Comparing two LEGO Robotics-Based Interventions for Social Skills Training with Children with ASD

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***Abstract*—This paper presents an analysis of two comparable studies with LEGO Robotics-based activities in a social skills training program for children with autism spectrum disorders (ASD). One study has been carried out with a group of 16 children in the Unit of Pediatrics Psychology and Psychiatry in HSJD in Barcelona , Spain and the other with a group of 17 children at the Center for Education and Engineering Outreach (Tufts U.) in Boston, USA. The aim of this comparison is discuss lessons learnt and develop empirical based guidelines for intervention design.**

I. Introduction

Autism Spectrum Disorders (ASD), defined in [1], are a group of neurodevelopmental disorders characterized by impairments in social interactions, communication and repetitive behaviors or interests. Social delays include qualitative delays in social interactions, social relationships and imaginative thought [2]. This delay in social skills makes it difficult for children with ASD to interact in teamwork activities with others [3]. In related literature we can find indications that social play interventions and engaging activities can be successful in training social skills and give the children a sense of achievement by working in groups [4-8].

In such a social play scenario, a robot can be either a facilitator or a social partner that stimulates social competence acquisition [9]. Also, different studies presented in [10-12] demonstrate promising results using LEGO building activities, showing statistically significant increases in the number of social interactions. In [3] pre-constructed LEGO Mindstorms robots were used to define role-based functions in working groups (i.e. programmer, downloader and tester). This study proved that there is a correlation between enjoyment and cooperation.

Children with ASD, because of their interest in robotics and restricted behaviors, could benefit from LEGO Robotics activities as a medium to develop social skills. In order to study this, two studies were designed simultaneously and independently in Barcelona and Boston. The designs of these studies differed in many aspects. Findings and comparative analysis could result in guidelines for the design of future studies with possibly an increased study population of children with ASD and common profiles.

Thus, in this paper, we discuss these studies, leading to a set of guidelines to run LEGO-robotics based activities to achieve social skills improvement in children with ASD. The current setup is the result of previous experiences that started in [13] in Barcelona and [14] in Boston, and then followed by the corresponding studies discussed in the following sections.

In section II we present the objectives and the expectations derived from previous studies, in section III we provide a description of the children that participated respectively in both studies, section IV describes the therapeutic program run in Barcelona and in Boston, in section V we compare both programs, and finally in section VI we present the derived guidelines, a short conclusion and possible future directions.

II. Objectives and Expectations

Previous studies in [13] and [14] proved that robot features and behaviors are likely to elicit desired social behavior in children. The next step consisted of designing new studies to: 1) describe and measure children's behavior during (e.g. look at behavior) and after the session (e.g. recalling situations and explaining it to their parents) to assess the intended social behaviors (e.g. initiating an interaction, asking for help, gaze behavior, joint attention) and psychological states such as attention, enjoyment or engagement; 2) understand and model the play/activity dynamics and their potential to facilitate children intended behaviors; 3) design and redesign the game/activity based on the empirical evidence (e.g. social scenarios, roles) to optimize children's engagement with the activity and emergence of intended behaviors; 4) investigate which individual variables affect children's social engagement with a LEGO-robot activity (e.g. age, perception of social presence, expectations, genre) and 5) infer reliably meaningful and relevant psychological states such as engagement or enjoyment from observed micro-behavior.

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In addition we wanted to explore how this kind of LEGO-robot based activity facilitates different therapy relevant behaviors and psychological states. We intended to 1) establish the relationship between game modality (i.e. competitive or cooperative) with children's behaviors and psychological states, and 2) provide a description of activity flow and their relationship to different behaviors.

Results obtained in [13] and [14] show that building and setting up robots that interact to complete a common task reinforce the social interaction to overcome complex problem solving and conflict resolution between participants.

III. PARTICIPANTS

The criteria to select the participants have been very similar. The pre-screening and baseline evaluation consist on:

1) In Barcelona: Achembach conductive questionnaires, The Social Skills Rating System (SSRS), Autism Treatment Evaluation Checklist (ATEC), ABC: Aberrant Behavior Checklist – Community, and Vineland Adaptative Behavior Scales (VABS).

2) In Boston: Kaufman Brief Intelligence Test-2 (KBIT-2), Social Skills Intervention System (SSiS), Social Rating Scale (SRS), Vineland Adaptative Behavior Scales (VABS), and Children's Communication Checklist-2 (CCC-2).

TABLE I. GROUPS

Barcelona				**Boston**			
Group	ID	Age	M/F	Group	ID	Age	M/F
A	1.1	12	M	A	02	14	M
A	1.2	10	M	A	03	8	M
A	1.3	11	M	A	04	11	M
A	1.4	11	M	A	05	10	M
A	2.1	12	M	A	06	11	M
A	2.2	10	M	A	07	8	M
A	2.3	11	M	A	08	9	M
A	2.4	10	M	A	09	9	M
B	1.1	8	M	B	11	8	M
B	1.2	9	M	B	12	13	M
B	1.3	9	M	B	13	7	M
B	1.4	8	M	B	14	10	M
B	2.1	12	M	B	15	11	F
B	2.2	10	M	B	17	12	M
B	2.3	8	M	B	18	11	M
B	2.4	12	F	B	19	10	F
				B	20	10	M

The inclusion criteria in both studies was very similar, the children had a normal cognitive scale, between 8 and 12 years old in Barcelona and between 7 and 14 in Boston, and that they do not participate in social skills training sessions at the same time.

IV. STUDY DESIGN

A. BARCELONA

In Barcelona the number of participants was 16. These children were assigned to groups of 4, not randomly but following clinical criteria to guarantee the effectiveness of group dynamics (effective therapy groups).

The 4 groups were randomly assigned to either the intervention group (Group A with team A1 and A2) or the comparison group (Group B with team B1 and B2). The intervention group carried out the robot based activity while the comparison group that followed a conventional social skills training program.

TABLE II. CODE SCHEME FOR BEHAVIOUR ANALYSES BARCELONA

Group	***Behavior***	***Description***
Social Interaction	Ask for Help	How many times the children ask for help from therapist or technician
	Ask for permission	How many times the children ask for permission from therapist or technician
	Group proxemics	When groupmates stand within 120 cm, or what is describes as the limit of ''personal distance'' in conversational interaction, of each other by [3]
	Shared gaze	When groupmates look at the same object or at each other [3]
	Pointing Behaviour	Indicating the robots, computers or activity material (i.e.: cards, board, etc.) to either the experimenter or groupmates (i.e.: during a conversation/explanation even if they don't saying nothing) through pointing at them [3]
	Shared Positive affect	How many times the children would laugh or smile with groupmates [3]
	Joint attention	Initiation and response
States of play	No playing	The play it hasn't started or user it isn't doing nothing related with the play
	Disengagement	Participant is no focusing to the task or other individuals within the group or the other group (not really interested) [15]
	Co-operative activity	Subject works with another person by turn-taking, or discussing play outcomes but where tasks are distributed Individual works together with somebody e.g. hands on something at same time or discussing outcome together [15]
	Onlooker	Participant is watching what the other individuals within the own group are doing but does not actively take part or is watching the experimenter [15]
	Onlooker of the other group	Participant is watching what the other group are doing and isn't playing or are speaking with the other group
	Playing alone	Subject is playing (with activity material, pc or computer) or focused to the task alone (the other user can be onlooker)
Children System Interact	Robot manipulation	Direct interaction manipulation with the robot (e.g. holding, connecting, assembling)
	PC	Direct or indirect (watching what the

Group	*Behavior*	*Description*
ion	Manipulation	other individual is doing) with the PC

A pre-test based on standardized test and direct observation) was carried out with both groups to assess the participants' pre-intervention social skills acting as the base line of the dependent variable.

The same therapist assisted by a technician conducted both groups.

Both groups took their sessions in the same classroom at Hospital Sant Joan de Déu. Two cameras had been placed in two corners of the classroom to cover the activity.

The activities took place every two weeks for each group, Thursdays and Wednesdays, one week group A and the following week group B. Each session took 1hour. The entire study was planned to be 6 months long. The therapist carried out an observation form with all participants immediately after every session, and the participants carried out a post-test every month.

The Analysis Plan is divided in observational data and social skills scores on standardized tests. The goals are (1) to obtain descriptive analyses of occurrences and percentage of time spent in target behaviors total, per team, individually and per genre and (2) to explore differences related to individual variables. The code scheme for the observational data is presented in Table II

The software used to analyze the video recordings is the Observer.

B. BOSTON

Following recruitment and screening of study participants, 17 children participated in either LEGO robotics club or a social skills group following the Social Skills Improvement System (SSiS) curriculum (Groups A and B, respectively). Participants in the comparison social skills group (Group B) received the same baseline and follow-up assessments as participants in the other group. Children continued to receive their original course of treatment with other institutions for the duration of the 16-week study period. Participants in the comparison group were invited to attend two 90-minute, free-play LEGO sessions at the Tufts CEEO as a reward for participation in the study.

Group B was conducted by a social skills teacher experienced with [16], assisted by three classroom aides.

Parents completed the SSiS, SRS, Vineland and CCC-2 questionnaires as a pre-test for collection of baseline data for both groups.

The activities took place every week for each group, Robotics on Wednesdays from 3:45pm to 5:15pm in the Tufts University Center for Engineering Education and Outreach (CEEO) workshop room. While the social skills was held on Monday from 3:45pm to 5:15pm in Tufts University Campus Center conference room. Each group attended session for 16-weeks.

Parents completed the SSiS, SRS, Vineland and CCC-2 questionnaires as a follow-up evaluation after the 16 weeks of class are completed.

The code scheme for the observational data is presented in Table III.

In order to most effectively compare the LEGO group and the social skills group, an unstructured 15-minute social activity session took place at the start of each session. This allowed the research team to observe any generalization of social skills learned in the two groups while participants played with board games and interacted outside of a structured session environment.

TABLE III. CODING SCHEME FOR BEHAVIOUR ANALYSES BOSTON

Group	*Behavior*	
Social Skills	Non Verbal Communication	Joint Attention (initiation and response)
		Gestures/pointing
		Showing
	Conversation with Partner	Initiation of conversation
		Response to conversation
		Conversation turns
		Commenting
		Interrupts partner
		Asks for help
		Arguing
		Resolved by themselves or adult intervention
	Conversation with Adult	Asks for help
		Teacher interferes to resolve arguing
		Teacher prompts an interaction between partners
States of play	Behaviour	Echolalia/Scripting
		Self-stemming behaviors
		Hyper/Hypo active (yes/no, duration)
		Frustration
		Sharing positive affect
		Difficulty turn taking/grabbing from partner/other children
		Description of other behaviors (ex. personal space, transitions)

V. ROBOTICS SESSION DESCRIPTION

A. BARCELONA

1) Structure

Robotics classes were 50 minutes long, allotting for 10 minutes of end free-game time. Children were placed together and given instructions on session rules and expectations, as well as the activity scheduling. Each group

of two received a Lego Mindstorms set specific for each session. The activity in the room was videotaped with two cameras.

2) Groups

Students were placed in groups of two or four that could change in each session.

3) Rules

The following rules are provided using Rules Reminder Cards [17] at the beginning of each session. Also are explained verbally.

4) Adult Intervention

The conductors of the activities, the therapist and the technician, explain the schedule and rules of each session. The therapist manages the session structure and the social dynamics, while the technician presents the robotic activity and solves the technical issues.

B. BOSTON

1) Structure

Robotics classes were 90 minutes long, allotting for 15 minutes of start-up/organizational time, 15 minutes of unstructured play, 45 minutes of building, and 15 minutes of cleanup time. Students were placed in groups of two and given instructions on classroom rules and expectations, as well as the day's building activity. Each group of two received a single LEGO Mindstorms kit and was videotaped with a single camera.

2) Groups

Students were placed in groups based on age and cognitive/verbal ability. Group size varied, based on the day's activity but will always consist of at least two students.

3) Rules

The following rules were explained to the students verbally at the beginning of each class and posted on the classroom wall: 1. Listen; 2. Take turns; 3. Share; 4. Ask first before taking it from someone else; 5. Keep your body to yourself; 6. Ask for help; 7. Keep your space clean; 8. Use kind words.

4) Adult Intervention and Reward System

The level of initial structure provided to encourage social interaction varied from activity to activity, for example separate "builder" and "programmer" roles, or two separate robots that must interact in some way, e.g. throwing and catching a ball. Children learned and practiced various social skills in a fun, safe and structured space. Various methods structured the interactions and sessions:

1) At the beginning of each session, a CEEO staff would go over the session rules to remind the children of how they are expected to behave while building and playing with the LEGO robots. These rules- such as taking turns, sharing the LEGO kit with your partner and respecting others in the room- were written on a poster in words and complementary colorful pictures. These stayed up at all times during the session.

2) The sessions were structured such that at the end of a specified time limit, or a little after half way through the activity, the teachers checked in with the subject pairs and encouraged them to transition to the next part of the activity.

3) During the sessions, the teachers would intervene to remind the pair about the class' rules when they had determined that a pair of subjects was having noticeable difficulty resolving an issue by themselves.

4) The teachers would encourage the pair to work together to come up with a solution to their problem, and they would facilitate practicing the social skill used as well as the solution.

5) At the end of each session, the teacher asked each student to complete the classroom questionnaire shown in Figure 1. Results included a smiley face for each of the questions and comments for the extended response questions. A child with responses that matched those of the instructor received a prize at the end of session, as a reward system.

6) In addition, activities that required collaboration between both team members were selected in the beginning few sessions so that children would get to know each other.

Figure 1. Session questionaire in Boston

	Questions:	No	Neutral	Yes	Teacher
1	I listened to my partner's ideas				
2	I worked well together with my partner				
3	I had fun in robotics today				
4	My partner had fun in robotics today				
5	I controlled my anger or frustration well today				
6	I followed the classroom rules				
7	How was today's activity?	Hard	Ok	Easy	

Figure 2. Session questionaire in Barcelona

¿?	NO	UN POCO	BASTANTE	SÍ
Me ha gustado la actividad de hoy				
He cumplido las reglas del grupo				
He trabajado en equipo				
La actividad de hoy me ha parecido fácil				
Me he divertido trabajando con mis compañeros				
He sido un buen compañero				
He escuchado las ideas de mis compañeros				
Estoy esperando la próxima sesión con el robot				
Me he divertido trabajando con el robot				
He controlado mi enfado				

VI. DISCUSSION

In order to see the Strengths and Weaknesses of the robotic training sessions done in Barcelona and in Boston we expose the main difference as follows.

Figure 3. Boston and Barcelona

1) The place

In Barcelona the sessions took place in the Hospital de Sant Joan de Déu, while in Boston the sessions took place in the CEEO robotics room. In Barcelona the room was completely isolated from people not involved with the activity, while in Boston contact between people participating in the activity and people who did not participate could be possible, especially during the breaking out sessions. In Figure 3 we can appreciate the setting up of the classroom, and in both studies critical recommendations from [21] are considered: size of the space and arrangement of materials in terms of organization and accessibility.

2) The activities

In Boston the activities design has focused on being similar to those kinds of LEGO Mindstorm NXT building sessions that children can have in their own school. On the other hand, following [21], in Barcelona the activities were designed the week before according to the preferences and motivational activities of the child with autism.

3) Free-play sessions

What was done in Boston in order to most effectively compare the Lego group and the social skills group, two unstructured social activity sessions took place to allow the research team to observe and compare any generalization of social skills learned in both groups.

4) Observed behavior coding system

Video scoring system used in Barcelona and the other one used in Boston are presented in table II and III.

5) Schedule and Rules explained verbally vs graphically

Tangible representations of activities, choices, or objects to use relevant to children with ASD can help them feeling more in control [17]. Digital photographs, clip art, and pictures are used, together with one or two words in Barcelona, while in the Boston sessions only text is used. Comparing the video recordings of both sessions is clear that the better performance of the activity is achieved using the visual support, specially the Rule Reminder Cards.

6) Reward system

In both sessions, a questionnaire about the activity is required to be filled by the Children (See Figure 1 and 2). The main difference is that in Boston the conductors established an award system to encourage participants to give right answers. The reward system consists in small toys that were given in case of three or more coincidence between child's answers and teacher's answer. In Barcelona the child and conductor filled in the surveys together.

7) Duration / frequency

In Barcelona the sessions are run with a periodicity of every two weeks, while in Boston is a weekly activity. In Barcelona we have a six-month long experiment, while in Boston is 10 weeks.

8) NXT-G Software vs Labview Software

One of the differences between Barcelona and Boston has been the software used. While in Barcelona the children programmed the robot using NXT-G Mindstorms Software, children in Boston programmed robots using Labview. Experimenter in Barcelona conducted a trial period for four building activities, programming the robot with two different software versions. A questionnaire thaws distributed to collect feedback on each software used. Experimenters have noted that the results of this questionnaire may not be accurate given the reluctance of children in the study to admit difficulty programming with Labview software. In spite of the general thought that children with ASD are not good at telling lies, in [18], it is possible that the high-functioning children with ASD in this group are able to tell lies of their own volition, however they have more difficulty in covering up these lies. We can appreciate this fact in the video recordings and interviews with the session's conductors. The time period dedicated to help children using Labview is much greater (12'44'' vs 5'50'' in one session), more often (11 times vs 8 times), and after two rounds of using both software platforms, children asked to use only the NXT-G MINDSTORM program in future sessions.

9) The Role of the LEGO robotics

While in Boston the LEGO material was used as a building tool, in Barcelona it plays two different roles. Not only the play-based activity role that permits to teach basic social interaction skills using turn taking, but also the social robot as mediators and as objects of shared attention that can encourage interaction with peers and adults [19].

VII. CONCLUSIONS AND FUTURE RESEARCH

1) Setting and material

The control group sessions took place in the same room that the robotic group and sometimes the participants were distracted by the equipment as long as they fell attracted by technologic devices.

With regard to the software we consider that the best way to program the robot is using a customized interface based in a Labview PILOT adapted to the preference of many children with ASD for visual cues and simplified programming software.

The presence of the cameras causes distraction to the children. So in further sessions they should be hidden from direct sight.

2) Session development

As was proposed in [21], we have contrasted that a consistent schedule and a routine are key factors to ensure a predictable and secure environment, as well as the formation of balanced groups.

In Barcelona the therapist had a talk with parents and children at he end of each session as a wrap up, explaining the goals of the activity, giving remarks on children performance and achievements, propose activities for home until next session. We consider that his feedback has an effect on the program effectiveness not only by reinforcing the skills with the training at home but also enhancing the therapeutic alliance, what presumably would have a positive effect on therapy adherence and clinical outcomes.

The LEGO club implementation in Boston allowed much more freedom to design their own engineering solution than the LEGO intervention completed in Barcelona. Given the open-ended nature of activities, it was noted that children in the study had some difficulty without specific instructions and in learning the unique Mindstorms NXT building platform. Given this initial difficulty learning the LEGO construction mechanics, activities originally planned for two weeks were extended for longer periods of time and a unit involving Stop Action Movies (SAM) was included to allow children to build and create in a collaborative way while removing the more complicated robotic and programming components. After children were more comfortable with the construction sets, robotics was reintroduced using simpler engineering challenges and with simplified Labview programming software.

In the future, the Boston research team is interested in exploring the merits of developing a curriculum utilizing many creative and collaborative technological activities in addition to LEGO Mindstorms such as SAM, Scratch, and others to determine whether robotics or simply the creation of materials in a group setting has an effect on social skills in children with ASD. This would also allow for a stronger performance of many children and also prevent any specific activity from becoming too discouraging.

A future line not contemplated in this study is to develop social interaction with non-disabled peers as is suggested in [20]. This would lead to more insight as to how social skills can be improved in a more natural environment with a mix of children with and without ASD.

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