Design and Evaluation of Applying Robots to Assisting and Inducing Children with Autism in Social Interaction

Conference Paper · July 2013

DOI: 10.1007/978-3-642-39191-0_57

Fangwu Tung
National Taiwan University of Science and Technology

Design and Evaluation of Applying Robots to Assisting and Inducing Children with Autism in Social Interaction

Tzu-Chi Yin, Fang-Wu Tung

Department of Industrial and Commercial Design, National Taiwan University of Science and Technology, 43,Sec. 4, Keelung Rd.,Taipei,106,Taiwan

yin.tzu.chi @gmail.com,fwtung@mail.ntust.edu.tw

Abstract. This article is a pilot study in which autistic children alternated between playing a diverse card game, physical instructions game with two different humanoid level robots. The purpose of the study was explores whether the differing humanoid levels and movements regarding robot appearance influence the responses of autistic children. The objective is to design an effective robot at a reasonable cost. The result of this study indicated that autistic children were happily involved in interactive scenarios. Two different humanoid level robots were able to guide the autistic children to complete the assigned experimental tasks, and generate basic social behavior. In other words, robots with various levels of physical similarity to humans are capable of generating positive effects in social interaction learning for autistic children.

Keywords: Autism, robot, humanoid, social interaction, turn-taking.

1 Introduction

People interact and communicate their emotions with others through language, physical movement, and imagination to learn and experience various sensory activities. Although average people deem this interaction and communication ability normal and natural, a portion of people in modern society cannot communicate and interact successfully with others. These people are categorized as having pervasive development disorder (PDD), which is also known as autism. Lacking the ability to interact with others, this group cannot effectively establish interpersonal relationships and become involved and integrated in society. However, people with autism desire contact with others. Studies have shown that certain robots programmed with socializing functions can prompt people with autism to generate a certain level of preference and acceptance, increasing their willingness to interact with robots. Therefore, this study explores whether the differing humanoid levels of appearances and behaviors for robots influences the acceptance levels and responses of children with autism toward robots. The findings of this study can serve as useful reference for robot designers in

adfa, p. 1, 2011.

creating a robot for autistic children to improve their social skills and engage them in learning activities.

1.1 Social Interaction Disorders Related to Autism

In recent years, the public has become increasingly aware of autism. With the help of mature screening technologies, early determination of autism cases is rising, which has led to the annual increase of the population of people with autism worldwide. On average, among every 88 children, one is diagnosed with autism spectrum disorder, and the majority of people with autism are male [1]. With such a high proportion of people diagnosed with autism, countries across the globe have actively targeted research fields pertaining to autism.

The DSM-IV-TR [2], published by the American Psychiatric Association, indicates that people with autism lack spontaneous social behaviors, which represents their most significant obstacle to social interaction. Because of their lack of abilities regarding social attention, people with autism have difficulty developing intimate relationships with primary caregivers beginning at infancy, and, thus, cannot be intimate with others. Generally, people with autism engage in seemingly meaningless behaviors alone or maintain a certain distance from other people. This is not because autistic people are unwilling to approach others; however, they are unable to complete normal social behaviors because of their disability. Even if they attempt to approach other people, the result is often undesirable or does not fulfill expectations. Therefore, people with autism rarely interact with peers or exhibit reciprocal behaviors such as eye contact and participation in games and activities.

Consequently, autistic people tend to lack stimulation from social information during their preschool stage, thereby influencing their subsequent behavioral development [3]. Hence, improving social communication ability during preschool years can improve social interaction models and modes for people with autism in the future. This focus has attracted substantial attention regarding autism research in recent years, and is also the main focus of the present study.

1.2 Using Robots to Support Social Interaction for Autistic Children

The first study that used robots to help autistic children was conducted in 1976. Weir and Emanuel employed a remote control robot to catalyze the social behavior of a seven-year-old child with autism and attained a positive experimental result [4]. Robins et al. (2006) found that children with autism react to robots similarly to normal children. Thus, in the Aurora project, robots were used as a medium and considered an effective and programmable tool to enhance strengths and modify relevant inadequacies [5] [6]. Simultaneously, Robins et al. further proposed a perceptual crossing concept to categorize robot interactive methods into patterns such as turn-taking and executing simple tasks [7]. Patrizia applied these interactive patterns to an interactive experiment using an Iromec robot and confirmed that the game method strengthened perceptual functions, and successfully enabled a nine-year-old child who was a slow learner with an inability to concentrate to interact in various forms with a robot [8].

Consequently, the nine-year-old could interact in social relationships while playing games, which assisted the child in noticing the existence of other people and establishing a sense of trust.

In turn-taking and imitation games, social cues provided by a robot can increase the social interactions and socializing skills of autistic children. Dautenhahn and Werry successfully attracted children's attention and improved eye contact using a robot's nonverbal social communication function [9]. This improved the interactive functions and methods of turn-taking and imitation games and helped overcome the difficulty of only using language as a necessary communication medium. Furthermore, Keepon is the emotive robot with tactile and visual interaction functions, to treat autistic children using nonverbal methods and simple social cues. Dancing or swaying with music or making eye contact can successfully attract autistic children's attention and help them develop social interaction skills [10].

Although using robots to help treat children with autism can attain favorable effects, manufacturing a robot is costly. According to the estimation by the Autism Society of America Foundation (ASAF), in 10 years, the annual cost will be $200-400 billion [11]. To provide excellent treatment for children with autism, families and associations or relevant organizations require considerable budgets. Therefore, effectively using budgets to attain a balance between people with autism and their families has become an area of interest for numerous research groups and teams worldwide.

In summary, social robots are suitable for use in interactive games for children with autism, because the robots perform predictable and nonthreatening movements; their tasks are also repeated and can be continuously executed [12] [13]. Thus, these robots can teach and enhance the social skills of autistic children. Although robots have gradually come to be regarded as toys and are being applied to many fields, few studies have investigated whether the different apperance designs of robots influence the interaction between children with autism and robots, and relevant studies have only rarely provided design criteria references. Therefore, this study explores whether the differing humanoid levels and movements regarding robot appearance influence the responses of autistic children. The objective is to design an effective robot at a reasonable cost.

2 Methods

2.1 Experimental Stimuli

Based on the experimental design requirements, two types of robots with different appearances and behaviors (Robots A and B) were used in this stuy. The differences between the two robots are shown in Table 1.

2.2 Participants

Evaluated by experts, study participants were children with high functioning autism or Asperger's syndrome between 8 and 12 years old. With the assistance of the special education section of the case school, five participants were recruited. All parents and educators of the participating children were formally informed of the content of the experiment and provided consent to participate. Information of the participants is shown in Table 2.

Table 1. Descriptions of the Robot A and B using in this study.

Name	Robot A	Robot B
		
Appearance	Head, extremity, and body sections of this robot can be clearly distinguished, and are combined with a humanoid frame and joints.	A prototype with head, hand, and body sections that possesses no clear humanoid characteristics.
Movement	A 19-axial humanoid robot that can perform comparatively complicated and smooth movements.	A simply-designed robot with only axes X and Y that can perform simple and singular movement.
Expression	LED arrays installed on the face can exhibit various expressions.	Single expression design with no variation.
Sound	Both robots are installed with an MP3 module that can play recorded sound tracks or files.	

Table 2. Descriptions of the children participating in this study.

Participant	Age	Sex	Function levels regarding autism
A	11	M	High Functioning
B	11	M	High Functioning
C	8	M	Asperger's Syndrome
D	10	M	High Functioning
F	9	M	High Functioning

2.3 Study Environment

Experts consulted in this study stated that children with autism tend to feel uneasy in strange environments and suggested that the experiment should be established in an environment that the participants were familiar with; this reduced the uneasiness of the children and prevented the interference of environmental factors. Consequently, the experimental environment was set in the participants' daily counseling or guidance classroom. The environment is shown in Figure 1. Two cameras were respectively installed at the diagonal front and rear of the children's seats in the study area to record the experimental process. Large objects were also placed in the classroom to conceal and reduce uncertain factors that could interfere with the experiment. The arrangement of the experimental environment is shown in Figure 1.

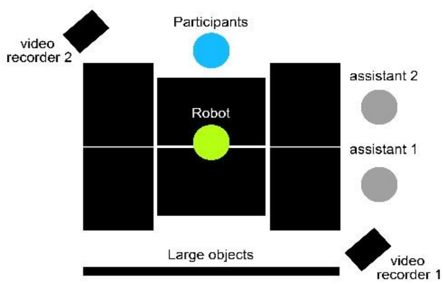

Fig. 1. Left: A view of the experimental setting. Right: Schematic representation of the experimental setting.

2.4 Procedures

Each child engaged in four interactions with each of the two robots, for a total of eight experiments. To achieve a balance between the reliability and validity of the experimental data for Robots A and B, interactions between the participants and each of the robots were conducted on different days. In addition, experiments using Robots A and B were conducted in alternating orders. For example, Participant A first interacted with Robot A in the first experiment and then with Robot B; however, Participant A interacted with Robot B before interacting with Robot A during the second experiment.

Before initiating the experiment, the researchers placed one of the robots on the classroom desk and sat behind the robot. The functioning of the remote control device was confirmed. A research assistant sitting to the left of the robot provided experimental auxiliary tools to the child and helped address unexpected events. When the participant entered the classroom, a counselor led the child to the front of the robot and relieved the child's feeling of strangeness or being unfamiliar with the environment by engaging in a casual conversation. The experiment was conducted only after the child's emotions and conditions were confirmed as suitable for the experiment.

The interactive content of the experiment was designed in four sequential stages, mainly comprising a story regarding a child going to school in the morning, as detailed in Table 3. After each stage of the experiment, an interview with the child's advisor was conducted to understand whether the behavior of the autistic child differed before and after interacting with the robot. Suggestions were extracted from the interview content and compiled to facilitate the improvement of future experiments.

Table 3. Descriptions of the experimental interaction between robots and children

Experimental stage	Experimental content
First stage	The first interaction began with morning greetings and self-introductions. Subsequently, using the diverse card to complete simple game tasks. The purpose of this stage is understanding the interaction between the robot and children, and whether the children could involve in the tasks made by the robot.
Second stage	Extend the strength of the first interaction content, at the same time increase the learning tasks of using diverse card game tasks. This stage aimed at understanding the participation of children for learning tasks.
Third stage	In addition to verbal interaction and instructions, physical instructions were included, such as performing morning exercises together. Purpose is to understanding whether the children will participate in the physical actions practice made by the robot.
Fourth stage	The fourth interaction contains the beginning of verbal interaction, and then the robot will lead the children singing a song. This stage aimed at understanding whether the children could develop and involve in singing with the robot.

2.5 Data Collection

To analyze the interaction between autistic children and robots A and B, two cameras were used during the experiment for documentation. Video footage of the experiment was divided into 1 s-long units. Interaction data in these units were then analyzed and compiled into the dataset. Finally, the results were integrated to compare the differences and influences of the two robots used in the experiment. This study defined interaction as the following:

1. Task completion level for the learning content: when the child's response fulfills the robot's commands.
2. Eye gaze: when the child looks at any part of the robot.
3. Touch: when the child touches any part of the robot.
4. Conversational content: when the child provides any verbal response to the robot. This can be categorized into active and passive conversations. Active conversations include meaningful conversational content, words or phrases, and meaningless imitations or interjections. Passive conversations indicate that the child only responds to questions posed by the robot, which is a comparatively passive method of interaction.

3 Results and Discussions

3.1 Task Completion Level for the Learning Content

Children's level of completion for experimental task implementation is somewhat correlated with the degree of similarity to humans, as shown in Figure 2. Four different activities were planned in this study to observe the interaction between autistic children and robots, as well as the children's degree of participation in the learning content planned provided by the robots. The levels of task completion by the children in each interaction are shown in Figure 2. The results indicate that the children were all capable of conducting verbal interactions with the robots, and that they completed the majority of the learning tasks. The results indicate that robotic technology can be used to assist autistic children practice verbal social interactions and can facilitate learning.

In addition to turn-talking activities, the contents of the learning tasks for each experiment differed; therefore, the children's level of task completion varied. The children exhibited excellent performance for task completion in the first and second task, which involved turn-taking learning activities using cards. Experiments three and four included additional interaction content involving physical and behavioral imitations (e.g., dancing and singing), which elevated task difficulty and increased implementation variables, thus, the level of task completion for these experiments were less ideal compared to tasks one and two.

Compared to Robot B, Robot A possesses movements more similar to that of a human. Thus, Robot A is capable of presenting comparatively vivid and complete movements. Therefore, it is effective in generating physical imitation in children. Although Robot B also led the children to conduct physical interaction, children's levels of precision and activeness when imitating Robot B were lower than that for Robot A.

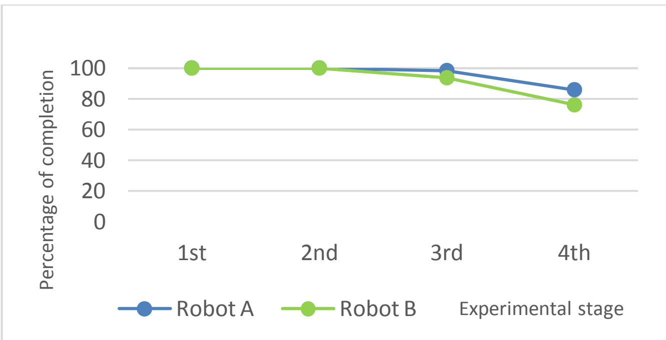

Fig. 2. Children's level of completion for learning content implementation

3.2 Eye Gaze

Figure 3 shows that overall; the children gaze upon the robots during the process of interactions. This shows that using robots as interaction and learning companions for autistic children can effectively capture their attention. Comparing Robots A and B shows that Robot A receives steadier gazes from children than that for Robot B.

During the first experiment, the autistic children were equally fascinated by both Robots, and the amount of gazes received by the two robots were approximate. During the second and third experiments, the card tasks were varied and complex; therefore, the children's attention was primarily focused on task implementation. As a result, the percentage of eye contact with the robots for these two experiments was lower. In the third and fourth experiments, task content involved physical imitation. Therefore, the children had a greater opportunity to gaze at the robot than in the second experiment, which was indicated in the increased percentages for gazes.

3.3 Touch

Figure 3 shows the percentage of time for children's physical contact with Robots A or B during the interaction process. Based on contact time, no significant difference was observed between the children's contact with robots A and B. The video records show that both Robots A and B were capable of inducing children to generate social behavior.

For example, children demonstrated communications and interpersonal social behavior with Robot A, such as hugging (i.e., holding), kissing, or attempting to make a pinky promise. Actions such as hugging (i.e., holding) and touching (i.e., pounding the chest) were also observed in interactions with Robot B. The video observation records show that Robot A is relatively more capable of inducing children to generate complex social interaction.

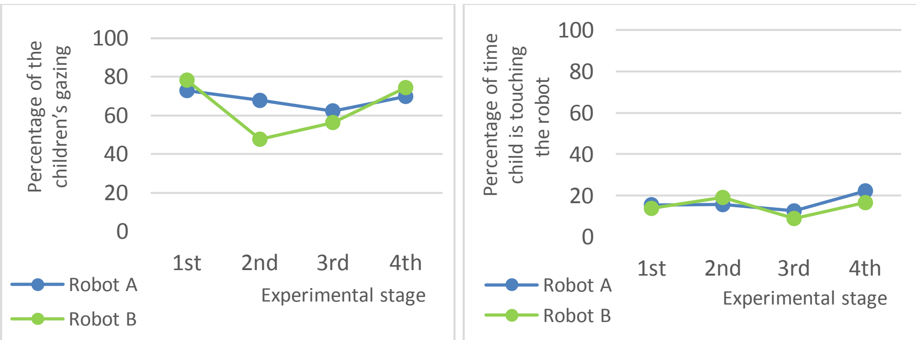

Fig. 3. Left: Percentage of the children's gazing duration for the robots. Right: Percentage of time in which the child is touching the robot

3.4 Conversational Content

To observe and assist the social interaction abilities of autistic children, interactions and task descriptions are mainly conducted through answering questions posed by the robots, which elicited verbal feedback from the children. The contents of the conversations were coded and integrated into active or passive conversational interaction modes. As shown in Figure 4, both Robots A and B were capable of eliciting verbal social interactions from autistic children, in which children were highly responsive to both Robots A and B in passive interactions.

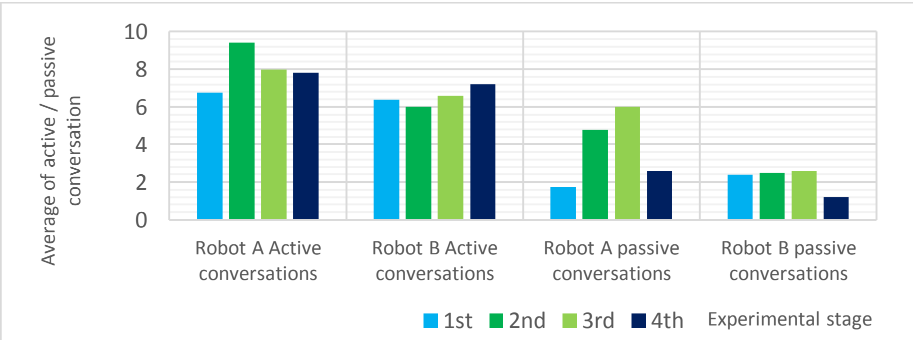

Fig. 4. Average of active / passive conversation per experimental stage

4 Conclusion

This study explored whether robots' level of physical similarity to humans and movement completeness affect their interactions with autistic children. The study results indicated that autistic children were happily involved in interactive scenarios. By interacting with Robots A and B, the children's negative emotions were alleviated during the experiments, and their in-classroom concentration was enhanced after the experiments.

Concerning Robots A and B, which had a high and low level, respectively, of similarity to humans, both were able to guide the autistic children to complete the assigned experimental tasks through interactive processes. In this interaction mode, both Robots A and B were capable of leading autistic children to generate basic social behavior and fulfill the achievement expectations. Because Robot A had smoother movements and could generate richer facial expressions, the autistic children were led to complete a greater amount of stable social interactions. In other words, robots with various levels of physical similarity to humans are capable of generating positive effects in social interaction learning for autistic children.

We anticipate that the results of this study can facilitate designers to create a robots with a reasonable cost and a certain level of effectiveness. The findings of this study can serve as a reference for research related to autistic children. In subsequent studies, we recommend that the number of participants and experimental trials be increased to generate a greater amount of effective experimental data and enhance the comprehensiveness of future studies.

Aknowledgments. This material is based upon work supported by the National Science Council of the Republic of China under grant NSC100-2410-H-011-035-MY2.

References

1. Centers for Disease Control and Prevention, http:// form www.cdc.gov
2. American Psychiatric Association. *DSM-IV-TR*. (2000)
3. MUNDY, P., NEAL, A.R.: Neural Plasticity, Joint Attention, and a Transactional Social-Orienting Model of Autism. In: L.M. GLIDDEN (ed.) International Review of Research in Mental Retardation, vol. 23, pp. 139–68. San Diego(2001)
4. Weir, S., & Emanuel, R.: Using LOGO to catalyse communication in an autistic child. Technical Report, DAI Research Report No 15(1976)
5. Dautenhahn, K., & Werry, I.: Towards interactive robots in autism therapy: Background, motivation and challenges. In: Pragmatic and Cognition, vol. 12, no. 1, pp. 1-35. (2004)
6. Robins, B., Dickerson, P. and Dautenhahn, K.: Robots as embodied beings - Interactionally sensitive body movements in interactions among autistic children and a robot. In: IEEE International Workshop on Robots and Human Interactive Communication 2005, pp. 54-59. (2005)
7. Robins, B., Ferrari, E., & Dautenhahn, K.:Developing scenarios for robot assisted play. In: *Robot and Human Interactive Communication, 2008. RO-MAN 2008. The 17th IEEE International Symposium on*. IEEE, 2008. pp. 180-186 (2008)
8. Marti, Patrizia.: Perceiving while being perceived. In: *International Journal of Design,* 4(2), pp. 27-38.(2010)
9. Dautenhahn, K., Werry, I.: Issues of robot-human interaction dynamics in the rehabilitation of children with autism. In: Proc. International Conference on the Simulation of Adaptive Behavior. pp. 519–528.(2000)
10. Kozima, H., Nakagawa, C., & Yasuda, Y.: Children-robot interaction: a pilot study in autism therapy. Prog. Brain Res. 164, pp.385-400 (2007)
11. Autism Society of America Foundation, http://www.autism-society.org
12. Marti, P., Pollini, A., Rullo, A., Shibata, T.: Engaging with artificial pets In: Proceedings of the 2005 annual conference on European association of cognitive ergonomics, pp. 99-106.(2005)
13. Pierno, A. C., Mari, M., Lusher, D., Castiello, U.: Robotic movement elicits visuomotor priming in children with autism. In: Neuropsychologia, Vol. 46, Issue 2, (2008)