An Interactive Tangram Game For Autistic Children

Beatriz Vila Bernardo

Instituto Superior Técnico

Abstract. This work explores the use of a social robot as an assistive agent during therapy sessions, in order to assist children with Autism Spectrum Disorder (ASD), through a Tangram puzzle game. Our aim was to transform the original Tangram, which is played in therapy sessions of children with ASD, into an engaging tablet game in the same environment. To achieve this, we included a humanoid robot - NAO. The game has two conditions: the Tutor Mode and the Peer Mode. In the first condition, the robot gives help whenever the child experiences difficulties during the game. In the second condition, the robot plays with the child in turn-taking. Eight children with ASD participated in this study. The results indicated that in the Tutor Mode the robot was capable of maintaining child's attention on the game and to help most of the times it was necessary. In the Peer Mode, the robot also stimulated child's attention on the game and was able to establish turns for the majority of the participants.

Keywords: Social Robot, Autism Spectrum Disorder, Children, Human-Robot Interaction

1 Introduction

Autism is a complex behavioral disorder that is characterized by a behavioral impairment in social interaction and communication, and the presence of repetitive patterns of behavior or interests [1]. However, people with autism may present difficulties at other levels, such as cognitive disabilities, avoiding eye contact with others, diminished attention, and other deficits in pragmatic skills (e.g., turn taking) [30, 19].

The interest of autistic children in robots has instigated the majority of the researches in this area. The Aurora Research Project is an excellent example of how robots can be integrated into therapy sessions with autistic children [25]. Dautenhahn *et al.* [25] aimed at developing and increasing communication and social interaction skills in children with ASD, through collaborative and turn-taking games with different robots. KASPAR's [8] slightly human traits help developing social skills, and, consequently, it promotes interaction between the child and the therapist. The use of robots in these cases induced a predictable and controlled environment, favoring a less frightening situation to an autistic child.

The puzzle developed in this work was the Tangram that consists in seven pieces with different geometric shapes with the goal of creating numerous different silhouettes with all of them. It is a game commonly played during therapy sessions by autistic children. We used a tablet version of the Tangram puzzle, together with the social robot - *NAO* [28]. The robot was programmed to function as a Tutor - helping the children through the game, or as a Peer - engaging the children in a turn-taking game. In order for this game to be attractive for most children of the spectrum, it has multiple settings. Thus, the game can be played by children with few or many cognitive and motor impairments. Our aim was never to use the robot to substitute the therapist within therapy, but to serve as an assistive tool.

We conducted a single-subject study at the Hospital Garcia de Orta, CADIn, and Francisco de Arruda school. We evaluated 8 participants individually during a number of sessions which varied for each participant and compared with the baseline and final results. In the best case, the results with the robot would be close to the results with the therapist.

2 Autism Spectrum Disorder

Autism spectrum disorder (ASD) is a complex neurodevelopmental disability that begins early in life and influences how an individual learns, interacts, and communicates with others [1]. According to the American Psychiatric Association [1], people with this disorder exhibit social communication and social interaction impairment, and also restricted/repetitive patterns of behavior, interests, or activities:

- **Absence of or Impairment in Social Communication and Social Interaction:** Delay in the improvement of spoken language accompanied by the misreading of nonverbal language (such as gestures, facial expressions and volume of voice), and the inability to create and maintaining social relationships. This trouble with social relationships includes the difficulty of establishing joint attention (i.e., child's capacity of pointing or bringing objects to share emotions and engage in turn-taking interactions) and reduced or absent imitation of others' behavior.
- **Repetitive and Stereotyped Activities:** Include basic motor stereotypes (e.g., hand flapping, finger flicking), repetitive utilization of objects (e.g., spinning coins, lining up toys), and repetitive speech (e.g., echolalia, or immediate repeating heard words; stereotyped use of words, phrases, or prosodic patterns). Inflexible adherence to routines may be manifested in refusal to change or repetitive patterns of verbal or nonverbal behavior (e.g., repetitive questioning).

In addition, children with ASD usually present other disabilities. Such as abnormalities of attention, intellectual disabilities, and motor deficits [1]. Briefly, people within the spectrum differ greatly from each other, and often present dissimilar characteristics.

Turn-taking is one of the most basic and important social skills required in everyday life. This ability is fundamental when it comes to developing friendships, communicating with others and playing games [27]. Autistic children are described to interrupt a speaker improperly or to remain in the speaker (or the listener) role for too long [2]. Also, these children are reported to have difficulties in initiating conversations and reply appropriately to peers. These are clear evidence that some children with ASD have difficulties in taking turns. Nadel [21] concluded that imitation, turn-taking, and recognition of conventional social patterns is a basis for developing social skills and understanding others' intentions [21]important to be acquired for these children in order to improve their social skills.

The Autism Diagnostic Observation Schedule (ADOS) [17] is an instrument to accurately assess and diagnose autism spectrum disorders. This method consists in scoring direct observations of the child's interactions and correlate the developmental level and age of the child. Currently, there is no cure for Autism, but early therapeutic intervention can greatly enhance children's development in order to expand their functional independence and improve their life quality [30]. The main goal of ASD therapy is to improve cognitive, language and social skills while minimizing fundamental deficits. The most effective treatment may differ for each patient [20]. Some of the common approaches are the Applied Behavior Analysis (ABA), Pivotal Response Therapy (PRT), Floortime, Treatment and Education of Autistic and related Communication handicapped Children (TEACCH), SCERTS, *et cetera* [30].

Applied Behavior Analysis (ABA): applies the following principle: *When a behavior is followed by some sort of reward, the behavior is more likely to be repeated.* So, whenever a child completes a task, the therapist reinforces him/her with a positive reward [30].

Floortime: is a specific procedure to both follow the child's natural emotional interests (lead), and in the meantime, challenge the child towards an enhancement of the social, emotional, and intellectual capacities. This method emphasizes the critical role of parents and other family members because of the importance of their emotional relationships with the child [20].

Treatment and Education of Autistic and related Communication-handicapped Children (TEACCH): uses visual cues to teach skills. The TEACCH method emphasizes structure including organization of the physical environment, predictable sequence of activities, visual schedules, routines with flexibility, structured work/activity systems, and visually structured activities [20].

3 Related Work

This section presents some of the works related to different aspects of my M.Sc. thesis. Firstly, the most relevant screen-based game for children with ASD is presented. Then the most emblematic social robots in this context used during therapy sessions are mentioned.

3.1 ECHOES

Bernardini *et al.* [4] implemented ECHOES, a serious game with the purpose of helping children with ASD gaining social communication skills. Their goal was to create an autonomous agent competent to interact with a child without the presence of a therapist. ECHOES' 12 activities are displayed in a multitouch display and take place in a sensory garden occupied by Andy, the autonomous virtual agent, and by

interactive objects that react when the agent or the child interacts with them through specific touch gestures. These action-reaction events intend to promote children's understanding of cause and effect. ECHOES learning activities' objectives are to improve joint attention and non-verbal skills. Andy has the role of a peer and a tutor - as a tutor, the agent has to develop child's expressive communication system; as a peer, the agent has to adapt itself to the preference of a child regarding structure and predictability. The authors emphasized the importance of giving positive feedback to the children, in order to reduce the anxiety related to social interactions. If Andy has suggested an action and the child does not perform it, the agent first waits and then interferes by repeating the action and inciting the child to do it again. The children that participated in the study demonstrated a comfort with the ECHOES environment and their responsiveness was stimulated. Over the three sessions, the number of initiations to Andy and to the practitioner increased. This increasing of responsiveness level might be elicited by the enjoyment that children experienced while playing ECHOES. It was expected a growing disinterest in Andy given the increasing complexity of the activities, but that did not happen.

3.2 The Aurora Project

The AuRoRA (Autonomous Robotic platform as a Remedial tool for children with Autism) research project's aim is to investigate the potential use of robots as therapeutic or *educational toys* for children with autism. Labo-1 was their first robot [31] but it could only provide a small range of interactions with the children, limited to spatial approach/avoidance turn-taking games. Later they decided to build Robota, a doll-shaped mini-humanoid robot, that can engage children in synchronous and imitative interaction games, in order to develop interaction skills in children with autism [7]. The investigators investigated how imitation and turn-taking games with a humanoid robot (i.e., a robot that can match some basic behaviors of humans) could empower social cooperation abilities in children with autism. And concluded that the children's participation in these trials was considerably initiated by the teacher. They also investigated what effects the robot's appearance has, and the authors concluded that children prefer interacting with a plain robot over a human-like robot [5]. In another study, Robota was used to elicit imitative behaviors in children with autism. The results showed that several participants demonstrated spontaneous imitation, and understood that their own movements were at the origin of Robota's motion.

KASPAR [8] is a minimally expressive humanoid robot which makes it suitable for interaction with children with ASD since it provides a safe and enjoyable interactive learning environment. Also, it is capable of developing social and communicative skills in children with ASD, through collaborative games. The robot was built to encourage tactile exploration on its body, which is important to increase body awareness and sense of self in children with autism. Another KASPAR's purpose is to mediate child/adult interaction and thus, break the isolation of the child. Besides that, the robot still seeks to teach social skills, through its facial/head and gestural expressions and promote collaborative play with other children and adults. In short, it was possible to observe in their study that KASPAR helped the children to generalize their behavior with the robot to the co-present others, by stimulating gazing and touching them.

3.3 NAO

Greczek *et al.* [11] developed a study aiming at analyzing the effects of a humanoid robot, giving graded cueing feedback, during an imitation game played with a child with ASD. Graded cueing is a method to improve people's skills (e.g., social skills) during therapy by giving them increasingly specific cues or prompts. The therapist requests the patient to perform a task, then prompts the patient with increasing specificity taking into account how much the patient struggles with the task. The authors questioned if this graded cueing method could improve child's performance and autonomy, with less intervention from the therapist. In the trials, the child had to play an imitation game with NAO[1], a humanoid robot which could play the role of a social mediator. NAO strikes one pose then the robot encourages the child to imitate it. If the child's pose is well performed, the robot gives positive verbal feedback, nods and flashes its eyes green. If the child does not imitate correctly, NAO begins the prompt system. After the first prompt, if the child needs more prompts, the robot continued to *climb* the levels of prompting:

- P0: No prompts given
- P1: Words
- P2: Words + Gesture

[1] https://www.aldebaran.com/

- P3: Specific Words + Gesture
- P4: Specific Words + Specific Gesture

In the case where the child has passed through these 4 levels and continued to not imitate successfully, the robot would change its pose, so that the children, would not lose interest in the game.

The goal of the graded cueing computational model is to minimize the number of prompts and its specificity while maximizing the user's success in performing the task. However during the experiment that did not happen for all participants. Although they came to the conclusion that varied feedback is more effective and less frustrating than non-adaptive feedback in a child-robot interaction.

4 Architecture

In this section will be described the original Tangram game, the tablet game functioning with all the different settings and the two initial studies conducted in this project. Then, the robot used in this experiment will be presented. Finally, the two developed conditions (Tutor and Peer) are introduced.

4.1 Tangram Puzzle Game

Tangram is a puzzle game with only 7 geometric and simple pieces that can be arranged in numerous ways in order to obtain more than 6500 silhouettes of animals, letters, numbers, objects, people, and so on [23]. This puzzle game has the capacity to improve some skills, such as imagination, visuospatial, logical and concentration [14, 29]. And can also extend child's knowledge about geometric figures and geometric spatial thinking [13]. The players have to assemble all seven pieces in order to achieve a figure. They have to drag, rotate and flip pieces, to understand the spatial relations between them and which shape stays the same no matter how it is turned. This sort of puzzles requires mathematics knowledge to solve them [26]. Tangram is frequently played during therapy sessions by autistic children starting from 3 years old. Therefore, this was the chosen game to be developed in our project. It is not an engaging game and child's enthusiasm on it has to be stimulated. Recreational devices such as computers may increase child's level of engagement in learning [6] so we expected that since the game was played on a tablet, it could overcome this problem, keeping children engaged in it. Also, since the game is played on a tablet, it can improve the evolution of coordination and fine motor skills [22]. It has been discussed by some researchers that the presence of an excess of details can be over appealing, becoming a factor of distraction, since it leads the children to concentrate on them instead of in the interaction [32, 15]. So it was important to have a simple and distractions-free interface.

For this reason, the game interface consists of only three components: (1) the solution area, (2) the pieces, and (3) a home button. During the game, the player has to drag the pieces with its finger to the right places. Whenever the player releases a piece within the solution area, if it is relatively close to the right spot, the piece anchors in it. If not, the piece returns to its default position. When all pieces are in their places, the puzzle is completed and after a few seconds appears a new puzzle. In order for this game be playable for most children of the spectrum some settings were added: difficulty levels, rotation modes, distance threshold and number of pieces.

There are three Difficulty Levels: easy, medium and hard. At the easy level, the solution area has all the board lines of the puzzle, and its interior is transparently colored in the color of the correct piece. The medium level consists only of the puzzle with the uncolored border lines. Finally, on the hard level, the solving area only shows the outline of the *shadow*.

It was created 3 modes of rotation: (1) Simple Mode - the pieces are already with the right angle according to their place in the puzzle; (2) Button Mode - the child has to click multiple times in the button of a certain piece to rotate it; and (3) Finger Mode - the child touches one of its corners and drags the piece around itself. The distance threshold defines the distance from the right place that the piece can be dropped. And finally, the common Tangram Game is played with 7 pieces, but we also decided to implement puzzles with fewer pieces (from 2 to 6).

In order to the children do not lose curiosity about the game over time and to avoid stress, the difficulty must be gradually increased [9, 33]. So in each game, this increment of difficulty is materialized by (1) increasing the complexity of the puzzle, (2) increasing the difficulty of rotation modes, and finally (3) decreasing the threshold of distance to the right spot. To manage all the aforementioned settings, was developed a Difficulty Manager.

4.2 Initial Studies

A five-year-old autistic child was monitored during a therapy session playing the original Tangram game. He was able to speak, but he could not focus on the same task for a long time and also had some difficulty in following instructions. With this study, we concluded that the puzzles are games that do not captivate, by themselves, the attention and interest of autistic children. In this manner, children's attention must be encouraged. On the other hand, we could confirm that is important the child receives tips and clues throughout the game so that the child does not lose interest and to stimulate child's reasoning. Also, positive feedback is fundamental during the game, as has been seen previously. In addition, the child needs to have a final reward for finishing the puzzle.

Another study was conducted months later, to verify the suitability of the developed tablet game. Three children with moderate autism participated in this experiment. We could conclude that the game in the tablet is captivating, and the feedback produces the desired effect. The children realized the goal of the game and improved slightly over the games. With this study, we realize what kind of utterances and advice the therapist gives throughout the game so that children can play. However, there are some behaviors that the robot cannot replicate. In the first participant the therapist had to grab his hand to help him, and in the second had to calm him down due to the aggressiveness. So, it is always important to have the presence of the therapist during the interventions.

4.3 Social Robot - NAO

For this project, we decided to use the robot NAO[2], a social interaction oriented robot, with an anthropomorphic appearance, perfect for interacting with autistic children as a peer [8]. Due to unavailability of the robot, we could not use what we had initially proposed - the MOnarCH robotic platform [18]. So we had to choose a robot to replace it that was also suitable for autistic children. The robot NAO was our choice for its design, the capacity to provide concrete feedback and the ease of the setup. It has minimal face characteristics which make it suitable to engage the children with ASD in therapy. Regarding the feedback, in the Larson's study [16] it was proved that the children with ASDs prefer concrete feedback (e.g., lights, colors and sounds) which NAO can provide. The last requirement equally important was the ease of installation and transportation of the robot, considering that it would be necessary to transport the robot from the laboratory to the testing sessions multiple times.

The Tangram game was developed in *Unity 5*[3] in C# and runs in an Android tablet. To communicate with the rest of the system, it was used a *bridge*, also developed in C#, that connects with the game in the tablet, using a C# client within the Thalamus middleware. Thalamus [24] is a cross-media body interface for multiple simultaneous artificial embodied characters. It acts as an abstract interface to the robot's controls (e.g., reading sensors, dealing with text-to-speech or controlling robot's body).

4.4 Tutor Mode - Prompting

The interaction between robot and child has two conditions. The Tutor Mode is the first one and has the purpose of helping and teaching the child during the game. The other will be presented in the next subsection. This present condition is adequate for children that have several difficulties playing puzzle games (e.g., motor, reasoning, and so on). During the game, the robot helps the child whenever is necessary. In the case, the child insists in placing the piece (1) in the wrong place, or (2) with the wrong angle, the agent begins the prompt system. Greczek *et al.* [11] proved that graded cueing has good results and is well suited for most children with ASD. This case has several prompts:

- P0 - no prompts
- P1 - the agent encourages the child to think about his/her decision;
- P2(1) - the agent gives a clue about the right spot;
- P2(2) - the agent gives a clue about the right angle;
- P3 - the correct spot starts to shine.

Also, there will be another prompt system in case the child does not move any piece within a few seconds. These prompts have the purpose of stimulating the concentration on the game:

[2] www.aldebaran.com/en/cool-robots/nao
[3] https://unity3d.com/

– P0 - no prompts
– P1 - random piece shakes and the agent asks where should it go;
– P2 - the agent gives a clue about the right spot;
– P3 - the correct spot starts to shine.

The visual stimulation (i.e., piece vibrating) is another form to maintain the child's focus and interest in the game. Besides that, in this prompt system for the game with fewer pieces, the visual cues arrive in the P2. In the hard level, the robot can also show the final puzzle within a few seconds, both in P1 and P2. In both prompt systems, the game starts at P0 level. If any of the three above options arise, the game goes to P1 level and so on. After some time on P3 level, the agent asks if he or she wants to give up on the puzzle, thus, getting a new one with a lower difficulty or if he or she wills at giving up at the game. The agent has to decide what action it should perform in both prompt systems, so it does not deliver an excess of information to the child. So it considers the information previously provided and also the current game state (e.g., how many mistakes made, how long without playing). In addition to this two prompt systems, there are also other types of help. Whenever the child has problems in moving or dropping pieces. Clues are be simple and clear, it is important to have a familiar and basic language. So there are two sets of utterances, one with normal phrases, and the other with brief and direct phrases, for children with extensive linguistic impairments.

4.5 Peer Mode - Turn-Taking Game

We decided to develop a condition in this game that could enhance the turn-taking competence of children with ASD. In the Peer Mode, the robot plays a turn-taking cooperative Tangram game with the child. It has to establish the turns, teach the child to wait for his/her turn and to incentive the children to help the other even when it is not their turn. If the child tries to play in the NAO's turn, the piece will not move, and the robot will repeat that it is its turn. Thus, reinforcing the idea that the child should not play in the others' turn. Autistic children are most often observed to be engaged in solitary independent play. To stimulate child's cooperative capacities, occasionally NAO asks for help during its turn. It can ask for touching the place where a certain piece fits. Or it can request for the child to rotate a particular piece so the robot could fit it. Since this method is suitable for children who have mastered the game, the aid provided by the robot are not as specific as in the previous condition. But still, NAO gives some help that corresponds to the P1 and P2 levels of the first aforementioned prompt system.

4.6 Feedback

As it was discussed by Bernardini *et al.* [4], children with ASD should receive positive feedback in order to maintain interest and experience a sense of self-efficacy and accomplishment. Besides, visual and auditory feedback make the interaction more appealing and comprehensible [3]. So whenever the child places a piece in the right spot, the agent gives positive feedback through congratulations and/or other social behaviors, such as gestures. It is worth to mention that children with ASD should not receive overly penalized negative feedback since these children tend to misinterpret this sort of feedback [33]. So the robot reacts negatively (depending on the number of failed attempts) but only with gestures or a negative word/onomatopoeia. This behavior demonstrates that the piece was dragged to the wrong place.

Once the puzzle is completed, the robot transmits a compliment message towards the child with enthusiastic gestures. Additionally, the tablet evokes a congratulation sound and materialize multiple fireworks upon the completed puzzle. This final reinforcement is mightiest than all of the other feedback, to convey the feeling of having reached the final goal. Regarding NAO's utterances, in few of them, the robot mentions the participant's name, in order to act as an acquaintance of the children and to stimulate them when they hear their name.

5 Evaluation

We proposed to explore how a humanoid robot could be incorporated as a tutor or as a peer into therapeutic sessions with children with ASDs. In order to do so, we conducted experiments during one month and a half in four locations: CDC[4] - Centro de Desenvolvimento da Criança Torrado da Silva (Child

[4] http://www.cdc-hgo.com/

Development Center) of Hospital Garcia de Horta in Almada, the public school Francisco de Arruda[5] in Lisbon, the CADIn[6] in Cascais and in Setúbal. Each participant was chosen by the therapist or teacher according to their characteristics. The 8 children performed 3 to 4 sessions, once a week. Each one took approximately 15 to 25 minutes and involved: one child, one therapist, the robot and one researcher. In the room the material was already disposed when the child arrived. The tablet and the robot are disposed in a table, two cameras (one for the face, and the other for the interaction) are already set. The therapist maintains his/her position next to the child, and if necessary intervenes. Still in the room, further away from the child, is also present the researcher with two computers and a router, responsible for maintaining the connection between the Thalamus (in computer 1), the bridge (in computer 2), the game (in the tablet) and the robot. The child plays 4 games in each session, but only if not showing signs of discomfort.

5.1 Evaluation Methodology

Since children in the spectrum can be so different and present such various characteristics from each other, we decided to base our study on Single-subject Design [10, 12]. This design is normally applied in studies where the sample size is one, or the individuals can be considered as a single group. This incorporates the *baseline logic* principle: the participants serve as their own control. In single subject design studies each participant is exposed to a non-treatment condition, the baseline. This condition consists in repeatedly measuring the performance (target behavior) of a participant before experimental phases. Then the experimental control is introduced and the target behavior continues to be observed and recorded in the intervention condition. The baseline (A) and intervention (B) conditions are gradually alternated across time, depending on the design used, in our research we used the A-B-A.

Before the trials with each child begin, the therapist fills out a form with the child description and his or her autism level according to the ADOS. At the end of each session, the therapist answered the questionnaires upon the interaction and also discuss with the investigator some relevant aspects. Finally, the researcher visualized the video recordings to collect information about eye gaze, turn-taking and game performance, help and external interventions, and others. Regarding the task performance we measure: the time to complete the puzzle, the time to place the piece, the turn time, the failed attempts to rotate the piece, the failed attempts to drag the piece, the attempts to place the piece in the wrong place, the attempts to place the piece close to the right place, the attempts during others' turn, the responses to help requests, the number of times he/she realize it is his/her turn, the number of helps. The affective attributes towards the robot are measured by the gestures and vocalizations. We also measure the gaze and the number of external interventions.

In the Tutor Condition, the participant goes through 4 sessions. In the first session - baseline, the child plays with the therapist the original Tangram game (one puzzle), then plays the tablet Tangram game also with the therapist (5 tablet games with fewer pieces or 2 games with seven pieces), and at the end the robot is presented. The child is encouraged to touch the robot and explore its body. If in this initial phase, the child feels comfortable with the robot, the session of the child playing the game in the tablet with the robot may begin. The second and third sessions consist of 4 games, played exclusively with the robot. The complexity of the games can increase gradually or not, depending on the performance of the child. Finally, in the forth session, phases of the first session are repeated.

In the Peer Condition, each participant could perform 3 or 4 sessions, depending on their availability, performance and the will to continue. The design of this experiment is very similar to the Tutor Condition, with some exceptions. The baseline, contrary to the previous condition, consists of 4 games with the 7 pieces played with the therapist in the turn-taking mode. The second and third sessions are also composed of 4 games with the robot in the turn-taking mode. Lastly, in the final session the child plays the last four games with the robot, and then plays additional four with the therapist in turn-taking mode.

6 Results

In this section will presented the results of each participant individually. The first participant is the only in the Tutor Condition. The other seven played in the Peer Condition. The results will be discussed at the end of this section in order to comprehend if our solution was capable of meeting our objectives.

[5] http://aefarruda.pt/portal/
[6] http://www.cadin.net/

6.1 Participant 1 - J.F.

J.F. is the oldest participant, he has 14 years old. He has severe autism and attends supporting functional behavioral classes at the Francisco de Arruda school. His linguistic, cognitive, and motor development are strongly underdeveloped. In the baseline, J.F. played the original Tangram game. He was not able to finish any puzzle without the help from the teacher. He was not concentrated on the game and spent much time exploring the pieces. Due to his motor impairments, this game was even more difficult. In the tablet game, he has always been very focused on the tablet and was always willing to play another. He laughed and was very excited when saw the fireworks at the end of each puzzle. Then he met NAO, he tried to establish physical contact with it. In the 4 sessions with the robot, J.F. was always very focused. In the first ones, he seemed to not being able to understand what the robot was saying to him. But throughout the sessions, he seemed more aware to NAO's utterances. It was possible to verify an increase of his performance and autonomy over the sessions. Throughout the games some external interventions were needed, in order to prevent him for touching the robot violently and to keep him concentrated on the game. In the final session, he played 2 games on the tablet with the teacher almost autonomously. And then played again the Tangram original puzzle. He was able to finish almost completely alone one of the puzzles, which was surprising. Also, he was much more focused on the puzzle, than in analyzing the pieces. This was only tested in just one day, so we can not confirm that this result was due to the games he had in the tablet.

6.2 Participant 2 - M.A.

This participant has six years and has moderate autism according to ADOS. He frequents the CDC of HGO to attend occupational therapy. M.A. presents a very good cognitive and motor development, and also a good linguistic development for his age. He attended 4 sessions - Baseline, First, Second, and Final. In the baseline, he was able to complete the puzzles without difficulty. M.A. noticed whenever it was his turn. Then, the robot was introduced to the participant but he was not comfortable with its presence. So he began the robot sessions next week. When he played with the robot, M.A. understood the concept of turn-taking. There was a large number of vocalizations because this participant answered the majority of robot's questions. Interestingly he began to imitate the robot's request for help. Since the robot did not respond to his request, he continued to play. He repeated this behavior over all games even in the final session.

6.3 Participant 3 - J.N.

The Participant 3 has four years and has mild autism according to ADOS. He also frequents the CDC of HGO to attend occupational therapy. J.N. presents a good cognitive and motor development. However, he is undeveloped linguistically given his age and has some difficulties taking turns and focusing on communication. In the baseline, when he had to share the game with the therapist he began to get angry because he preferred to play alone. He tried to play in the therapist's turns for several times. When he met the robot, he got angry and yelled at the robot to leave. In the next session, he had a similar reaction. The therapist covered the robot with a towel and J.N. played 3 games in which did not respect robot's instructions, however, he was aware of what it was telling him. He wanted to play alone and not be contradicted. In the next sessions, he had a better reaction and even smiled at it. He was more concentrated on robot's instructions, but sometimes he played in its turn. Although the increased game difficulty, he improved his performance. The therapist told him that now he was going to play with her, but he did not want to play anymore, so we do not have results of the final session.

6.4 Participant 4 - H.R.

H.R. has six years and has mild to moderate autism according to ADOS. As the previous two participants, he frequents the CDC of HGO to attend occupational therapy. H.R. presents a good linguistic and cognitive development, and a very good motor development for his age. This participant had no trouble finding out who should play in each turn and was very focused on the game. During the game with the robot, he was excited and answered the robot's questions. As the difficulty of the games were increasing, he showed no difficulty playing them, neither in taking turns. He played 4 sessions with the robot. And in the final he played with the therapist in an advanced level of difficulty. He said whose turn it was to

play, and mimicked some of the robot's speech. Sometimes he tried to help the therapist when she did not know where to put the piece. Interestingly when the session ended, as the H.R. was already capable solving the most difficult puzzles, the therapist decided to get the original Tangram game. He could easily solve the first puzzle, and H.R. insisted on playing more Tangram puzzles. During this interaction he used some of the robot lines, for example, *I am thinking* (when it was NAO's turn).

6.5 Participant 5 - A.S.

The participant 5 has twelve years old and presents mild autism. He attends supporting functional behaviorist classes at the Francisco de Arruda school. He presents a highly cognitive and linguist development, and a normal motor development for his age. A.S. held 5 sessions, two with the therapist and three with the robot. In the baseline, A.S. did not have any difficulty to play the game or to realize what was his turn to play. When he met NAO, he asked many questions about it and its functioning. In the sessions with the robot, he played with ease, always respecting his and robot's turn. Occasionally he established a dialogue with the robot and even smiled multiple times. Sometimes mimicked some of the robot vocalizations. His performance has improved dramatically as he was capable of completing the hardest puzzles. Despite he did not appreciate the original Tangram game, he was very interested and focused on the game. Although he manifested a crescent lack of interest for the robot throughout the sessions.

6.6 Participant 6 - A.J.

This child has 10 years old, has mild autism and frequents psychology sessions at CADIn Cascais. His cognitive and linguistic capabilities are normal for his age. At first, he had some difficulties on taking turns, but then easily realized who should play and when. He was able to easily solve the most difficult puzzles. The hardest game proved to be too difficult for him so it was necessary external interventions as the robot was not able to help at all the times. Throughout the game, he always followed NAO's instructions and responded to its questions. He was smiling and having fun with the robot's actions. Throughout the sessions he seemed to have lost some interest in the interaction. Although, he always respected NAO's turn, and helped when it asked. This child perceived a delay in robot's utterances that happened occasionally and began to laugh at its *confusion*.

6.7 Participant 7 - M.C.

M.C. has 10 years old and attends special education sessions on CADIn Cascais. The therapist did not know his autism level, however his cognitive and linguistic development are below normal for his age. This child is not capable of focusing in a certain task for a long time. Also, he has some difficulties taking turns and focusing on communication. In the baseline, he had some difficulties understanding when he should play, but only in the first games. He smiled and became very excited when finished each puzzle. When he was playing with the robot, there were times he was so focused on it that he did not realize that it was his turn to play. Also, sometimes when the robot asked for help, he realized what he had to do, but he did not know how. In the next sessions he seemed more intimidated by the robot than in the first and was also widely dispersed. Therefore, it was necessary more external interventions. He had problems realizing that in his turn he had to drag the piece, but when he helped the robot he only had to touch the place where the piece fits. In the four games with the therapist, he had better results in terms of performance despite its difficulty level being similar to the last session with the robot. However, he tried to play more often out of his turn because he was very distracted.

6.8 Participant 8 - D.B.

The last participant has five years old and attends early intervention in CADIn Setúbal. Cognitive development of D.B. is slightly below the normal level for his age. His linguistic and motor development are also below. He has difficulty in concentrating, taking turns and focusing on communication. At baseline, he did not present many difficulties realizing when should play. In the first games with the robot, he was very concentrated doing what it told him to do and followed all of its instructions. However, with the advance of the game he was losing focus on the robot and concentrated only in the game, so he started to trying to play more out of turn and sometimes he did not help NAO (requiring therapist intervention).

According to the therapist, this was due to the fact that he possibly has not realized how the robot was playing (i.e., NAO did not need to touch the tablet to play). But when the final session with the therapist started, he was more focused and interested again in the game. This was due to the therapist being able to provide more frequent and enthusiastic feedback. It was easier for the participant to realize when it was his turn to play, and this also helped his performance on this session.

6.9 Discussion of the Results

Considering the turn-taking results, for most participants (2, 4, 5, 6, and 7) the robot was able to stipulate the turns to play. Clearly the other two participants who did not have such positive results (3 and 8) are also the youngest participants, and so had more difficulty on the turn-taking. Almost all participants processed robot's help requests and promptly helped him, few exceptions due to lack of attention. Over time, all participants improved their performance, as they played an increasingly difficult level games and were proving to be able to solve almost independently in some cases. There was a huge interest in the robot by almost all participants (except J.N. - Section 6.3) at the first session. However, this interest noticeably decreased over the sessions due to habituation to the robot. Also, it was surprising to see that all children respond to questions asked by NAO, and some participants (2, 4, and 5) spontaneously imitated NAO's lines. It was really a challenge to transform a monotonous and uninteresting game, into something appealing that could engage all children with ASD. We think this has been achieved, because although none of the participants particularly like the Tangram, everyone was excited and engaged while playing. However, throughout the sessions, there was a gradual growing disinterest by some of the participants (3, 5, 6, and 8), this was due in part to the fact that the game always had the same flow and it became monotonous.

7 Conclusion

The purpose of this M.Sc. thesis project was to analyze how engaging a social robot can be to children with ASD during a therapy session. We initiated this report by explaining the Autism Spectrum Disorder, the main characteristics of children with ASD and some of the treatment approaches most commonly used in therapy. Then, some of the more important works related to this research field were presented. For example, in The Aurora Project it was shown that a humanoid robot can encourage the children developing their communication and social behaviors, such as imitation and turn taking skills [25, 8]. And the work of Greczek *et al.* with Nao demonstrated that through the graded cueing feedback, the children could improve their performance over time [11]. Therefore, we developed a tablet game normally played in autistic children therapy sessions. And programmed a social robot to play with the children as a tutor and as a peer. Two experimental studies were conducted to test the viability and the value of this approach. Eight children participated in this study. Their autonomy in the game increased throughout the sessions, as the game difficulty level has also increased. Overall, the participants in the Peer Condition showed little difficulty in taking turns with the robot. Our goal in this condition was to study if the child is as or more autonomous with the robot as with the therapist. Given the decreased number of external interventions and helps in the majority, the aforementioned goal was verified. All the participants showed a great interest in the robot and the game. Although, in the following sessions was measured a drastic decrement in the enthusiasm for NAO. This may be justified by the participant becoming accustomed with it. Given the heterogeneity of the autistic spectrum, it was not expected that a single methodology would be adequate to all subjects.

With our study, we realized that a few details could be addressed in subsequent work. Regarding the study, a long-term experiment should be done with a larger number of participants from both the Tutor and Peer conditions. Regarding the game, there should be a negotiation between the child and the robot in Peer mode to decide who plays first. Moreover, other aspects and features should be added to the game so the interest in it does not diminish. It should also be developed a web interface targeted to the therapist so that could be analyzed the progress of each child, their greatest strengths and weaknesses, and to control the game.

References

1. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, 5th Ed. American Psychiatric Association, Arlington, VA (2013)

2. Baron-Cohen, S.: Social and pragmatic deficits in autism: cognitive or affective? Journal of autism and developmental disorders 18(3), 379–402 (1988)
3. Battocchi, A., Pianesi, F., Tomasini, D., Zancanaro, M., Esposito, G., Venuti, P., Ben Sasson, A., Gal, E., Weiss, P.L.: Collaborative Puzzle Game: a tabletop interactive game for fostering collaboration in children with autism spectrum disorders (ASD). In: Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces (2009)
4. Bernardini, S., Porayska-Pomsta, K., Smith, T.J.: ECHOES: An intelligent serious game for fostering social communication in children with autism. Information Sciences 264, 41–60 (2014)
5. Billard, A., Robins, B., Nadel, J., Dautenhahn, K.: Building Robota, a mini-humanoid robot for the rehabilitation of children with autism. Assistive Technology 19(1) (2007)
6. Clements, D.H.: 'concrete' manipulatives, concrete ideas. Contemporary Issues in Early Childhood 1(1), 45–60 (2000)
7. Dautenhahn, K., Billard, A.: Games children with autism can play with Robota, a humanoid robotic doll. In: Universal Access and Assistive Technology, pp. 179–190. Springer (2002)
8. Dautenhahn, K., Nehaniv, C.L., Walters, M.L., Robins, B., Kose-Bagci, H., Mirza, N.A., Blow, M.: KASPAR – a minimally expressive humanoid robot for human–robot interaction research. Applied Bionics and Biomechanics 6(3-4), 369–397 (2009)
9. Ferrari, E., Robins, B., Dautenhahn, K.: Therapeutic and educational objectives in robot assisted play for children with autism. In: Proceedings of the IEEE International Symposium on Robot and Human Interactive Communication (2009)
10. Gast, D.L., Ledford, J.R.: Single subject research methodology in behavioral sciences. Routledge (2009)
11. Greczek, J., Kaszubski, E., Atrash, A., Matarić, M.J.: Graded cueing feedback in robot-mediated imitation practice for children with autism spectrum disorders. In: Proceedings of the IEEE International Symposium on Robot and Human Interactive Communication. pp. 561–566 (2014)
12. Horner, R.H., Carr, E.G., Halle, J., McGee, G., Odom, S., Wolery, M.: The use of single-subject research to identify evidence-based practice in special education. Exceptional children 71(2), 165–179 (2005)
13. Khairiree, K.: Creative thinking in mathematics with tangrams and the geometer's sketchpad. In: Proceedings of the Asian Technology Conference in Mathematics. ATCM (2015)
14. Kohanová, I., Ochodničanová, I.: Developmente of geometric imagination in lower secondary education. In: Proceedings of the International Conference on Mathematical Conference in Nitra. pp. 75–80. Department of Mathematics FNS CPU in Nitra (2014)
15. Kozima, H., Nakagawa, C., Kawai, N., Kosugi, D., Yano, Y.: A humanoid in company with children. In: Proceedings of the IEEE/RAS International Conference on Humanoid Robots. vol. 1 (2004)
16. Larson, M.J., South, M., Krauskopf, E., Clawson, A., Crowley, M.J.: Feedback and reward processing in high-functioning autism. Psychiatry Research 187(1), 198–203 (2011)
17. Lord, C., Rutter, M., DiLavore, P.C., Risi, S., Gotham, K., Bishop, S.: Autism diagnostic observation schedule: ADOS-2. Western Psychological Services Los Angeles, CA (2012)
18. Messias, J., Ventura, R., Lima, P., Sequeira, J., Alvito, P., Marques, C., Carriço, P.: A robotic platform for edutainment activities in a pediatric hospital. In: Proceedings of the International Conference on Autonomous Robot Systems and Competitions. IEEE (2014)
19. Miles, J., McCathren, R.: Autism overview. GeneReviews at GeneTests: Medical Genetics Information Resource (2005)
20. Myers, S.M., Johnson, C.P.: Management of children with autism spectrum disorders. Pediatrics 120(5), 1162–1182 (2007)
21. Nadel, J.: Early imitation and the emergence of a sense of agency. In: Proceedings of the International Workshop on Epigenetic Robotics. Lund University Cognitive Studies (2004)
22. Piper, A.M., O'Brien, E., Morris, M.R., Winograd, T.: SIDES: a cooperative tabletop computer game for social skills development. In: Proceedings of the Conference on Computer Supported Cooperative Work. ACM (2006)
23. Read, R.C.: Tangrams: 330 puzzles. Courier Corporation (1965)
24. Ribeiro, T., Vala, M., Paiva, A.: Thalamus: Closing the mind-body loop in interactive embodied characters. In: Intelligent Virtual Agents. pp. 189–195. Springer (2012)
25. Robins, B., Dautenhahn, K., Dickerson, P.: From isolation to communication: A case study evaluation of robot assisted play for children with autism with a minimally expressive humanoid robot. In: Proceedings of the International Conference on Advances in Computer-Human Interactions. IEEE (2009)
26. Russell, D.S., Bologna, E.M.: Teaching geometry with tangrams. The Arithmetic Teacher 30(2), 34–38 (1982)
27. Sacks, H., Schegloff, E.A., Jefferson, G.: A simplest systematics for the organization of turn-taking for conversation. Language pp. 696–735 (1974)
28. Shamsuddin, S., Ismail, L.I., Yussof, H., Zahari, N.I., Bahari, S., Hashim, H., Jaffar, A.: Humanoid robot nao: Review of control and motion exploration. In: Proceedings of the International Conference on Control System, Computing and Engineering (ICCSCE). pp. 511–516. IEEE (2011)
29. Siew, N.M., Chong, C.L.: Fostering students' creativity through van hiele's 5 phase-based tangram activities. Journal of Education and Learning 3(2), 66 (2014)

30. The National Autistic Society: Autism Speaks. http://www.autismspeaks.org/ (2015), [Last accessed May, 2015]
31. Werry, I., Dautenhahn, K.: Applying mobile robot technology to the rehabilitation of autistic children. In: Proceedings of the Intelligent Robotic Systems (1999)
32. Wong, A.W., Chan, C.C., Li-Tsang, C.W., Lam, C.S.: Neuropsychological function for accessibility of computer program for people with mental retardation. Springer (2004)
33. Zancanaro, M., Giusti, L., Gal, E., Weiss, P.T.: Three Around a Table: the facilitator role in a co-located interface for social competence training of children with autism spectrum disorder. In: Human-Computer Interaction, pp. 123–140. Springer (2011)