet together		One foot in front of other	
Spread feet apart		Cross legs sitting	
Place foot forward		Stomp both feet (alternating)	
Place foot backward		Tap table with palms	
Hop with two feet		Turn palms up and down	
Hop on one foot		Elbows at waist/palms up	
Clap hands		Elbows at waist/palms down	
Arms up (over head)		Elbows at waist/palms sideways	
Arms out to side		Hands together over head	
Hands to cheeks		Make circle to side with 1 arm	
Hands cover mouth		Make circles to side with 2 arms	
Arms out in front		Grab wrists	
Arms out to back		Wave with hand/up & down	
Arms to side/move up and down		Wave with hand/side to side	
Hands on head		Rub hands (palms together)	
Hands on shoulders		Wash hands movement	
Hands on knees		Tongue out	
Hands on waist		Tongue out & side to side	
Touch toes		Tongue out/up and down	

Fig. 1. Tasks of VB-MAPP (level 1) that were implemented with the robot. For each child, we selected 3 tasks (T1, T2, T3) that he was not able to perform and trained him with the assistance of the robot.

The robot-assisted tasks were designed after preliminary evaluation and planning with the therapeutic team, who administered the VB-MAPP for the experiment. After analyse performance in each relevant skill area the clinician selected for each child, three gross motor imitation tasks (T1, T2 and T3) that the children were not able to do or did not perform properly, i.e. that received a milestone score of 0 or 0.5.

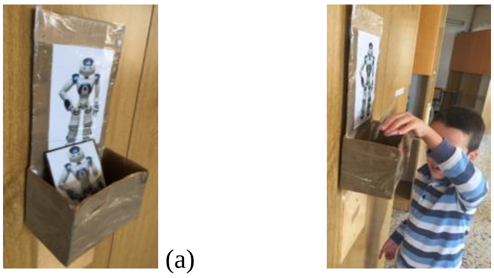
The experimental procedure comprised a preliminary session to decrease the novelty effect. The robot was presented to all the children in a non-therapeutic setting for a total of approximately 10 minutes.

The actual experimentation started after 7 days following the preliminary encounter. The experimental study includes a total of 14 training encounters over one month, i.e. 3 sessions per week. The experiments were carried out in the same room in which is where children usually do their treatment sessions.

Each session was approximately of 6-8 minutes per child including 1-minute breaks to let children rest. The gross motor imitation procedure was repeated six times for each task, and video was recorded by NAO.

In this paper, we present the results after the first 7 training encounters.

The robot-assisted therapy was included in the TEACCH program among the standard activities, which are identified via a specific visual schedule (Fig. 3a and b). Visual schedules are designed to match the individual needs of a child. A visual schedule communicates the sequence of upcoming activities or events through the use of objects, photographs, icons, words, or a combination of tangible supports. A visual schedule tells a child where he/she should be and when he/she should be there.



(a) (b)

Fig. 2. (a) the *visual schedule* for the robot-assisted therapy; (b) A child returning the visual schedule after a daily session.

During a training encounter, the robot was deployed on a table, in order to be approximately at the same height of the child, initially at a distance of at least 1 meter. The child was allowed to move backwards or forwards to be more comfortable.

Taking into account the Proximal Development Zone [21], we decided to engage the children with activities of a slightly higher level of their current competencies, but still simple enough to be comprehended.

The training encounters comprised three sessions, one for each task. In each session, the children were encouraged to imitate the task performed by the robot. Tasks were proposed daily in a randomized modality to avoid stereotypical learning. First, the robot verbally presented the behaviour to perform in a simple and clear language, then, it solicited the child to imitate its movements while doing them (Fig. 4).

The robot addressed the child by his name to make the intervention more personalized. At the end of each session, the child was free to rest in an adjacent area in the room about for 1 minute.

Fig. 3. An example of training with robot-assisted.

A professional educator, selected among those involved in the everyday treatment, was always present to represent a "secure base" for the children [4]. The educator used *prompts* in order to encourage the production of a new behaviour in presence of a defined stimulus. During sessions, the educator's *prompts* were systematically reduced so that the behaviour produced by the child became responsive to the stimulus and not to the *prompt* response. The professional educator gave a positive verbal reinforcement ("good" and/or "right") along in some cases with a physical reinforcement (a caress). Moreover, the types of reinforcement used have been previously defined with clinicians and consisted of reinforcement variation. These reinforcements were different for each child and were connected directly to responses, behavior and to the child's difficulties.

2.4 Measures and Evaluation

Before the start of the experiment to evaluates the impact of the robot-assisted imitation therapy, the therapeutic team administered the VB-MAPP psycho-diagnostic and training instrument. The VB-MAPP was administered Ex-Ante by a qualified clinician, without the robot.

To further analyse the child behaviours during the interaction, used the imitation criterion [6], which is the percentage of time the child was actively imitating the robot's movements when prompted.

The interactions were recorded using the NAO webcam to measure the children's tasks during the sessions. After, all video episodes of the tasks were coded separately by two researchers, with the use of a record sheet divided into seconds, who were separately compiled. Inter-coder agreement score was 0.94, producing a reliability (measured by Cohen's kappa) of 0.85. Discrepancies were resolved via discussion.

3 Results and Discussion

In Figure 4, we report the comparison between the time spent by the children in imitating the robot movements in the first therapeutic session (Ex-ante) and the improvement shown after the robot-assisted training (Ex-post). In both cases, the children were interacting with the robot without educator *prompts*.

Fig. 4. Imitation time. The graphs show the percentage of time spent by each child (P01-06) in imitating the robot. Ex-ante is the result at the first encounter, before the robot-assisted training. Ex-post is the increase of imitation time at the end of the robot-assisted therapy.

Children P01, P02 slightly increased their imitative time, but this didn't result in learning any of the imitative tasks as shown in Figure 5. This is because, even if they tried, the imitation was partial and incorrect. All the others significantly increased their imitation time and were able to successfully execute the imitative tasks after the training with the robot.

Figure 5 reports the scores of VB-MAPP psycho-diagnostic instrument Ex-Ante (before the robot-assisted training) and Ex-Post (after the robot training).

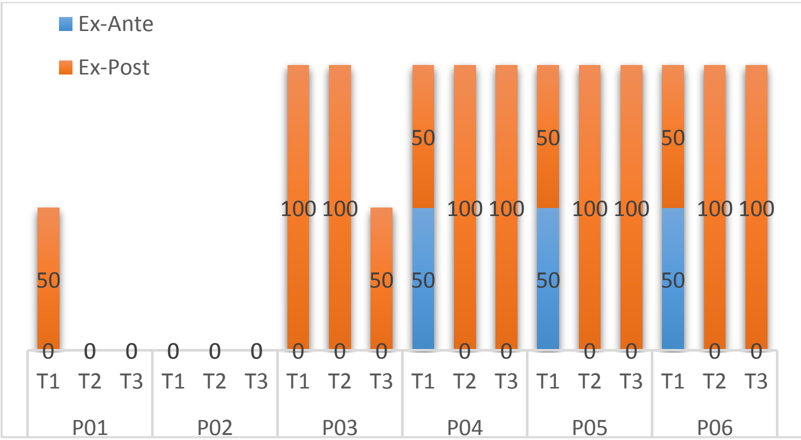


Fig. 5. Score of VB-MAPP for each task (T1, T2, T3) Ex-Ante and Ex-Post the robot training

We can see that in the Ex-Ante condition all 6 children had a score of 0 and this is because the tasks were selected among those the children were not able to perform. Only in three children and for a single task (T1) the initial score was 0.5, i.e. a partial and incorrect execution of the task (blue line).

Children with mild, moderate, and severe ID were successful at the end of the therapy, in fact they were able to perform adequately the VB-MAPP tasks. On the other side, two children with profound ID did not benefit from the robot-assisted therapy as they were not able to perform any task. This is could be due to their mental age equivalent to less than a 2 years old child that identify also difficulties in comprehension of stimuli. However, in the psychometric assessment P01 increased T1 to 0.5, i.e. he was able to learn a partial execution, even if not fully correct.

The video analysis shows that all children increased the time spent in imitating the robot. More significant is the progress of those that learned how to perform the task, while it is negligible, around 5%, the increase of the two children that were not successful.

4 Conclusion

Results of our clinical experiment confirm that the robotic-assisted therapy can be successfully integrated into the standard treatment of autistic children with mild, moderate and severe intellectual disability. Indeed, the scores of the psycho-diagnostic instrument VB-MAPP show that these children significantly increased their imitative level and acquired the capability to perform three new tasks.

However, the participants with a profound intellectual disability did not learn any tasks and show a modest (5%) increase in the gross motor imitation of the robot. This is related to their mental conditions as both children have been diagnosed with profound ID and have difficulties in comprehending the stimuli. In fact, children with more intellectual disability were less engaged than other participants. In this regard, their behaviour with the robot was comparable to their behaviour with other human beings. This result is also supported by the studies of Pioggia et al. [14], where the participants who got less benefit by the robot-assisted therapy were the ones with a more severe form of autism and also with the lowest IQ.

This suggests that there is the need to find more advanced solutions and approaches for persons with profound ID. This is the case that requires more care and, thus, the robot-assisted therapy may be very welcome by the therapeutic team, who can reduce their workload by allowing parts of the treatment be taken over by a robot.

Due to the relatively low number of participants and the absence of a control group, results of this study only indicate the underlying potential of research in this field. The use of an automatic method for assessing the response of different types of patients during the interaction with robots is of ultimate importance. This will also allow the autonomous change of the robot's behaviour according to the current response of the patients, this feature is also of great interest for future work.

Acknowledgments

The authors gratefully thank all children, parents, and educators D. Maccarrone, G. Artimagnella and S. Nigro.

This work was supported by the European Union’s H2020 research and innovation program under the Marie Skłodowska Curie Action - Individual Fellowship (CAREER-AID) grant agreement no. 703489.

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