An Interactive Tangram Game For Children With Autism

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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 game. This experiment has two conditions: the Tutor Mode - the robot gives help whenever the child needs; and the Peer Mode - the robot plays with the child in turn-taking. The results showed that, in the TM, the robot was capable of stimulating children's attention towards the game and to assist them most of the times. In the PM, the robot also stimulated children's attention to the game and was able to establish turns for most participants.

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

1 Introduction

Autism is a behavioral disorder characterized by behavioral impairment in social interaction and communication, and the presence of repetitive patterns of behavior [1]. Also, children with ASD have difficulties in taking turns. The turn-taking skill is crucial for these children so that their social skills are improved [6]. Thus, part of our work focuses on improving this ability.

The interest in robots by children with ASD has instigated the majority of the research work in this area. The Aurora Research Project is an excellent example of how robots can be integrated into therapy sessions for improving social skills in these children [7]. Also, some studies [2] showed that children with autism are fascinated by electronic devices and also that screen-based games can be adopted in therapy sessions, in order to enhance children's abilities.

The Tangram is a puzzle with 7 geometric pieces usually played during therapy sessions by children with autism. This led us to choose this game. The Tangram has the capacity to improve several skills (e.g., visuospatial, logical, concentration, etc) [5]. However, it is not an engaging game. Thus, we decided to use a tablet version of the Tangram puzzle, together with a social robot - *NAO*[4]. The robot functions as a Tutor - helping the children through the game, or as a Peer - engaging the children in a turn-taking game. Finally, we conducted a single-subject study with eight participants.

[4] www.aldebaran.com/en/cool-robots/nao

2 A Robot Peer for Tangram

The game interface consists of only 3 components: (1) the solution area, (2) the pieces, and (3) a home button. During the game, the players have to drag the pieces to the right places. When all the pieces are placed, the puzzle is completed. In order for this game to be playable by most children of the spectrum, some settings were added: difficulty levels, rotation modes, distance threshold, and number of pieces. For this project, we decided to use the robot NAO, a social interaction oriented robot, with an anthropomorphic appearance, perfect for interacting with children with ASD as a peer.

Children with autism should receive positive feedback in order to maintain interest and experience a sense of self-efficacy and accomplishment [2]. So, whenever the child places a piece in the right spot, the robot gives positive feedback through congratulations and/or other social behaviors (e.g., gestures). Also, the robot reacts negatively (depending on the number of failed attempts), but only with gestures or a negative word. 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 materializes multiple fireworks upon the completed puzzle. This final reinforcement is mightier 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.

2.1 Tutor Mode - Prompting

The study 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 is presented in the next subsection. For this mode we got inspired in the work of Greczek *et al.* [4]. They demonstrated that graded cueing feedback is well suited for most children 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. In our game, if the child insists on placing the piece (1) in the wrong place, or (2) with the wrong angle, the robot begins the prompt system:

- Prompt 0 - no prompts
- Prompt 1 - the agent encourages the child to think about his/her decision;
- Prompt 2(1) - the agent gives a clue about the right spot;
- Prompt 2(2) - the agent gives a clue about the right angle;
- Prompt 3 - the correct spot starts to shine.

Also, there is another prompt system similar to the previous in case the child does not move any piece within a few seconds. These prompts include visual stimulation (i.e., piece vibrating) which is another form to maintain the child's focus and interest in the game. In both prompt systems, the game starts at P0 level. If any of the three above options arise, the game goes to P1 level. If

after some insistence, it still does not take effect on the child, the agent moves to the next prompt level, and so on. NAO has to consider the previously provided information and also the current game state (e.g., how many mistakes were made or how long without playing).

2.2 Peer Mode - Turn-Taking Game

In the second condition of this study - 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 incentivize the children to help the other even when it is not their turn. Each time they switch shifts, the robot explicitly says *Now I am playing* or *It's your turn to play* followed by a gesture pointing to the child. If the child tries to play in NAO's turn, the piece will not move, and the robot will repeat that it is its turn. To stimulate child's cooperative capacities, occasionally NAO asks for help in its turn.

3 Evaluation

Since children in the spectrum can be so different and present distinct characteristics from each other, we decided to base our study on Single-subject Design [3]. This incorporates the *baseline logic* principle: the participants serve as their own control. In single-subject design studies, the session with the therapist (A) and intervention sessions (B) are gradually alternated across time, depending on the design used. In our research, we used the A-B-A design.

The 8 children with autism performed sessions that took approximately 20 minutes. In the baseline and the last session of the Tutor Condition (TC), the participant plays the original Tangram with the therapist, then plays the tablet Tangram game, and at the end, the robot is presented. Then he/she has 4 sessions with the robot that consist of 4 puzzles played exclusively with NAO. The Peer Condition (PC) design is very similar to the TC, except the baseline and final sessions consist of 4 games played with the therapist in the turn-taking mode.

4 Results

The TC only had 1 participant. In the robot sessions, he was almost as concentrated as when he was with the teacher. In general, his autonomy increased over the games. In the final game with the original Tangram, the results were much better comparing with the baseline.

For most participants in PC, the robot was able to stipulate the turns to play. The two children who did not have such positive results are also the youngest participants, and so had more difficulty on the turn-taking. Almost all participants promptly helped NAO, with the few exceptions being due to lack of attention. Over time, all participants improved their performance. The interest in the robot decreased over the sessions due to habituation to NAO. Also, it was surprising to see that all children responded to questions asked by the robot, and some participants spontaneously imitated NAO's lines.

5 Conclusion

The purpose of this project was to analyze how engaging a social robot can be to children with ASD during a therapy session. It was really a challenge to transform an 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 liked the Tangram, everyone was excited and engaged while playing. However, the intervention sessions registered a drastic decrement in the enthusiasm towards NAO. Given the heterogeneity of the autism 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. Moreover, so the interest in the game and the robot does not diminish, children non-verbal behavior should be detected (through the camera or sensors), so that NAO could act optimally.

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References

1. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders (DSM-5®). American Psychiatric Pub, Arlington, VA (2013)
2. 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)
3. Gast, D.L., Ledford, J.R.: Single subject research methodology in behavioral sciences. Routledge (2009)
4. 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)
5. Kohanová, I., Ochodničanová, I.: Development of geometric imagination in lower secondary education. In: Proceedings of the International Conference on Mathematical Conference in Nitra. pp. 75–80 (2014)
6. Nadel, J.: Early imitation and the emergence of a sense of agency. In: Proceedings of the International Workshop on Epigenetic Robotics. pp. 15–16. Lund University Cognitive Studies (2004)
7. 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. pp. 205–211. IEEE (2009)