Development of Robot-enhanced Therapy for Children with Autism Spectrum Disorders

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DREAM

Development of Robot-enhanced Therapy for Children with Autism Spectrum Disorders

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D2.1.1 Tasks for social robots on developing social skills (Wizard of Oz system)

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Dissemination Level		
PU	Public	**PU**
PP	Restricted to other programme participants (including the Commission Service)	
RE	Restricted to a group specified by the consortium (including the Commission Service)	
CO	Confidential, only for members of the consortium (including the Commission Service)	

Contents

Executive Summary

This preliminary version of the D2.1 Tasks for social robots on developing social skills (Wizard of Oz system) is based on the results from the exploratory studies carried out in task T2.1, in which we have started to test the effectiveness of RAT using a Wizard of Oz system. The effectiveness of RAT is being tested for: joint attention, imitation, and turn-taking skills. The principal results in this deliverable are the parameters and parameter values that characterize the child behaviours identified in deliverable D1.3. These provide the basis for classification of behaviours, i.e. behaviour assessment, in work package WP5 and, in particular, this deliverable provides the training set for the learning process that maps sensory cues to classes of behaviours. In this preliminary version of D2.1 we will present: the theoretical background, objectives, design, procedure, environmental setup, preliminary results from the experiments carried in task 2.1.

Principal Contributors

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Revision History

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Results were included.

Introduction

Autism Spectrum Disorder (ASD) is characterized by characterized by widespread abnormalities in social interactions and communication, as well as severely restricted interests and highly repetitive behaviour (American Psychiatric Association, 2013). These core symptoms emerge early and persist in development and most individuals with ASD require professional care throughout their lives (Howlin, Goode, Hutton, & Rutter, 2004). In terms of assessment and diagnostic process, ASD children are identified based on the behavioural phenotype, A*utism Diagnostic Interview-Revised* (ADI-R) (Lord, Rutter, & Le Couteur, 1994) and *The Autism Diagnostic Observation Schedule* (ADOS) (Lord, Rutter, Goode et. al., 1989) being used by researchers and academic centres as golden standards.

Currently, no biological marker is identified and causal mechanisms are not well understood and/or integrated into a rigorous etiopatogenetic theory, although several hypotheses have been advanced. For example, *Empathizing-Systemizing (E-S) Theory* of psychological sex differences, proposed by Baron-Cohen, (e.g., Baron-Cohen, 2009; Baron-Cohen, Knickmeyer, & Belmonte, 2005), which states that human males have stronger systemizing tendencies (i.e., analysing a system in terms of the rules that govern it, in order to predict its behaviour) compared to females, who exhibit stronger empathizing tendencies (i.e., the drive to identify another's mental states and to respond to them appropriately)(D1.1:David et al., 2014).

Several theories try to explain why children with autism prefer to interact with technological tools. One of them, the Theory of Mind (TOM) (Baron-Cohen, 1997) explains that children with autism tend to have difficulties in identifying the mental states of others (e.g., beliefs, intentions, emotions) that may cause some difficulties in interacting with others (Baron-Cohen, 1997). Consequently, it can be very hard for them to understand social human-human interactions and thus, they prefer technological tools in order to simplify their interactions and make it more predictable.

The choice for a robot-mediated approach to psychological intervention for ASD children is justified by several advantages: 1) Children with ASD are more responsive to feedback, when administered via technology rather than a human (Ozonoff, 1995); 2) The anthropomorphic embodiment of the robot offers human like social cues, while keeping at the same time object-like simplicity; 3) Robots can be programmed to gradually increase the complexity of the tasks, by solely presenting relevant information; moreover, information can be repeated in the same format, without trainer fatigue; 4) Robots are predictable and, therefore, controllable, enable errors to be made safely and give possibilities to train a wide range of social and communication behaviours to prepare for real life exposition.

Taking into account that ASD patients tend to learn more from the interaction with technology rather than from the interaction with the human beings, robots might have the potential to be used in ASD therapies as mediators between human models and ASD patients (David, Matu, & David, 2014). In the Robo-Mediator approach the robot acts as an intermediary for the therapist and it enables faster and better gains from the therapeutic intervention as compared to the classical condition (therapist – child interaction). The robot acts as a necessary component in the process and without it the learning progress will be slower and maybe the treatment would attain poorer results (David, et al., 2014). In our specific tasks, children with ASD might have a greater performance when it comes to abilities like: imitation, joint attention and turn taking when using the robot compared to standard interventions.

Imitation plays a very important role in development, laying the foundation for communication and language. There is considerable evidence for imitation deficiencies in ASD children (Williams, Whiten & Singh, 2004). There is also empirical data suggesting that repeated sessions of imitation leads to improvements in imitation skills and to enhanced social responsiveness in children (Field et al., 2001). In line with previous studies (Dautenhahn & Billard, 2002; Robins et al., 2005; Tapus et al., 2012), we assume that the use of robots as imitation partners for children with ASD can provide a simplified, safe, predictable and reliable environment.

Regarding out second targeted ability, joint attention (JA) it is considered to have a pivotal role in the development of language and social skills for children with ASD (Murray et al. 2008; Whalen et al. 2006). Comparisons between children with ASD and other populations of children, both with and without disabilities showed that children with ASD display deficits in eye-gaze shifting deficits, in gestural JA and show that they are less responsive to JA episodes (Charman, 2003; Loveland, 2007). Emerging research in RAT shows that robots can be used to elicit JA episodes (Robins et al. 2009).

Turn-taking skills are frequently targeted in social skills interventions for children with disabilities. Turn-taking refers to "smooth interchanges between communicative partners" (Goldstein et al., 2002) and includes behaviours like: rapid turning, avoidance of overlaps, observance of tasks that are needed to be responded and topic-relatedness (Stanton-Chapman & Snell, 2011). Successful turn-taking requires children to maintain their turn, which is often very challenging for children with autism when interacting with peers or with adults. Social robots proved to be good social partners in playing with children with ASD (Wainer et al., 2010).

Our objectives are to teach imitation, JA and turn taking behaviours during repeated sessions of interactive games using social robots. This training is expected to lay a foundation for developing a set of implicit rules about communication, rules that will be transferred to the interaction with human persons. The research questions is to identify to what degree social robots (using Wizard of Oz system) can improve JA, imitation skills and turn-taking skills and whether or not these type of intervention provides similar or better gains that standard intervention.

Method

Participants

We have recruited 7 participants with ASD aged between 4 and 5 years old from Autism Transylvanian Association, out of which 4 participants were selected to follow the intervention sessions. The inclusion criteria were: a. children are diagnosed with ASD using DSM-V criteria by a psychiatrist, b. their diagnosed is confirmed by the Autism Diagnostic Observation Scale (ADOS) (Lord et al., 2000), adapted into Romanian by our group (David, Anton, Stefan, Mogoase, & Matu, 2010), c. they have difficulties in performing at least two of the targeted behaviours in the evaluation phase (imitation, JA and turn taking) d. they have enjoyed playing with the robot. The ADOS was administered by two experienced clinical psychologists, certified by the National Board of Psychologists.

Design

We are using single case experiments in order to assess the effectiveness of robot enhanced interventions for children with ASD, which represent a valuable, common and evidence-based methodology for clinical research (Janosky et.al, 2009; Riley-Tillman & Burns, 2009). A classic single-case alternative treatments design (Barlow & Hayes, 1979) is being used.

Environmental Setup

In the RET condition children are interacting directly with the robot that is standing on the therapy table. In the right part of the room the operator is controlling the robot's movements by using a Wizard of Oz paradigm. In standard treatment a therapist will be sitting in front of the child. The video cameras and sensors are placed in the experimental room, behind the robot, capturing the facial expressions, the gaze and the movements of the children, as they interacted with the robot.

Procedure

We are implementing the tasks following the discrete trial format, a commonly used approach in early intervention programs for autism (Ingersoll, 2008). This approach targets several skills, which are later used to teach more complex behaviours (Ingersoll, 2008; Lovaas, Freitas, Nelson, & Whalen, 1967). The elements that characterize this approach are: the teaching environment is highly structured, behaviours are broken into discrete sub-skills, which are presented over multiple, successive trials; the child is taught to respond to the partner's discriminative stimulus (e.g. do like me) through explicit prompting; prompt fading; and contingent reinforcement (see Ingersoll, 2008).

Following the single case experiment design each child will go through the next scenario:

- Baseline measurements (BM; for imitation/joint attention/turn taking) for approximate 6 to 8 measurements, our until a stable baseline level has been established;
- Robot-enhanced treatment (RET; for imitation/joint attention/turn taking) for approximate 8 sessions;
- Standard human treatment (SHT; for imitation/joint attention/turn taking) for approximate 8 sessions;
- RET or SHT depending on which of the treatments worked better for each child, for approximate 8 sessions.

Each session lasts between 15 - 20 minutes and is being delivered daily. The order between RET and SHT is randomized to avoid order effects. The baseline sessions for each ability are delivered in interaction with the therapist and they respect partially the discrete trial format. The child is tested to see if he/she responds to the partner's discriminative stimulus, without explicit prompting, prompt fading or contingent reinforcement. We established a priori to test for trends in baseline measurements starting with the 6-th session. If no trends or negative trends were found (indicating that the baseline is stable or, in the latter case, that is performing worse form one session to another) than the child was moved to the intervention phase.

The standard treatment for each ability (imitation, joint attention and turn taking) is delivered by the therapist respecting the discrete trial format. In the RET sessions the discriminative stimulus is delivered by the robot NAO. The robot also provides the contingent reinforcement based on the child's answer.

In order to avoid interference between different skills, the interventions for the three abilities are implemented sequentially for each child, meaning that we focus on one ability at a time and move to the next one only after ending the intervention for the previous one. The order of the target abilities was randomized across children.

Platforms used for delivering the intervention

For this study we are using the main DREAM experimental platform – the humanoid robot NAO developed by Aldebaran Robotics (Gouaillier et al., 2009). NAO is 58-cm tall, has 5-kg in weight and 25 degrees of freedom for movements. It is equipped with a rich array of sensors: 2 cameras, 4 microphones, sonar rangefinder, 2 IR emitters and receivers, 1 inertial board, 9 tactile sensors, and 8 pressure sensors. NAO has various communication devices including LED lights, two loud-speakers, a voice synthesizer with language-specific intonation and pronunciation. However, the Romanian voice is not yet available on the NAO platform so that a pre-recorded human voice with sound processing effects was used in these experiments.

An additional technological tool integrated in this research was the electronic "Sandtray" developed by the team from Plymouth University (Baxter et al., 2012). Inspiration for this platform is drawn from the "sandbox" technique in child therapy where sand play is used to foster collaborative story-telling interactions between child and therapist (Bradway, 1999). The interaction platform described here uses a touchscreen as opposed to a sandbox. However, it allows social engagement through a collaborative interaction platform. The hardware consists of a 26-inch capacitive touchscreen and associated control server, upon which a series of pictures can be manipulated by dragging (on the part of the human partner), or simulated dragging (on the part of the robot partner). The touchscreen thus serves as a medium for collaboration.

We are recording the therapy sessions using two Kinect sensors (Microsoft Corporation) and three high resolution cameras (1280*960pixels) that are all connected to a central workstation.

Measurements

Primary outcomes

In order to assess the child **imitation skills** (with or without using objects) are using the following behavioural grid:

Imitation with objects- functional behaviour	2 - Child imitates the functional behaviour (movement and sound) 1 - Attempts of the child to imitate the movement OR sound 0 - Child does not react/does something else
Imitation with objects- symbolic behaviour	2 - Child imitates the symbolic behaviour (movement and sound) 1 - Attempts of the child to imitate the movement OR sound 0 - Child does not react/does something else

Imitation without objects	2 - Child imitates the behaviour with movement and sound 1 - Attempts of the child to imitate the movement or sound 0 - Child does not react/does something else
Imitation of emotional gestures	2 - Imitation of the gestures made by the robot, gestures that refer to a specific emotion (anger, happiness, sadness and fear) which include hand movements, head movements and sound 1 - Attempts of the child to imitate the gestures (hand movement OR head movement) made by the robot that refer to a specific emotion 0 - Child does not react/does something else

In order to assess the child **joint attention** skills we are using the following behavioural grid:

Response to joint attention - head	1 - Child reacts and turns his head immediately after the robot does it 0- Child does not react/does something else
Response to joint attention – head + point	2 - Child reacts and turns his head immediately after the robot does it 1 - Child points immediately after the robot does it 0- Child does not react/does something else
Response to joint attention – head + point + vocal instruction	2 - Child reacts and turns his head immediately after the robot does it 1 - Child points or gives vocal instruction immediately after the robot does it 0- Child does not react/does something else
Initiation of joint attention episodes	2– Child tries to show something to the robot by integrating different ways of showing: using gaze, vocalization and pointing 1 - Child tries to show something to the robot by using only one behaviour from different ways of showing: using gaze, vocalization or pointing 0- Child has no attempts to initiate any joint attention episode

In order to assess the child **turn taking skills** we are using a sorting task game with facial expressions which is played on the Sandtray, while we are coding the following behaviours:

Turn taking – Showing enthusiasm - Eye contact	2 – Child shows enthusiasm, makes eye contact and respects turns when playing with the robot or partner 1 – Child plays and shows enthusiasm, makes eye contact without considering the robot's/ partners answers 0 - Child does not react/does something else
Turn taking engagement	2 - Child spontaneously engages with the robot/adult. 1 - Child plays the game with the robot/adult after the initiation of the therapist. 0 - Child does not react/does something else

Secondary outcomes

Besides these primary outcomes we also have some secondary outcomes that are relevant for every session with the robot or the therapist regardless of the task:

Engagement in the task:

Rating	*Meaning*	*Description*
0	*Intense noncompliance*	*The child walked away from the place in which the robot/human interaction took place*
1	*Noncompliance*	*The child refused to comply with the experimenter's request to play with the robot/adult*
2	*Neutral*	*The child complied with instructions to play the game with the robot/adult after several prompts from the experimenter.*
3	*Slight interest*	*The child required two or three prompts from the experimenter before responding to the robot/adult.*
4	*Engagement*	*The child complied immediately following the experimenter's request to play with the robot/adult.*
5	*Intense engagement*	*The child spontaneously engaged with the robot/adult.*

Stereotypical behaviours: a repetitive or ritualistic movement (especially hand mannerisms), posture, or utterances (frequency – the number of stereotype behaviours performed by the child during the task).

Positive emotions: the child laughed or smiled while interacting with the robot/human (frequency – the number of smiles or laughs performed by the child during the task).

Contingent utterances: verbal utterances (one word or a couple of words) that are in context, congruous with the interaction with the partner (e.g. yes-no responses, responses to the questions) (frequency – the number of contingent utterances said by the child during the task).

Verbal initiations: verbal utterances (one word or a couple of words) that are in context, congruous with the interaction with the robot/human partner and adds a new information, including expansion, adding to the content of the robot/human utterances or introducing new related topics (e.g. ask some questions, makes references to their own personal experience; frequency – the number of verbal initiations made by the child during the task).

Eye contact: looking at the upper region (not necessary at the eyes) of the robot/human for more than 3 seconds (frequency).

Negative emotions: the child shows anger, sadness or fear while interacting with the robot /human (frequency – the number of facial expressions that express anger/sadness or fear performed by the child during the task).

Rational/Irrational beliefs (definition by Dryden & DiGiuseppe, 2003).

1. Demandingness (irrational) *vs. preferences* (flexible but strong belief; rational). Demandingness refers to the tendency to make absolutist demands instead of (strong) wishes or preferences and is expressed in the form of "musts", "should", and "oughts".

2. *Awfulizing* (appraising an event as catastrophic or as the worst things that could happen; irrational) vs. *non- awfulizing* (evaluating an event in terms of badness, as extremely bad but not the worst it could happen; rational). Awfulizing refers to the tendency to evaluate events as being the worst in the world instead of evaluating them on a continuum of badness.

3. *Low frustration tolerance* (irrational) vs. *frustration tolerance* (rational). Low frustration tolerance refers to an individual's belief that he or she will not be able to endure a specific situation. Frustration tolerance implies that a situation might be appraised as extremely distressful and in need of change, but however endurable.

4. *Global evaluation of the self, others, and/or life (irrational) vs. non-global evaluation of the self, others, and/or life* (accepting and focusing on changing specific behaviours; rational). Global evaluation refers to instances in which individuals make generalized evaluations or denigrations (i.e., overgeneralizations) about themselves, others, or the entire world instead of accepting and focusing on conditionally accepting the human person/life and evaluating specific behaviours.

These beliefs were measured in frequency by analysing the content of the children's speech during the task.

Adaptive behaviours – generally imply the skills needed for successful adaptation and in our study they are measured through strategies that communicate an interest in the interaction partner and in searching different ways of communication: approach in order to get some help, orienting behaviours and seeking comfort. For example, approach for help might be reflected by one of the following: trying to solve the problem by making statements and questions that are aimed at understanding the situation. Orienting behaviours might be reflected by: behaviours of orienting in the environment and looking to the experimenter. Seeking comfort might be reflected by: soothing/communication self-comforting, gesture, and seeking comfort/ contact.

Maladaptive behaviours – are those behaviours that interfere with effective adjustment (e.g., aggression and hostility). We have grouped them in three categories: behavioural distraction/avoidance, demands and aggression. Behavioural distraction/ avoidance could be indicated by: doing something else than focusing on the task, turning attention away from the task (e.g. shifting gaze, staring into space, laying his or her head on the table). Demands are reflected by: expressing requests to others to do something in a louder voice and with an imposing tone; socially inappropriate words. Aggression (direct and indirect) could be reflected by disruptive behaviours like: socially inappropriate actions directed toward the experimenter, or the robot (e.g. throwing objects, self-aggression, physically aggressive toward others or others' toys).

Results

Current progress in the experiments

As it was planned, this deliverable provides only partial data coming from the intervention studies. Three of the four children that were recruited finalised baseline measurements for one ability and are undergoing the alternative treatments (RET and SHT). Only a small number of treatment sessions were offered at this point to each child. The fourth child is still in the baseline measurement phases (BM) for the first ability. Bellow we provide the result based on the available data. No firm conclusion regarding the comparison between RET and SHT can be formulated based on what is available at this point. However, these results offer useful information on each child's level of development on the targeted abilities, as well as their evolution in the experimental tasks if no intervention is applied.

Data analysis

The data-analysis plan includes the following steps:

1. **Plotting and visual analysis of the data**. To facilitate interpretation, data from each phase is plotted along with trend and variability indicators, such as the median line, the celeration line, the first and the third quartile lines, (Nugent, 2010).
2. **Statistical analysis for testing trends in data or changes in trends.** To check for possible trends in baseline data as well as to compare the effect of the two interventions we endorsed the C statistics. This test is regarded as sensitive in identifying trends in data coming from single case research as well as to changes in trends that might be due to the effects of experimental manipulations (Janosky, Leininger, Hoerger, & Libkuman, 2009; Jones, 2003).
3. **Parametric and non-parametric comparisons between the outcomes of the interventions**. Where visual and trend analysis are not conclusive additional parametric (if assumptions are met) or non-parametric statistical analysis is employed.

Given that data collection is undergoing, only partial analysis are reported here. More specifically, we plotted all the available data and visual aids for the baseline measurements. Also, for baselines with more than six measurements, results of the C statistics are presented. Interpretation of the results was restricted to the limited data that was collected until this point.

Child 1. Imitations skills

Data form the experimental sessions with the first child are presented in Figure 1. Visual analysis suggests that with the exception of imitation with objects all trend lines for baseline measurements are descending. This indicates that his performance decreases along trials. However, statistical analysis based on the C test for the overall imitation ability (the average of scores on all sub-tasks across sessions) indicated no significant trend in the data, $C = .243$, $se_C = .338$, $p = .472$. Also, the BM trends were not significant for any of the sub-tasks: imitation with objects, $C = -.113$, $se_C = .338$, $p = .738$; symbolic imitation with objects, $C = .567$, $se_C = .338$, $p = .093$; imitation without objects, $C = .142$, $se_C = .338$, $p = .673$; imitation of emotions, $C = .439$, $se_C = .338$, $p = .110$.

Performance recorded in RET sessions fall below the median value of BM, however, with the exceptions of imitation with objects and imitation without objects, which are somewhat descending, all other trends are ascending. The small numbers of measurements in the RET conditions does not allow us to perform additional analysis based on the available data.

Child 2. Joint attention

Due to practical reasons only two baseline session were available for this subject. All data is depicted in Figure 2. No data analysis was performed for this case.

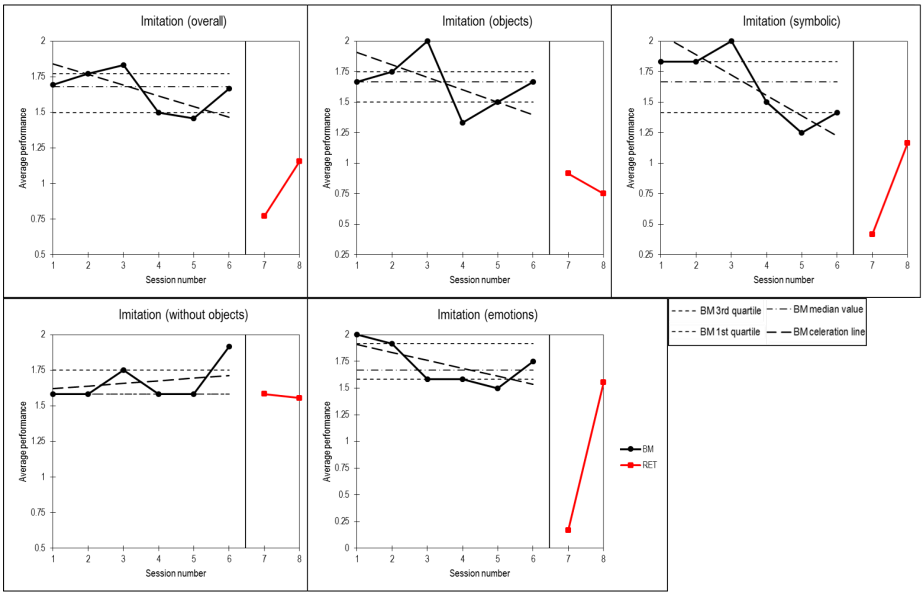

Figure 1. Results on imitation for Child 1. Data is available from six baseline sessions and two robot-enhanced therapy sessions.

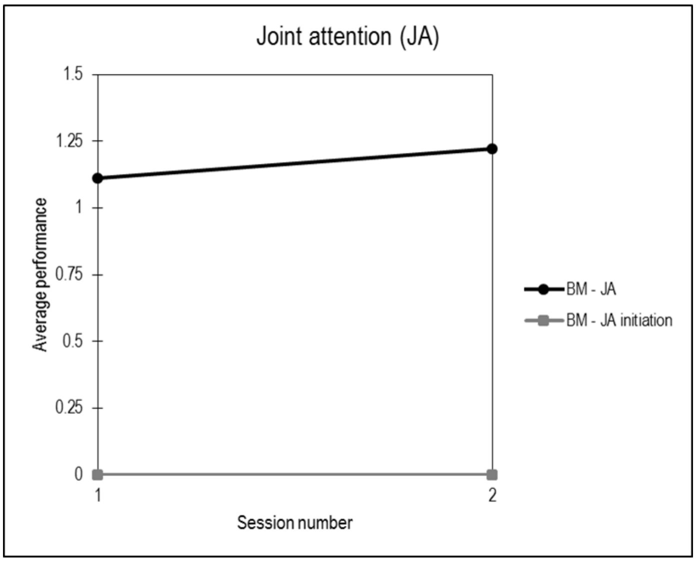

Figure 2. Joint attention and joint attention initiation results for Child 2. Data is available only from two baseline sessions.

Child 3. Turn taking

Figure 3 depicts the results for this subject on the turn taking task, using the electronic Sandtray. The child did not express turn-taking behaviours in none of the six baseline measurements. Given that all BM scores were equal to 0, was impossible to calculate the C statistics. However, the constant trend is evident form visual analysis. Only two sessions of SHT and one session of RET were offered until now. Performance increased in the first SHT session but the progress was lost in the next session. No additional analyses were performed at this point.

Child 4. Turn taking

Figure 4 depicts results for this subject in the turn-taking task. Visual analysis form baseline data shows a descending trend line, suggesting that his performance decreased during baseline measurements. However, C statistic indicated that this trend was not significant, C = .100, se_C = .338, p = .765. There are only one RET and one SHT sessions delivered at this time and thus additional analyses cannot be performed.

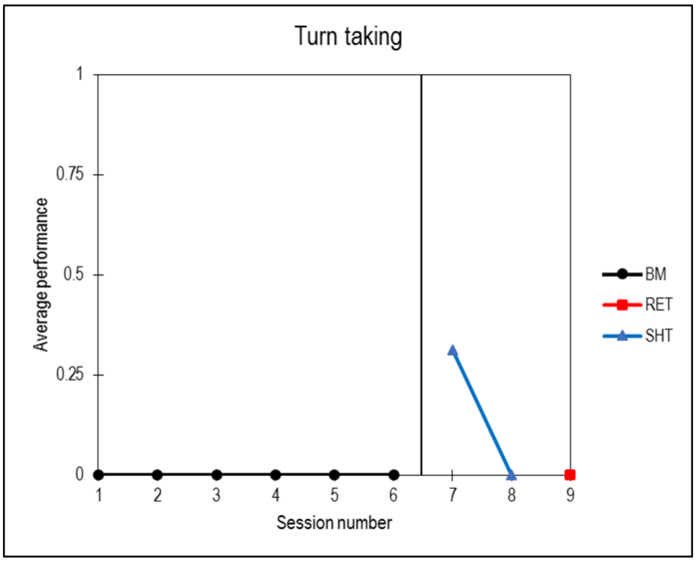

Figure 3. Turn taking results for Child 3. Data is available from six baseline sessions, from two SHT sessions and from one RET session.

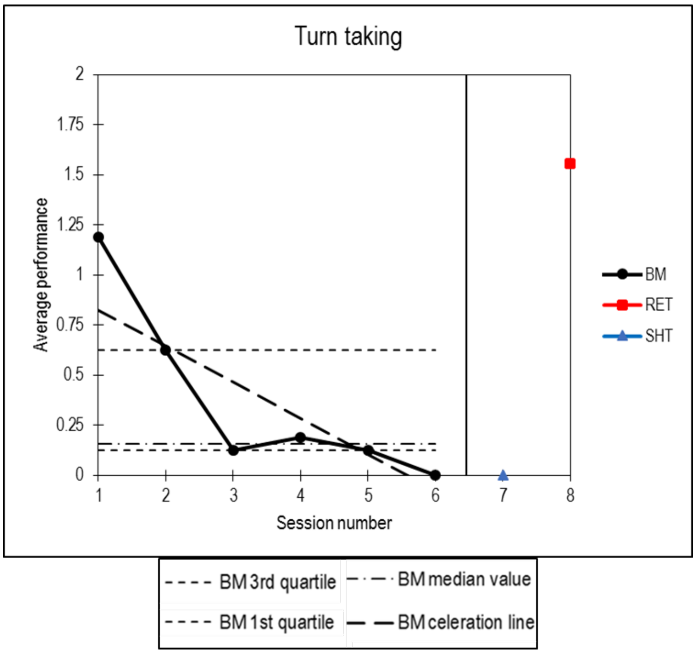

Figure 4. Turn taking results for Child 4. Data is available from six baseline sessions, from one SHT session and from one RET session.

Conclusion

This deliverable presented the preliminary results from the Wizard of Oz experiments using the NAO robotic platform and the experimental setup developed as part of the DREAM project. Also, the deliverable presents in details the methodology that will be used to collect the data and the strategy for data-analysis. Although the preliminary results available at this point do not allow us to formulate conclusions one the efficacy of the robot-enhanced treatment, is worth mentioning that all children expressed a somewhat descending trend line or low levels of performance. Thus, there is space for improvements for all subjects on each of the variables that were targeted. Moreover, all the participants accepted the robots as therapeutical agents and interacted well with the robots; more than that, both the therapists and the parents had a positive attitude toward using the robots as therapeutical agent. The next deliverable will present full data and results collected using the methodology described in this document.

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