Playful Interaction with Humanoid Robots for Social Development in Autistic Children: a Pilot Study

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***Abstract*— Children with a diagnosis of Autism Spectrum Disorder (ASD) have serious difficulties in the development of their communicative and social skills. In recent years, robots have been tested in the therapy of autistic children as a promising tool for increasing their interest and motivation in the activities. In this paper we present the results of a pilot study with playful robot-child interaction developed for the therapy of diagnosed children aged between 3 and 5. The children were separated into an intervention and a control group. Their progress in development was measured before and after the intervention. Although the experience was unanimously considered as positive by parents and caregivers, we have found no significative differences between the intervention and control groups. Some observed trends demand more caution and additional studies for identifying not only the advantages but also the possible pitfalls of the use of robots in the therapy of autistic children.**

I. INTRODUCTION

Difficulties in communicative and social interaction are the most notable characteristics among children with a diagnosis of Autism Spectrum Disorder (ASD). In many cases, those children do not look into other people's face, they do not have communicative intention, they do not present behavior of joint attention, they have difficulties to distinguish non-verbal communication and they also have difficulties in the area of language development [1]. All these aspects result in serious difficulties in initiating and maintaining adequate communication, developing an adequate social interaction, imitating, and acting in collaboration with other children.

These difficulties are caused by a dominant visual process over a weaker hearing process. This characteristic way of processing information makes children with ASD show greater interest in images and everything related to new technologies, which has led to the development of novel proposals for intervention in this field. Such is the case of using humanoid robots as supportive partners [2], [3], [4], since they can be a useful and effective tool in the intervention and development of the communication and social skills of children with ASD [5], [6].

The aim of this pilot study is to develop an ecologically valid scenario (i.e. usable in real situations) and analyze the effectiveness of the robot as a support for children with autism between 3 and 5 years, in a real environment, in learning semantic fields (clothes, transports, colors and animals) that had not yet been acquired by the children.

Fig. 1. Agents involved in the activity: caregiver, child, and small humanoid robot.

The robot is not replacing the caregiver, but it is a new agent involved in the interaction with the child (Fig. 1), attracting the interest in the child for a better involvement in the game and, therefore, in the development process.

A. Related work

Several studies have been carried out with the NAO robot on ASD children in recent years. Shamsuddin et al. [11] developed some simple HRI modules for testing with 5 children aged between 7 and 13. During the interaction, the robot does head-turn, blinks, talks, moves its arms, and finally plays a song. The total duration is about 14 minutes.

To assess the children's autistic characteristics, the team utilizes a behavior score sheet that is based on the Gilliam Autism Rating Scale-Second Edition (GARS-2). The GARS-2 is an autism screening tool developed to assist teachers, parents and other people who observe children to identify and diagnose autism [12].

According to their results, 4 out of the 5 children exhibited a decrease in autistic behavior (communication sub-scale) when the robot is executing HRI modules during the single session of child-robot interaction.

In another study with the NAO robot by Tapus et al. [13], the aim was to investigate whether ASD children showed more social engagement when interacting with the NAO robot, compared to a human partner in a motor imitation task. Different behavioral criteria (gaze, free initiations, smile/laughter) were analyzed based on the video data of the interaction.

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Four ASD children aged from 2 years and 8 month to 6 years participated in the study, which took place over a 4-week period (two intervention sessions per day). The results of the study are mixed, showing some effect in some children on some variables and in others on other variables, but not in all four children. Their results indicate a high variability of reactions to the robot.

Chevalier et al. [14] developed personalized social interaction models with a NAO robot to enhance the social and communication skills of ASD persons. Their subject pool was formed by 7 adults and 6 children aged 9-13. Only a first HRI experiment was conducted, the interaction was to present the robot to the participants for a short duration, up to 2 minutes.

They analyzed the video recording the participants gaze direction and gestures towards the robot. The children group had gaze direction more focused on NAO and switched less their gaze than the adult groups. They also had more social gestures toward the robot, such as waving back to NAO while it was presenting itself.

Besides the description of the behaviors, there are no statistical results nor any long-term comparison of the effect of a therapy with humanoid robots.

In a recent study by Sartorato et al. [15], a number of social robots used in therapeutic applications for ASD are reviewed, with a variety of capabilities and appearances, including the NAO humanoid.

Particularly, children with ASD spend significantly more time looking at the NAO robot, and the robot was able to facilitate joint attention behaviors. They report a particular case study of a child with ASD, in which the boy avoided a human adult's gaze but made eye contact readily and easily with NAO.

They claim, and we fully agree with them, that studies tend to vary along a number of different dimensions (duration, sample size, qualitative vs. quantitative analysis), and long-term studies are needed to follow children's progress.

II. METHODOLOGY

For the design of the study, we interviewed the caregivers, and their feedback inspired the development of the scenario. They were also involved during the programming and testing of the robot applications.

The applications were based on two visual games that were already played in the therapy sessions. First game is an *expressive* activity: the caregiver shows the child a card with the image of an animal, a vehicle, a cloth, or a vehicle; the child is asked about the name of the item. The second game is an *understanding* activity: the caregiver shows two cards to the child, one is the correct item, and the other is a different item from the same class. Then, the child is asked to point at the correct item as named by the caregiver.

Figure 2 depicts the robot dialogues for both activities. Initially the robot greets the child and asks for a game of choice. Then it iterates for a set of cards, asking the child either the name of the item (expressive), or to point at the correct answer (understanding). An example with vehicles is

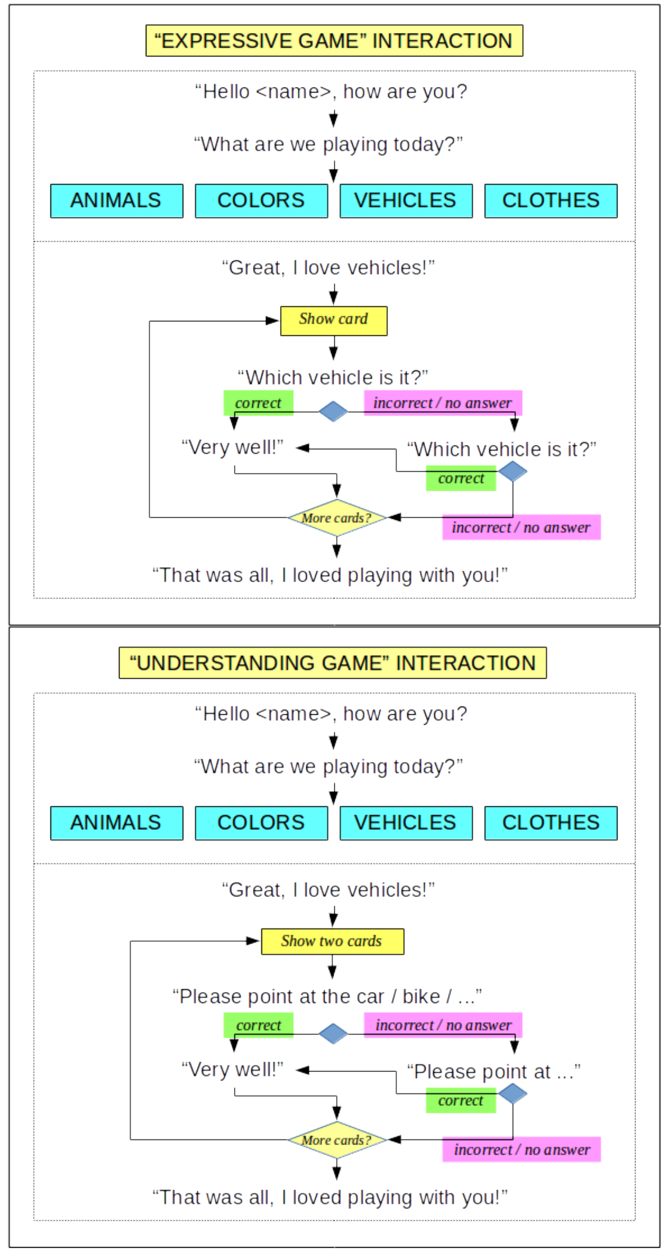

Fig. 2. Robot dialogues for the expressive (top) and understanding (bottom) games.

shown, but the structure is similar for animals, colors, and clothes.

When playing with animals or vehicles, the robot dialogues are enriched with sound effects: the robot imitates the sound of the animal or the vehicle.

The caregiver was in charge of handling the cards to the child. She also controlled the behavior of the robot, since there was no automatic voice recognition. The caregiver observed the child, and signaled the answer to the robot with a small remote command hidden in her hand. The command featured only two buttons for signaling either a correct or incorrect answer. The robot answered to the child according to this signal, as if it had recognized itself the action of the child.

The robot used in the sessions is a small humanoid robot, the NAO by Softbank Robotics (formerly Aldebaran Robotics) [7]. It is 57 cm high, and weighs only 4.5 kg, thus being adequate and safe for small children. It has 25 DOF, voice synthesis and recognition capabilities, and on-board vision processing.

III. PILOT STUDY

The actual therapy sessions were carried out during ten months, starting on March 2016 and ending in January 2017.

The sample consisted of 14 children with ASD (5 in the control group and 9 in the intervention group) aged between 3 and 5, with similar level of cognitive development, with a diagnosis of ASD (according to the criteria of the DSM 5 and the ADOS-G scale [8]) and absence of language.

The type of intervention that was carried out during the study was similar in all cases with a number of logo-therapy sessions (once per week).

1) Within the session, an intervention scenario was created for the group with the robot, in which a structured intervention was carried out, divided into two blocks of 15 minutes each (expressive and understanding, respectively) and working in four different semantic fields: colors, type of transport, clothes and animals (see Fig. 3).
2) The intervention of the control group was similar except for the robot support, i.e. the caregiver played the same game alone with the child.
3) The selection of participants in one group or another was random.
4) The actual duration of the pilot study was 10 months, measurements were taken at the beginning and end of the study, and data were analyzed.
5) Intergroup and intragroup analysis were performed and compared over time.
6) The variables were based on observation: two experienced professionals recorded the sessions and labeled the images when the children were watching, pointing, or uttering.

IV. RESULTS

The evolution of children was measured before and after the 10-month therapy. Measurements consisted of video recording and annotation during the interaction with the robot and caregiver (Table I, discussed in section IV-A), and a developmental index (Table II, discussed in section IV-B).

A. Measurements of interaction

The results indicate significant differences in gazing between the control group and the group with the robot, yet those differences diminish with time: Fig. 4 (top) depicts in box plots the total number of gazes before and after the 10-month intervention, for the control (no robot) group, and the group using the robot in the therapy.

It seems obvious that the robot attracted the attention of the child, and this impression is confirmed by the measurements of the targets of gazing. As seen in Fig 5 (top), the children in the robot-assisted group looked at the robot more than to the caregiver (therapist) who was present in the session.

Fig. 3. Robot scenario for the understanding game with animals: two cards are shown to the child, and the robot asks him to point at the requested item.

However, the results are not so positive for other measurements: the control group (without robot) exhibits better numbers in pointing (mid plots of Fig. 4) and uttering (bottom plots) than the group with the robot, and the difference slightly increases with time.

It is also worth to mention that the difference of targets does not hold for utterances: children only utter slightly more towards the robot than towards the caregiver, as shown in Fig. 5 (bottom). In any case, the number of utterances is quite small, except for outliers, due to the fact that the children have not yet acquired language skills.

B. Analysis of development

The Battelle Developmental Inventory (BDI) [9] measures the progress of development for children through age seven, when they acquire skills and behaviors from simple to complex. It is based on a combination of sources such as observation of the child, and interviews with parents and caregivers.

The BDI has been used as a screening tool to identify children with ASD, and the results can be used to determine treatment targets [10].

In this study, we have assessed the social, communication, and cognitive skill sets, before and after the intervention (Fig. 6), i.e. within an interval of ten months.

Due to the small size of the population, the results are not statistically significant (non-parametric analysis yielded no difference between groups).

However, some trends can be observed in the plots: for the cognitive domain (left column of Fig. 6), both the robot and control group behave similarly, with a slight increase with time. This behavior is compatible with a proper cognitive development, with increasing scores in skills like discrimination, memory, reasoning and concepts.

TABLE I

MEASUREMENTS OF GAZING, POINTING, AND UTTERING BEFORE AND AFTER THE 10-MONTH INTERVENTION.

			Participants													
			Robot group									Control group				
			1	2	3	4	5	6	7	8	9	1	2	3	4	5
Number of gazes	BEFORE	Therapist	0	4	1	0	2	5	0	12	8	9	5	12	6	0
		Robot	2	15	11	16	10	10	14	9	15	0	0	0	0	0
		Total	2	19	12	16	12	15	14	21	23	9	5	12	6	0
	AFTER	Therapist	0	2	1	2	0	5	0	5	1	15	12	6	11	3
		Robot	6	13	16	15	12	8	9	7	13	0	0	0	0	0
		Total	6	15	17	17	12	13	9	12	14	15	12	6	11	3
Number of pointings	BEFORE		0	8	3	16	1	2	1	12	4	13	2	19	8	11
	AFTER		3	16	2	20	18	1	4	5	17	15	20	19	12	12
Number of utterances	BEFORE	Therapist	0	0	0	0	0	1	1	8	0	12	1	16	0	16
		Robot	1	13	0	16	1	0	1	0	0	0	0	0	0	0
		Total	1	13	0	16	1	1	2	8	0	12	1	16	0	16
	AFTER	Therapist	0	0	0	0	0	1	0	4	0	20	19	21	1	11
		Robot	0	16	0	18	3	0	0	1	0	0	0	0	0	0
		Total	0	16	0	18	3	1	0	5	0	20	19	21	1	11

TABLE II

BDI RESULTS BEFORE AND AFTER THE 10-MONTH INTERVENTION.

			Participants													
			Robot group									Control group				
			1	2	3	4	5	6	7	8	9	1	2	3	4	5
BEFORE	Cognitive Domain	Discrimination	27	27	27	27	27	27	27	27	27	68	32	27	27	27
		Memory	27	27	27	27	27	27	27	27	27	27	37	27	27	27
		Reasoning	39	27	27	27	27	27	27	27	27	39	27	27	27	39
		Concepts	27	27	27	27	27	27	27	27	27	27	27	27	27	37
		Total	27	27	27	27	27	27	27	27	27	53	27	27	27	27
	Social Domain	Interaction w. adults	27	27	27	27	27	27	27	27	27	27	27	27	27	27
		Expression of feelings	27	27	27	27	27	27	27	27	27	27	27	27	27	27
		Self-concepts	27	27	27	27	27	27	27	27	27	29	27	27	27	27
		Interaction w. partners	27	27	27	27	27	27	27	27	27	35	27	27	27	27
		Collaboration	27	27	27	27	34	27	27	27	27	40	34	27	27	27
		Social role	27	27	27	27	27	27	27	27	27	27	27	27	27	27
		Total	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Communicative Domain	Reception	27	27	27	27	27	27	27	27	27	27	27	27	27	27
		Expression	27	27	27	27	27	27	27	27	27	27	27	27	27	27
		Total	27	27	27	27	27	27	27	27	27	27	27	27	27	27
AFTER	Cognitive Domain	Discrimination	27	34	27	27	46	27	34	34	27	46	27	27	27	34
		Memory	27	27	27	27	27	27	34	34	27	31	27	27	27	41
		Reasoning	27	27	27	31	32	27	39	39	27	36	27	56	27	53
		Concepts	27	27	27	34	31	27	27	36	27	40	27	53	27	50
		Total	27	27	27	27	27	27	31	27	27	36	27	40	27	49
	Social Domain	Interaction w. adults	27	27	27	27	27	27	27	27	27	27	27	53	27	27
		Expression of feelings	27	27	27	27	27	27	27	27	27	27	27	48	27	27
		Self-concepts	27	27	27	27	27	27	27	27	27	27	27	43	27	27
		Interaction w. partners	27	27	27	27	27	27	27	27	27	27	27	41	27	27
		Collaboration	27	27	27	27	27	27	27	27	27	27	27	34	27	48
		Social role	27	27	27	27	27	27	27	27	27	27	27	32	27	29
		Total	27	27	27	27	27	27	27	27	27	27	27	41	27	27
	Communicative Domain	Reception	27	27	27	27	27	27	27	27	27	29	27	48	27	36
		Expression	27	27	27	27	27	27	27	27	27	42	27	31	27	27
		Total	27	27	27	27	27	27	27	27	27	34	27	38	27	27

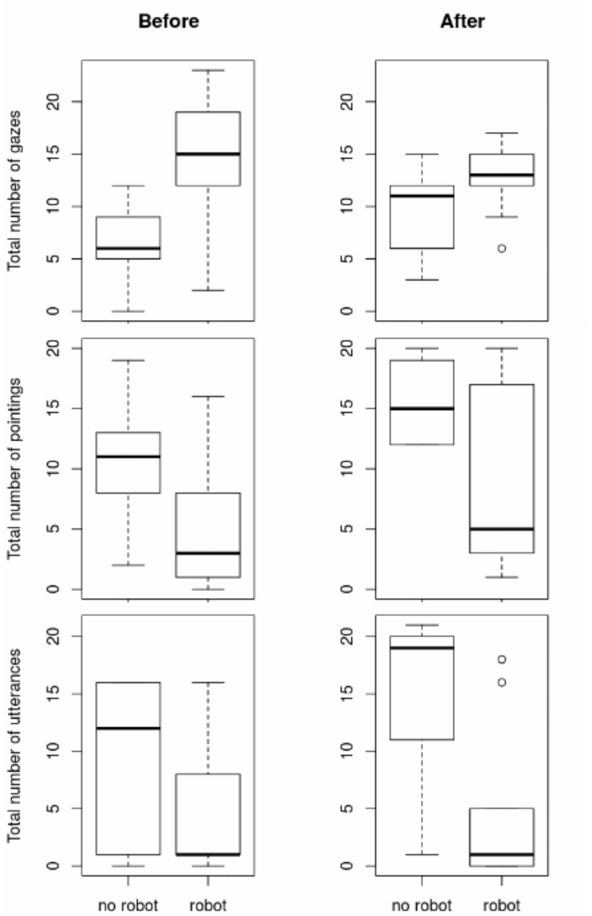

Fig. 4. Measurements of gazing, pointing, and uttering before and after the 10-month intervention, for the control group and robot group (left and right boxes respectively, on each axes).

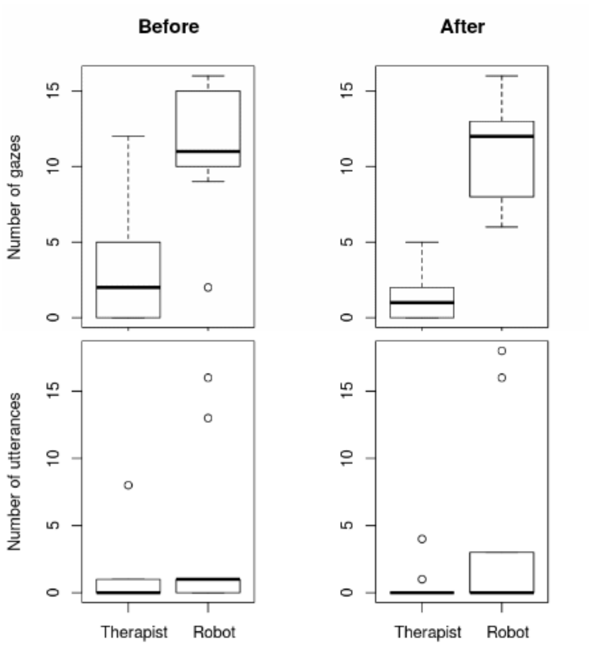

Fig. 5. Gazing and utterances before and after the 10-month intervention to caregiver (therapist) and robot (left and right boxes on each axes).

Yet in the communicative and social domains, the robot group shows mostly no variation before and after the intervention (Fig. 6, middle and right). In the control group, with less children, a few of them show changing values. As mentioned before, social and communication are hard challenges for ASD children: in these domains, expression and reception skills were measured in the communicative domain, and collaboration, interaction, and expression of feelings were considered, among others, in the social domain.

Although the numbers are not statistically significant due to the small population, it is somewhat shocking to see zero progress in the robot group, in contrast with the control group (without robot), as if the interaction with the robot actually inhibited the development of those skills.

V. CONCLUSIONS

According to the literature, robots have shown to generate a number of behavioral benefits in children with ASD, e.g. engagement, increased attention, and decreased social anxiety.

In our study, the use of a supportive robot in interventions with young children with autism is positive in some attitudes, e.g. gazing, since they observe more than the control group.

But robot-child interaction could be less effective in other aspects like pointing and uttering. The richer interaction with a human caregiver could possibly increase the response of the child in these cases.

Therefore, there is no evidence yet that social robots enhance social skills and communication of ASD children, when compared to traditional therapy with a human caregiver. However, more trials are needed in a larger population to confirm the obtained results.

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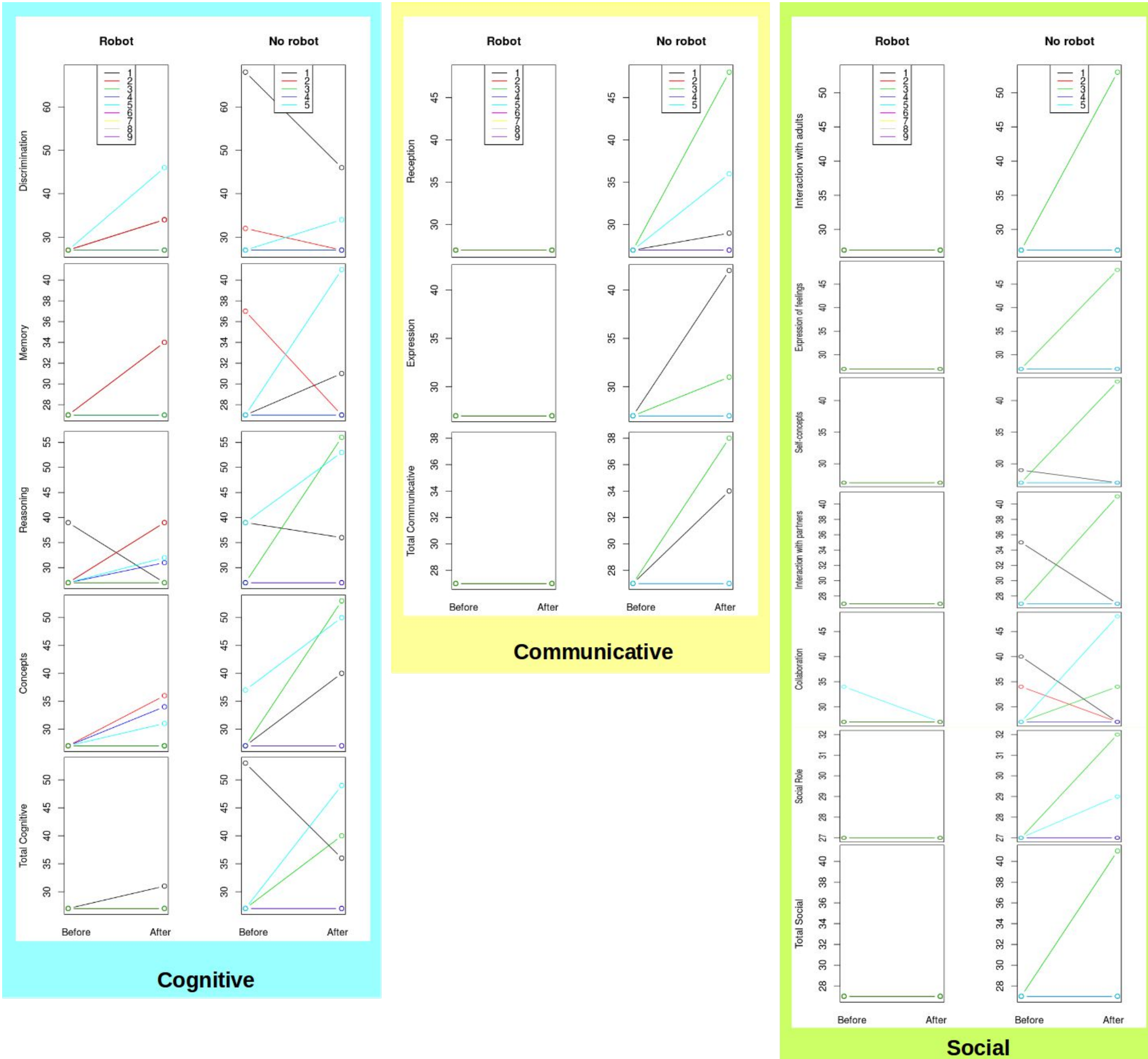

Fig. 6. BDI results for the children of the robot group (9 individuals) and the control group (no robot, 5 individuals) before and after the intervention, for cognitive, communicative, and social domains.

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