eefdergi
Cilt 21 Sayı 1 Erzincan Üniversitesi Eğitim Fakültesi Dergisi
e-ISSN 2148-7510
http://eefdergi.erzincan.edu.tr | eefdergi@erzincan.edu.tr
Doi numarası: 10.17556/erziefd.472009

Robot Assistants in Education of Children with Autism: Interaction between the Robot and the Child

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Received date: 18.10.2018 **Accepted date: 19.11.2018**

Abstract

This study examined the interaction between humanoid robot and children with autism. In this study, multiple probe design was used from single-sample research models. The study was conducted in a special rehabilitation center. Participants of the study were three boys and one girl, four children with autism, aged between 6-9 years. Within the scope of the study, four social activities have been developed in which humanoid robot and children could interact. The study lasted for three weeks and each week 20-minute sessions were held for each student. Video footages and structured interview forms developed by the researchers were used as data collection tools. Video footage of the third trial was analyzed to determine the interaction level of the robot and the children. In addition, the content analysis of the interviews with the families was conducted. The interaction level scores of the students were calculated and it was concluded that there was a high interaction between the robot and autism with children. This result is parallel to similar studies using robot and robot systems in the education of children with autism in the literature. The future studies can be designed using humanoid robots to gain basic skills for children with autism.

Keywords: Autism, humanoid robots, interaction, interaction level.

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Otizmli Çocukların Eğitiminde Robot Yardımcılar: Robot ve Çocuk Arasındaki Etkileşim

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Geliş tarihi: 18.10.2018 **Kabul tarihi: 19.11.2018**

Öz

Bu çalışmada insansı robot ile otizmli çocukların arasındaki etkileşim incelenmiştir. Araştırmada tek denekli araştırma modellerinden denekler arası çoklu yoklama deseni kullanılmıştır. Araştırma özel bir rehabilitasyon merkezinde gerçekleştirilmiştir. Araştırmanın katılımcıları yaşları 6-9 arasında değişen 3 erkek ve 1 kız, dört otizmli çocuktur. Araştırma kapsamında insansı robot ve çocukların etkileşime girebileceği dört sosyal etkinlik geliştirilmiştir. Çalışma üç hafta sürmüştür ve her hafta her bir öğrenci için 20'şer dakikalık oturumlar düzenlenmiştir. Veri toplama aracı olarak denemelerde yapılan video kayıtları ve araştırmacılar tarafından geliştirilen yapılandırılmış görüşme formları kullanılmıştır. Üçüncü denemedeki video kayıtları analiz edilerek robot ile çocukların etkileşim düzeyi belirlenmiştir. Ayrıca ailelerle yapılan görüşmelerin betimsel analiz yapılmıştır. Öğrencilerin etkileşim düzey puanları hesaplanmış ve elde edilen verilerin değerlendirilmesiyle robot ile otizmli çocuklar arasında yüksek bir etkileşim olduğu sonucuna ulaşılmıştır. Bu sonuç alanyazındaki otizmli çocukların eğitimlerinde robot ve robot sistemlerinin kullanıldığı benzer çalışmalarla da paralellik göstermektedir. Gelecekteki çalışmalar sosyal etkileşimli insansı robotlar ile otizmli çocuklara temel beceriler kazandırmaya yönelik olarak tasarlanabilir.

Anahtar kelimeler: Otizm, insansı robotlar, etkileşim, etkileşim düzeyi.

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1. Introduction

Autism is a neurodevelopmental disorder that shows itself within social interaction, especially in verbal communication, with stereotypical behaviors (Myles, 2007; Zimmerman, 2008). Researchers do not know the exact causes of autism (Hergüner & Hergüner, 2011). In 1943, Leo Kanner was the first to identify a group of children displaying extreme withdrawal and disability in forming usual social relations with others. Complex developmental disabilities associated with Autism Spectrum Disorder (ASD) can be realized in the first three years of life (Kırcaali-iftar, 2007). This inefficacy can adversely affect the brain, the structure and/or functioning as a neurological origin. Individuals with ASD face problems in interaction, communication and behavior (American Psychiatric Association, 2001). Autism shows itself on many different levels and forms (Jordan, 1999). The main characteristics of individuals with autism, according to the National Autistic Society (NAS, 2005), are impaired social interaction, communication, and imagination:

Impairment in social interaction: This refers to an inability to relate to others in meaningful ways. The condition is comprised of a difficulty in forming social relationships and in understanding others' intentions, feelings, and mental states.

Impairment in social communication: This includes verbal and non-verbal communication. It manifests itself, for example, as a difficulty in understanding gestures and facial expressions as well as metaphors or other 'non-literal' interpretations of verbal and non-verbal language.

Impairment in imagination and fantasy: The development of the ability to play and to perform imaginative activities is limited.

Children exhibiting normal development use a wide range of social interaction (such as mimics, gestures, speech, social association and face expressions, etc.) while interacting with their families and peers (Charlop, Dennis, Carpenter, & Greenberg, 2010). Contrary to this situation, individuals with ASD may also exhibit deficiencies in some skills related to social interaction. In these individuals, resistance to touch or hug, preference of objects to people, requesting to be alone, lack of common attention and expressing their thoughts on limited subject can be observed (Ingersoll & Dvortcsak, 2010). The difficulties experienced in the social interaction and communication fields of individuals with ASD restrict their interaction with their environment and hence prevent them from expressing their needs, wishes or preferences. This situation causes individuals diagnosed with ASD to face certain problems in their lives and to show inappropriate behavior characteristics. People with ASD experience difficulties in establishing and maintaining relationships. They are unable to respond to various forms of non-verbal communication that many people take for granted, such as facial expressions, physical gestures and eye contact. Difficulties in social interaction may manifest themselves in one or more of the following ways: avoidance, gazing, touching, keeping distance, vocal and facial expressions (Robins & Kerstin, 2007). For this reason, increasing the level of interaction of these individuals with their environment will help them to adapt more easily to the social life.

Recent advancements in diagnosis of this disorder and setting up criteria, as well as growing public awareness about autism have led children with ASD to become more visible and uncovered new educational problems and needs in this area (Fombonne, 2005). The number of people with autistic characteristics is gradually increasing in the community (King & Bearman, 2011). The majority of applications to deal with autism in educational settings are not scientifically-based. Realization of this fact has amplified the information needs of professionals working in the field and led to a search for scientifically-based practices in education (Ryan, Hughes, Katsiyannis, McDaniel, & Sprinkle, 2011).

Individuals with ASD should be given the opportunity to be useful and productive, by being accepted and respected within society. For this reason, educating individuals with ASD with the intent to strengthen the development of their social skills is an important factor (Laarhoven, Jhonson, Laarhoven-Myers, Grider, & Grider, 2009). Many methods and tools are used to gain social skills in the education of individuals with ASD. Technology integration is one of these methods. This technology is also used in the education of individuals with ASD and provides effective results (Hedges, Odom, Hume, & Sam, 2018). One of the technologies that has become widespread in recent years is the robotics (Torresen, 2018). The number of studies involving integration of robotics into education is increasing (Causo, Vo, Chen, & Yeo, 2016; Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013; Özdemir, Karaman, Özgenel, & Özbolat, 2015; Pandey & Gelin, 2016). In addition, studies have been carried out in which robots are used in the education of children with ASD.

Robots, as they first appeared in the media and in literature, are often taken as a servant which is meant to help people. Today, robots are not only used as servants but also utilized in several different applications. These applications vary from a support element for education, to treatment or rehabilitation, and entertainment (Flores, Tobon, Cavallaro, Cavallaro, Perry, & Keller, 2008) Human-robot interaction (HRI) reflects the need for attention to many interdisciplinary problems such as motor and cognitive abilities, limitations, robotics and computer software, robot hardware features and interfaces (Rahimi & Karwowski, 1992).

The use of robots for individuals with ASD is a relatively novel therapeutic tool gaining traction over the last decade (Coeckelbergh et al., 2016). Scassellati, Admoni, and Matarić (2012) indicated that a new generation of methods of education and therapy where robots are included are effective in educating individuals with ASD and help them adapt appropriate social skills. Computer software and robotic-based interactive learning environments have been used in the treatment and education of individuals with ASD in recent years (Robins, Dautenhahn, Te Boekhorst, & Billard, 2005). People with ASD generally feel comfortable in predictable environments, and more specifically, enjoy interacting with computers and robots (Robins et al, 2005). Robot-assisted therapy and education require a different interdisciplinary collaboration with disciplines such as psychology, social sciences, cognitive science, language, artificial intelligence, mathematics, computer science, and robotics (Dautenhahn, 2007).

Recent developments in the robotics field have led to the emergence of a new research field known as interaction-oriented robots or socially interactive humanoid robots. Socially interactive robots are designed to communicate with people and are a part of human society (Fong, Nourbakhsh, & Dautenhahn, 2003; Kanda, Hirano, Eaton, & Ishiguro, 2004). A social robot is an autonomous robot that interacts and communicates with humans or other autonomous physical agents by following social behaviors and rules. Interactive features of interactive humanoid robots include various degrees of capability with respect to biological motion (walking, dancing, etc.), body language (shrugging shoulders, tilting, turning, shaking head, etc.), gaze direction to indicate attention, facial expression (smiling or frowning, lip/eyebrow/eyelid/ear movement, etc.), and vocalization (with varying levels of emotional prosody, from more robotics to more human-like speech)

(Pennisi et al., 2016). Socially interactive robots are used in communicating and understanding feelings and perceptions, maintaining social relationships, and developing social competencies (Fong, Nourbakhsh, & Dautenhahn, 2003; Li, Cabibihan & Tan, 2011). Research has begun to use socially interactive humanoid robots and practice with them in the therapy and education of children with ASD (Costa, Lehmann, Dautenhahn, Robins, & Soares, 2015; Kozima, Michalowski, & Nakagawa, 2009; Wainer, Dautenhahn, Robins, & Amirabdollahian, 2014). Social interactive humanoid robots create interesting and attractive interactive environments that allow children with ASD to interact with themselves (Dautenhahn & Werry, 2004). According to the Yun, Choi, Park, Bong and Yoo (2017) children with ASD showed clear interest in the robots and responded positively and correctly to them throughout the treatment sessions.

Studies have shown that children with ASD interacted with robots using vocal communication as a social behavior (Kozima, Michalowski, & Nakagawa, 2009; Robins et al, 2005). Some of these studies have further indicated that children with ASD interacted with a parent, teacher, or another human while engaged with a robot partner (Kozima, Michalowski, & Nakagawa, 2009; Robins et al, 2005). Kozima, Michalowski and Nakagawa (2009) observed that children with ASD demonstrated their excitements to a robot and transferred these excitements to parents.

Research results have been obtained along with using socially interactive robots in children with ASD for the development of children's social-communicative behaviors, because robots are simpler and more predictable (Robins et al, 2005). According to Robins et al. (2005) children with ASD paid more attention to a robot than a human therapist and followed its instructions almost as well. The human-robot interaction process helps children to overcome fears about complexities of verbal and nonverbal communication, as well as improving their communication process (Dautenhahn, 2003). Children with ASD can overcome their verbal and nonverbal communication fears and focus their attention; interactive social robots can also provide support for parents, educators, and clinicians (Scassellati, 2007).

There are only a few studies using social interactive humanoid robots to educate children with ASD, and the results showed robots could be more efficient in education of children with ASD. The interaction is one the most significant part of education. The main goal of this study is to reveal the level of interaction between a humanoid robot and children with ASD. Determination the level of interaction with the humanoid robot could offer insights into other educational and therapeutic programs for children with ASD, in which humanoid robots could be implemented.

2. Method

In this study a humanoid robot, called ROB, was employed. Moreover, interactive activities were developed by researchers. Video footages of children were recorded to analyze their level of interaction. Detailed information about the robot, children and procedure are given in the following.

2.1. Research Model

In the study, multiple probe design were used from single-sample research models. The single-subject research method developed on the basis of quantitative research methods is included in the experimental research group. In single-subject studies, the effect of the independent variable on the dependent variable is investigated on a single subject. In the case of more than one subject in the study, the cause-effect relationship between the independent variable and the dependent variable is examined separately with each subject without comparison between the subjects

(Kırcaali-İftar & Tekin, 1997). Moreover, interviews were conducted with families to determine children's attitudes towards activities with robot and how these activities reflected in their daily lives.

2.2. Participants

A total of four children (3 boys, 1 girl) with ASD, ranging from ages 6 to 9 who were attending a special education and rehabilitation center, participated in the study. Necessary permissions were obtained from the parents. Informed consents were obtained from the parents. Students were given the pseudonyms as C1, C2, C3 and C4. Children were selected according to their individual educational program by their teacher to participate in the study. All of the participants were identified by DSM-IV. The characteristics of the children were as follows:

C1 was 8 years old. He was in the first grade. He had high-functioning autism. He was enrolled in a supportive intervention program. The support modules in his intervention program included social skills, motor skills, mathematics, expressive language, game and music skills, reading and writing skills. For two years, his intervention program was continued as 2-hour-long individual and 2-hour-long group interventions per a week.

C2 was 8 years old and in the second grade. He had high-functioning autism. His special support program contained social skills, mathematics, expressive language, game and music skills, reading and writing skills modules. He was given a 2-hour-long individual and 2-hour-long group intervention programs per week. He attending to the rehabilitation center for two years.

C3 was 7 years old. She was enrolled in preschool. She attended the center for a year, and her program included 2-hour-long individual and 2-hour-long group interventions. She had high-functioning autism. Besides autism, she was also diagnosed with attention deficit hyperactivity disorder (ADHD). She also had limited verbal expression. The modules in her supportive program contained language, motor, and cognitive skills.

C4, aged 9, had problems in interaction and communication with other students. He had low-functioning autism. He was in the second grade. In the center, he was given a 4-hour-long intervention program consisting of 2 hours of individual, an hour of group and an hour of sensory integration. His supportive program contained the following: direction skills, social skills, mathematics, expressive language, game and music skills, reading and writing skills modules.

2.3. Research Process

The study was conducted once a week and lasted for three weeks in total. Each trial lasted about 20 minutes. The research process is given in Figure 1.

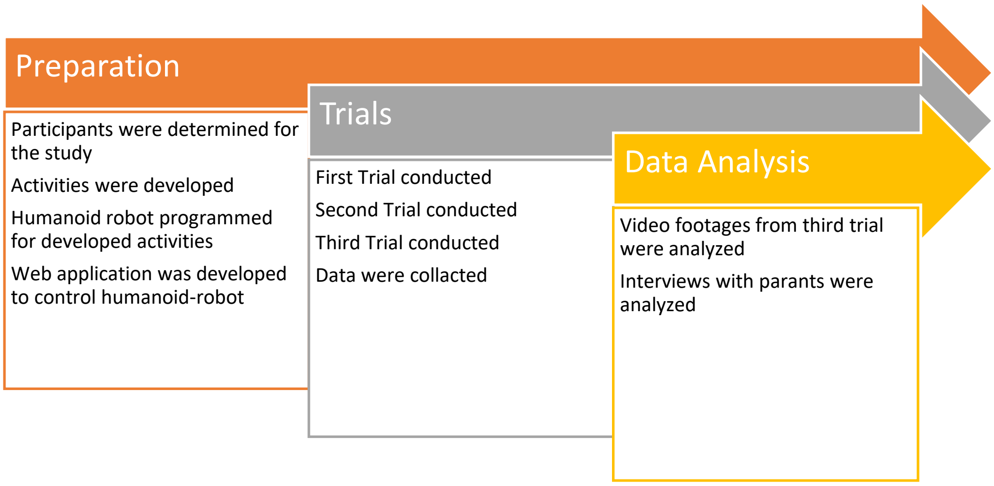

Figure 1. Research process

A Nao H25 model humanoid robot (manufactured by Aldebaran Robotics Inc.) was used in the study. This type of robot was used also in other studies (Anzalone et al., 2018; Bekele, Crittendon, Swanson, Sarkar & Warren, 2014; Esteban et al., 2017; Fridin, 2014). The robot is 58 cm high and its voice is like a child. The picture of the robot is given in Figure 2. Nao is more similar to human than the other humanoid robots. Therefore, this robot was preferred in this study.

Figure 2. Nao H25 model robot

Four social activities were developed by researchers. The activities were introducing, one-to-one conversation, one-to-one dancing/singing and dancing/singing as a group.

Introducing activity: The robot greets the child and introduced itself by saying: "I am a robot. My name is Rob.". Afterwards, the robot asks the child his/her name. When child tells his/her name. The robot answers “Nice to meet you”. Later, the robot sings two children's songs and performs two popular dances (Macarena and Gangnam style).

One-to-one conversation: The robot asks child to come next to it. During this activity, the robot calls the child by his/her name. The robot first asks to child such questions "How are you today?, Have you had your breakfast?" and waits for a response. This activity includes daily life dialogs.

One-to-one dancing/singing: The robot invites the child to sing together, asks the child some questions (e.g. "Would you like to dance together?"), and waits for a positive response. Once the child gives a positive response, the robot begins to sing a Turkish children's song called "Vücudumuz" ("our body" in English) and dance. While the robot is dancing, the child should stand in front of the robot, sing and/or dance together.

Dancing/singing as a group: The robot invites all children to come together and the robot again asks some questions (e.g. "Do you want to dance altogether?" "Are you ready?"). If the children do not give any response, the robot insists on receiving a response from children by saying more loudly "Don't you want to dance?" If any child gives a positive response, the robot says "Good. Let's start." The robot starts the group dance activity with the same song as the one used in the one-to-one dancing/singing activity.

Possible course scenario (reactions of children, possible answers or questions that might come up during an interaction) was examined and created flow diagrams to programing the robot. A part of an example flow diagram is given in Figure 3.

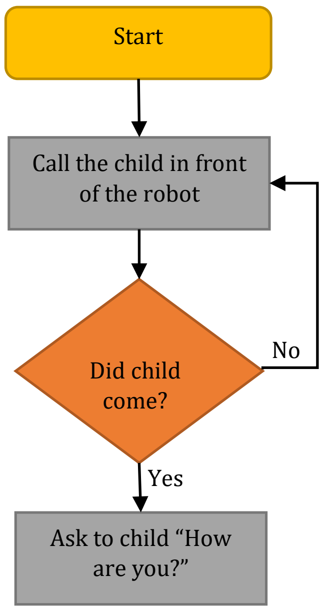

Figure 3. A flow diagram example

Depending on the flow diagrams dialogues, questions and movements programmed to the robot. Moreover, a web application developed (which could have accessed from smart phones, tablets or computers) to control the robot remotely during the trials by researchers.

The physiotherapy room was used for trials. The room was designed for child to sit on cushion. The robot was placed in the room. The distance between the child and the robot was about 2 meters. Teacher was in the room throughout the trails, seated next to the door, one meter away from the robot and child. The teacher occasionally provided support and encouragement when the child did not want to participate. A researcher who managed the robot was positioned in a corner in order not to draw the child's attention. Two cameras were placed in the room to obtain as much information as possible during the trials. All trials were set up in the same way and recorded on video to measure children's level of interaction in detail. The schema of the trial room is given in Figure 4. A picture from trials is given in Figure 5.

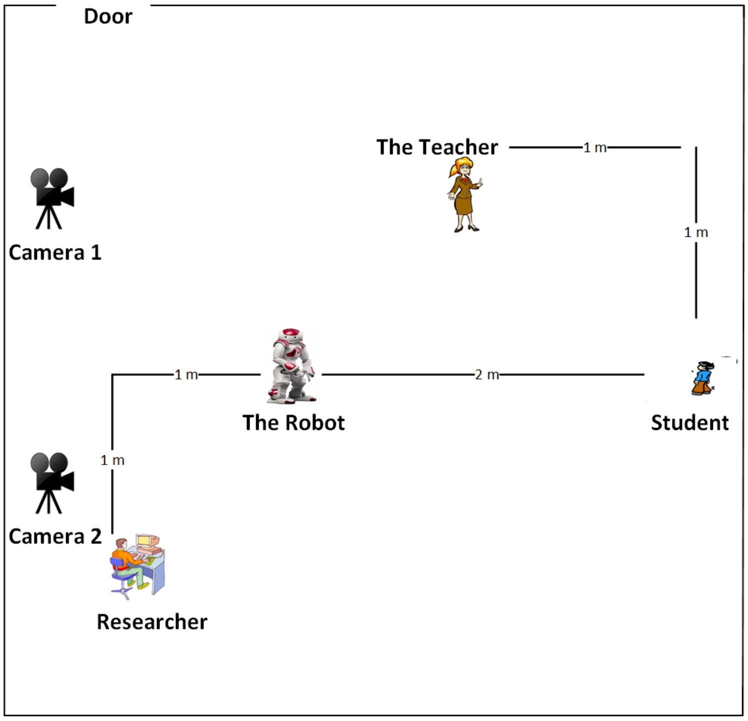

Figure 4. The trial room

Three trials were conducted to examine the level of interaction between the humanoid robot and the children. The trials were designed to move progressively from a very simple exposure to the robot to more complex opportunities for interaction. Activities of trials are given in Figure 6. The first two trials were carried out to introduce the robot to children and to get them to familiarize with the robot. The children met the robot for the first time. In this case, the possibility of the novelty effect may have an impact on measurement and results. Therefore, the data of first two trials were not analyzed. Only the data of the third trial were examined. These three trials are described in detail as follows:

Figure 5. A picture from trials

First trial: This trial was intended for introducing the robot to the children and engaging them with it. When the children were in their regular classroom (not in the trial room), the teacher gave them an introduction about robots during preparation for the trial. Then, the teacher brought the child one by one into the trial room. The robot performed introducing activity. The trial was designed mainly for the children to familiarize themselves with the robot. Therefore, the teacher did not give any instructions or tasks for the child to do. The teacher simply provided minimal verbal encouragement when needed (e.g. "Look there," "What is it?" etc.).

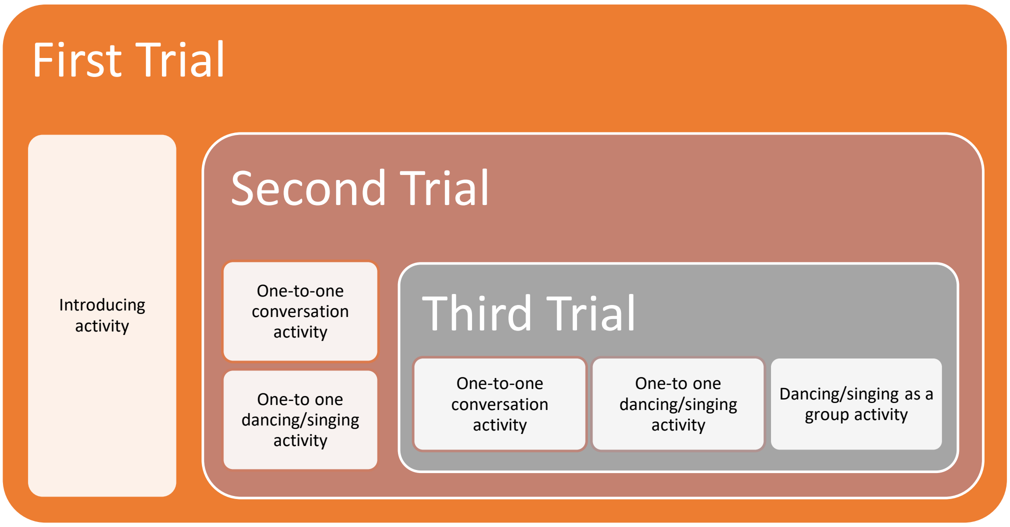

Figure 6. Activities of the trials

Second trial: This trial was designed to prepare the children for the third trial. In this trial, the one-to-one conversation activity and one-to-one dancing/singing activity were performed, respectively. The teacher mimicked and responded to the robot during the activities. For instance, when the robot said "Hi," the teacher said "Hi, Rob" just for this trial. Once this activity was completed, the child was ready to move on to interact with the robot on his/her own.

Third trial: Firstly, the one-to-one conversation activity and the one-to-one dancing/singing activity was performed with each child. Afterwards, all children were placed into the trial room altogether. The trial was ended with the dancing/singing as a group activity. The teacher gave as minimum encouragement as possible to the children when needed. Children were allowed to touch the robot if they wanted to.

2.3.1. Data Collection Tools and Measurement

Video data were recorded during the trials for analysis. Video cameras were located behind the robot to capture the faces of children clearly. Moreover, the researchers developed a structured interview form to allow families to investigate the status of their children at home. The interview form was re-shaped after taken three experts' opinion. Interviews were conducted with the families of children two weeks after the third trial. The family interview form had four questions: Has your child mentioned the robot at home? Has your child mentioned if she/he loves the robot? Has your child sung any song you have not heard before? If your child sang, did he also dance at the same time?

To investigate the level of interaction between the robot and the children, six behaviors were defined as criteria. These behaviors are:

- Avoidance (avoiding the robot or moving away from the setting)
- Eye Gaze (staring at the robot)
- Touch (touching any part of the robot).
- Distance (approaching the robot and standing in close proximity to the robot)
- Vocal Expression (making a sound)
- Facial Expression (creating a gesture when performing the task)

A new formula (in Equation 1) was generated by using Fridin's (2014) formula to evaluate the level of child–robot interaction (ID). The formula was created using the six behaviors as determined by the researchers. The formula is:

Child–robot interaction [CRI] = Avoidance [A] × (Eye Gaze [EG]) × (Distance [D] + Touch [T] + Vocal Expression [VE] + Facial Expression [FE])

The formula can briefly be presented as:

$$CRI = A(EG(D+T+VE+FE)) \qquad (1)$$

According to the formula, the level of interaction varies from -1 to 14. Therefore, the highest score that can be obtained from the formula is 14. The formula indicates whether a child forms an interaction with the robot and what the level of interaction is. The coding scheme consisted of six criteria created from the behaviors listed in the formula. The schema for eye gaze (EG), Distance (D), Touch (T), Vocal Expression (VE), Avoidance (A) and Facial Expression (FE) is given in Table 1.

Table 1. Coding schema

parameters	by himself/herself	support/encouragement from teacher or other children	no interaction
EG	2	1	0
D	2	1	0
T	2	1	0
VE	2	1	0
	child stays		**child leave from the setting**
A	1		0
	positive	**negative**	**no FE**
FE	1	-1	0

The parameters of the formula are explained as follows:

Avoidance: If the child leaves the setting because he/she ignores or is scared of the robot, this indicates that there is not any engagement with the robot and A gets the value of 0. If the child does not leave the setting, the score is 1. If A=0, CIR equals to 0, too.

Facial Expression: Facial expression is an important source of communication. One can obtain social and emotional information through facial expressions (Adolphs, 2003). Face communicates a great deal of information (Calder & Young, 2005). In the context of this study, face is hoped to facilitate understanding the emotion of children when carrying out a task. FE was coded based on the following rules: If the child has a positive facial expression, FE=1. If the child has a negative facial expression, then facial expression will be negative, so FE=-1. If the child has no facial expression during the task, FE=0.

Eye Gaze: In order to investigate the gaze pattern of the children, their gaze direction is manually coded by using 0, 1 or 2. Eye gaze and distance were chosen because they play significant roles in social communication and interaction (Bancroft, 1995). These parameters also represent areas of deficiency for children with autism (Dautenhahn & Werry, 2004; Robins, Dickerson, Stribling & Dautenhahn 2004). Eye gaze is an essential component of human communication. İf there is an eye gaze, the level of attention will be the highest, and therefore, the engagement in human–robot interaction is at its height. EG was coded based on the following rules: if the child looks at the robot's eyes for at least 3 seconds during the activity without any intervention or encouragement, EG=2. If the child looks at it for at least 3 seconds by the support of the surrounding children or the teacher, EG=1. If the child does not look at the robot's eyes or looks at it for less than 3 seconds, EG=0.

Distance: The distance means moving towards and getting close to the robot, to be within at least 50 cm near it. This approach must also be a deliberate movement towards the robot. D was coded based on the following rules: if the child approaches the robot within at least 50 cm from it during the activity without any intervention or encouragement, D=2. If the child approaches the robot to be at least 50 cm away from it by the support of the surrounding children or the teacher, D=1. If the child does not approach the robot to be within at least 50 cm from it or approaches the robot to be at a distance further than 50 cm, D=0.

Touch: Touch refers to the physical contact with the robot while performing the task for interaction, rather than for aggression or fear. Touch is considered the most fundamental means of contact with the external world. The sense of touch is a channel of communication (Hertenstein, 2002). Field (2001) claims that touch is ten times stronger than verbal or emotional contact. Coding rules for T was as: if the child touches any part of the robot during the activity without any intervention or encouragement, T=2. If the child touches any part of the robot during the activity by the support of the surrounding children or the teacher, T=1. If the child does not touch any part of the robot during the activity, T=0.

Vocal Expression: The human voice is one of the basic conveyers of communication. Voice continues to be a primary channel of emotion expression during development (Shackman & Pollak, 2005). Voice is the basic building block of speech that is necessary for learning, interacting with others, and personal development. During the trials, sounds the children made as they interacted with the robot such as yelling, mumbling, word utterances, echolalia, non-speech sounds with repetition or without clear purpose were ignored. VE was coded based on the following rules: if the child demonstrates vocal expression in response to the robot's conversation during the activity without any intervention or encouragement, VE=2. If the child performs vocal expression in response to the robot's conversation during the activity by the support of the surrounding children or the teacher, VE=1. If the child does not give any vocal expressions to the robot during the task, VE=0.

2.4. Data Analyses

Behaviors of children were analyzed in terms of the behaviors (Eye Gaze, Touch, Distance, Vocal Expression, and Facial Expression) that were presented in the formula (Equation 1) to reveal interaction level. Qualitative evaluations are important and useful for analyzing the interaction between robots and children (Scassellati, Admoni, & Matarić, 2012). In order to analyze the video footages regarding the children's behaviors, coding scheme (Table 1) was used. Two independent observers coded the video data to ensure reliability. The average agreement between the two observers was 88%. This level of agreement between observers is commonly considered to be 'good' (Bakeman, 1986).

Voice recordings were made during interviews with parents based on structured interview forms. These records were typed-up transcript. Afterwards, descriptive analysis was performed according to two categories: "positive" and "negative."

3. Findings

Three social contexts, which were determined in the 3rd trial session, were analyzed from the video data, and the children's level of interaction in each activity was calculated using the formula (Equation 1). The interaction level results are given in Table 2.

Table 2. Interaction levels

Section	C1	C2	C3	C4	Mean
One-to-one conversation	14	10	10	8	10.5
One-to-one dancing/singing	14	10	10	8	10.5
Dancing/Singing as a group	10	10	10	2	8.0
Mean	12,7	10	10	6	9.7

According to the one-to-one conversation activity, C1's interaction level is 14, which is the highest value. While C2's and C3's interaction levels are 10, C4's interaction level is 8. The average interaction level of one-to-one conversation is 10.5. Each child's interaction levels in the one-to-one dancing/singing activity were the same as those in the one-to-one conversation. With regard to the group dancing/singing activity, the interaction levels of C1, C2 and C3 were 10. However, C4's interaction level was down to 2. Separate mean interaction levels of all children are as follows: C1,12.7; C2 and C3, 10; C4, 6. The mean interaction level of dancing/singing as group activity is 8. The average interaction level scores of all students is 9.7.

The descriptive analyze method was used to examine interviews. The results are given in Table 3.

Table 3. The results of interviews

Questions	Family of C1	Family of C2	Family of C3	Family of C4
Has your child mentioned the robot at home?	Positive	Positive	Positive	Positive
Has your child mentioned whether she/he loves the robot?	Positive	Positive	Positive	Negative
Has your child sung any song you have not heard before?	Positive	Positive	Positive	Positive
If your child sang, did he also dance at the same time?	Negative	Negative	Negative	Negative

All of the families indicated that their children had a positive attitude towards the humanoid robot and the children loved the robot. In addition, all families stated that their children sang the song at home which the robot sang. They also added that none of the children danced at home. Some quotes from the family interviews are given in following:

C1's family: "*Today we met with a robot named Bob. Bob sang a song to us.*" (Here, the child remembered the robot named Bob, and he told the robot's name to his family.)

C2's family: "*I heard that he sang the song only once at the house.*"

C3's family: "*She was trying to tell us about the robot very excitedly.*"

C4's family: "*My son said that he had met a robot at school. I asked him if he had liked the robot. He approved by nodding his head.*"

4. Discussion

The main goal of this study is to reveal the level of interaction between a humanoid robot and children with ASD. Therefore, three different social contexts were evaluated according to a formula (Equation 1) developed to calculate the level of interaction. 14 points was the highest score that could be taken from this formula. The children's average level of interaction was 9.7 points. This shows that the robot–child interaction was high. This result is parallel with the literature. Research shows that children with ASD enjoy interacting with other robot models due to robots' simple and predictable behaviors (Robins et al, 2005). Children with ASD demonstrate attentional preferences for robotic interactions over brief intervals of time (Bekele et al., 2014).

One-to-one activities hold the highest average interaction level in the three social contexts. The one-to-one conversation (m=10.5) and one-to-one dancing/singing (m=10.5) activities have higher interaction levels than the group activity (m=8). Similarly, Ülke-Kürkçüoğlu (2007) have found that behaviors of children with ASD are more closely related to the actions provided in one-to-one activities, and this leads to higher interaction rates.

C4's interaction level score is 6. This score shows that the interaction with C4 and the robot is not high. C4 has low-functioning autism, this situation probably affects the interaction level. Children with low-functioning autism show less social involvement with peers and other people compared to children with high-functioning autism (Bauminger, Shulman, & Agam, 2003). Moreover, children with high-functioning autism display a greater capacity for social-emotional expressiveness and responsiveness compared to children with low-functioning autism (Sigman & Ruskin, 1999). Therefore, it is thought that C1, C2, C3 were diagnosed with high-functioning autism so that their interaction levels are higher than C4. In addition, although C4's interaction level is not high (he did not sing the song) in the trials, but his parents stated that he sang the song at home. This may indicate that C4 has a higher interaction than the interaction exhibited in trials.

It was ensured that a pleasant and attractive atmosphere was offered to the students with games and musical events using the robot, which might have encouraged the child to interact with the robot freely. The results, concurring with the literature, shows that socially interactive humanoid robots help children with ASD to participate in enjoyable and interesting game activities (Kozima, Nakagawa, & Yasuda, 2007).

According to the interviews with the families, children talked about the robot at their home. They stated that their children even hummed the song at home. Families' feedbacks are important, because skills, which are acquired at schools, can be repeated and actualized by the children in daily life largely with the help of participation of their family (Mesibov, Shea, & Schopler, 2004). Based on the results from the descriptive analyze, it can be said that the children with ASD interacted with the robot at a high level as indicated by the calculations through the formula 1.

In addition, this study shows that the robots could be used in the education of autism, and robots would be ideal for simplifying social behaviors to facilitate learning. The results parallel with the literature, which shows that robots play an important role in education and treatment of children with ASD (Robins & Dautenhahn, 2007).

There were some methodological limitations of this study that are worthy to highlight. The robot's movement were limited to certain actions based on its model, which were not capable to perform all kinds of dances. However, it is important for future research on robots —with the aim to educate children with ASD— to focus on determining which features of robots are most effective in facilitating the acquisition of different skills by children with ASD.

The potential role of robots as social mediators can also be investigated in terms of encouraging interaction between children with autism and other people (e.g. peers and adults). In the present study, the robot, the teacher, and the researchers were all together in the classroom with the child during the trials. In the future studies, similar investigations can be conducted in an environment where robot and children are alone, in order to eliminate the independent variables that may affect the level of interaction. Moreover, the studies can be designed using robots to gain basic skills for children with ASD. In addition, similar studies can be performed using humanoid robots for other children need special education.

Acknowledgments

This study was supported by the Scientific Research Project Coordination Unit of Istanbul University. Project number: 53244.

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