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Development of Interaction Scenarios based on Pre-School Curriculum in Robotic Intervention for Children with Autism

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Abstract

This research deals with the fundamental study on the social effects of robotic interaction to children with autism. Autism is a developmental disorder caused by abnormal development of the brain. It is characterized by deficits in social and communication skills and also behavior stereotypies. Robotic intervention has been identified as one of the methods that are producing encouraging outcome in the rehabilitation of children with autism. The main purpose of this project is to design interactive scenarios according to its level of complexity using a humanoid robot based on the pre-school curriculum for children with special needs by the Ministry of Education Malaysia. Expertise from related field including rehabilitation and special education are involved to ensure that the scenarios' designs meet the requirement and needs of children with autistic characteristics. Focusing on language skills, the interaction aims to facilitate autistic children who face difficulties in communication and socializing. This shall help them to express themselves better to their peers and other people.

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Keywords: humanoid robot; rehabilitation robotics; Autism Spectrum Disorders (ASD) and human-robot interaction (HRI)

1. Background

This research explores the social effects of human-robot interaction (HRI) approach to children with autism, a population that is characterized by social-interaction difficulties and communication problems. Autism is defined as a developmental disorder that appears in children in their first 3 years of life caused by the brain's abnormal development. Since autism has no cure, specific treatments and therapy programs are conducted to help people with autism to lead meaningful lives and increase their independence. Proper support and effective therapy intervention in the early years are vital to improve the overall outcome of individuals inflicted with autism.

Rehabilitation robotics is a juncture of study that intertwines knowledge in engineering and medical field for the

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benefit of mankind. By convention, a robot is defined in the International Standard of Organization as a reprogrammable, multifunctional manipulator programmed to move parts for the performance of variety of tasks [1]. Assistive robots on the other hand hold one of the most promising robotic applications today due to its increasing applications in the rehabilitation of disabled and elderly people.

1.1. Autism and its prevalence

Autism has shown significant increase in prevalence in the recent years regardless of of race, religion and geographical locations all over the world. Children diagnosed with autism are typically characterized by the three main symptoms: impairments in the area of social interaction, communication, and repetitive behavior [2]. Most of the children identified with autism have inadequate language for effective communication and also show inability to establish and maintain joint attention, in which they cannot share a focus of interest with their interactional partners. This deficiency is pervasive and is associated with the problems in language, cognitive, and social development [3].

The latest prevalence studies of autism indicate that 1.1% of the population in the UK may be born with autism. This means that over 695,000 people in the UK may be affected [4]. Also, autism seems to affect more boys than girls by the ratio 4 boys for 1 girl [5]. The National Autism Society of Malaysia (NASOM) estimates that one in every 150 children born today has a typical autism. With the increasing prevalence, early detection and access to intervention are essential for the affected children to experience better outcome in later years.

1.2. Robotic intervention for autism

Previous research in rehabilitation robotics show encouraging outcome in helping autistic children to improve their joint attention skills. Naturally, children are interested in robots and this might encourage their voluntary communication. There is anecdotal evidence that autistic children exhibit less severe autistic behavior when interacting with robot compared to during interacting with their peers [6]. This study also shows that robots may hold promise for autism interventions because the children are more engaged with an autonomous robot in the reactive mode compared to an inanimate toy or robot. In another study, children with autism tend to communicate and interact more with robots that do not resemble human being [7]. However, in order for the children to generalize what they had learned to real interaction scenarios outside the clinic, naturalistic approaches to autism therapy suggest that a clinical setting approach that resembles the real world would be preferable [8].

Researchers have developed humanoid robotic platforms that exactly resembles a real person while others have built non-humanoid robots that does not have any human-like appearance. Some examples are Kaspar a child-sized humanoid used at the University of Hertfordshire, FACE the realistic robot at the University of Pisa, a less realistic humanoid robot which is Tito at the University of Sherbrook and Pleo the dinosaur robot at Yale University. Interacting with humanoid robots that provide simple emotional response and interaction has been shown to improve the communication skills of autistic children. In particular, early intervention and continuous care provide significantly better outcomes [9].

Recently, a worldwide robotic company Aldebaran Robotics, the creator of humanoid robot NAO, has recently launched a special project to utilize NAO in therapy of children with autism. This initiative was developed after noticing that many children with autism seem impulsively attracted to technology therefore allowing NAO to become the perfect bridge between technology and human social world. NAO's features are simpler than a real human therefore displays less information to process and so decreases overstimulation risks. A robot is also predictable and this minimizes unexpected interactions that might lead to increased anxiety in autistic children.

1.3. Pre-school curriculum for children with special needs by the Ministry of Education Malaysia

This curriculum is known as *'Program Pendidikan Khas Prasekolah Masalah Pembelajaran'* and developed by the Ministry of Education Malaysia. This study only focuses on the Communication Strand under the English language section in the curriculum that aims to improve a child's ability to communicate and understand simple words. The target is for pupils to be able to: listen, imitate and understand simple spoken English, speak and respond accordingly and be able to use the language acquired to function in society. The listening and speaking scenarios

Table 1: The Communication Strand for English Language

Focus English Language	Standard Content	Learning Standard	
		Level 1	Level 2
1.0 Listening Skills	1.1 Listen and respond to familiar sound	1.1.1 Respond to own name 1.1.2 Respond to sound of animals 1.1.3 Respond to sound of objects 1.1.4 Respond to sound of vehicles	
	1.2 Listen and respond to simple instructions	1.2.1 Listen and respond to one word instructions	1.2.2 Listen to and respond to simple instructions
	1.3 Listen and respond to simple songs and rhymes	1.3.1 Listen to simple songs and rhymes and perform simple related actions	
2.0 Speaking Skills	2.1 Imitate sounds meaningfully	2.1.1 Imitate sounds that gives meaning	
	2.2 Give single word answer	2.2.1 Respond with 'Yes' or 'No'	2.2.2 Respond with single word answer
	2.3 Name objects in the environment	2.3.1 Name three objects in the environment	2.3.2 Name five objects in the environment

from the curriculum that are embedded in our robotic intervention program are shown in Table 1.

1.4. Applied-Behavior Analysis (ABA)

Typically developing children learn without any intervention because their surroundings provide the right conditions to learn language, play, and practice social skills. However, children with autism experience difficulties to learn through the environment around them

Applied Behavior Analysis (ABA) is a behavior-modification approach where target behavior is broken down into small discrete tasks that are simple and achievable. ABA is a therapy that is focused on providing the conducive environment to enable individuals to learn. This therapy is based on reinforced behavior which means that the child will be rewarded every time he/she does the right action at the right time [10]. This therapy is very effective for children undergoing a learning process in academic, social, communicative and adaptive skills. This technique is probably the most widely used intervention currently use to treat child with autism.

2. Flow of methods

The flow chart in Fig. 1 illustrates the developmental stages in this study where the term 'interaction scenario' means a segment of the humanoid's behavior that is programmed to elicit specific response from the children. In the first stage, the existing curriculum is studied to identify contents that are suitable for robotic intervention. Then each interaction scenario is developed by programming the robot using the Choregraphe software. The scenarios are then presented to a clinician to gain input on robot movements and interaction content. Next, modifications are done to the robot programs until they are ready for evaluation by a Special Education teacher. A special education teacher is someone who works with children with special needs and is familiar with the appropriate tools and guidance needed for the children to reach their learning potential. The evaluation is to obtain feedback on appropriate content of robotic interaction to be suit learning situations for children with autism.

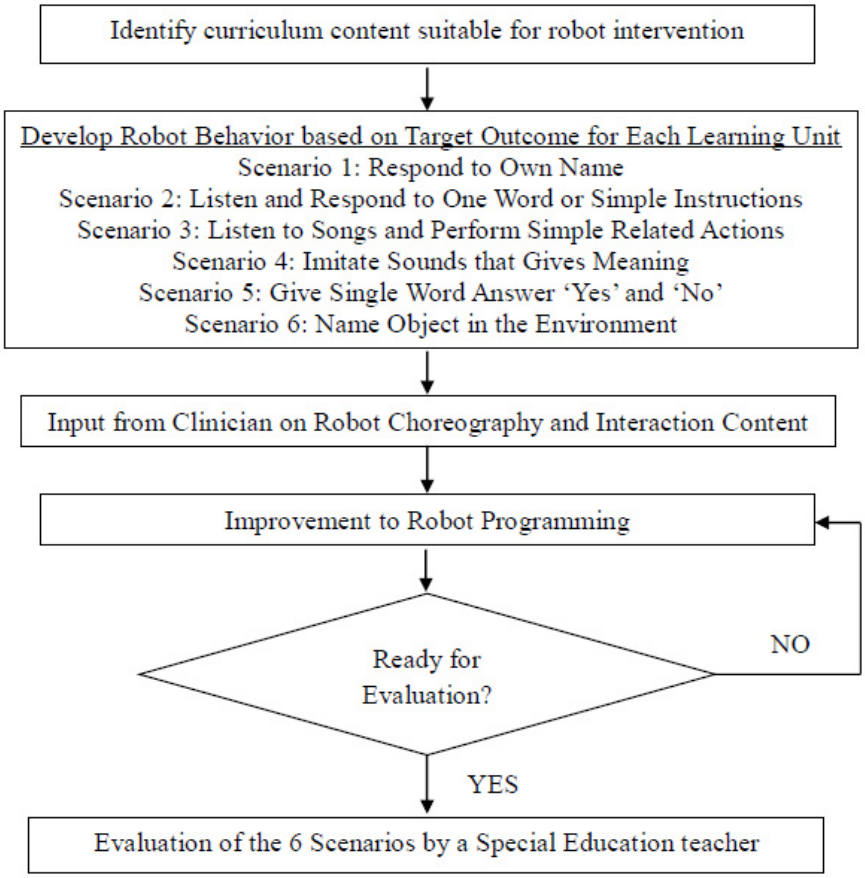

Fig. 1: The development stages in the study

2.1. Identifying suitable curriculum and developing 6 new robotic programs

In our research study, 6 scenarios in the curriculum (Table 2) have been identified as suitable and fit to be programmed into the humanoid robot NAO. The robot's technical capabilities and limitations are the important factors to be considered in this stage.

Table 2: List of the 6 interaction scenarios and description

#	Scenario	Description
1.	Respond to own name	'Ice-breaking' session with NAO introducing itself. NAO calls the child's name aloud
2.	Listen and respond to one word or simple instructions	NAO asks the child to do the simple instructions related to the body movement
3.	Listen To Songs and Perform Simple Related Actions	NAO sings popular nursery rhymes with simple choreographed actions that portrays related gestures and emotions
4.	Imitate Sounds that Give Meaning	NAO say sounds aloud for the child to repeat. Starts with two familiar sounds so that the child could easily imitate the sound.
5.	Give Single Word Answer 'Yes' and 'No'	NAO asks simple questions regarding pictures of objects placed at the right and left side of the NAO. Child needs to understand the question and respond with the simple answer 'Yes' or 'No'.
6.	Name Object in the Environment	NAO simply explains the names of about 2 items placed at the right and left side of NAO. Child needs to remember and answer when asked.

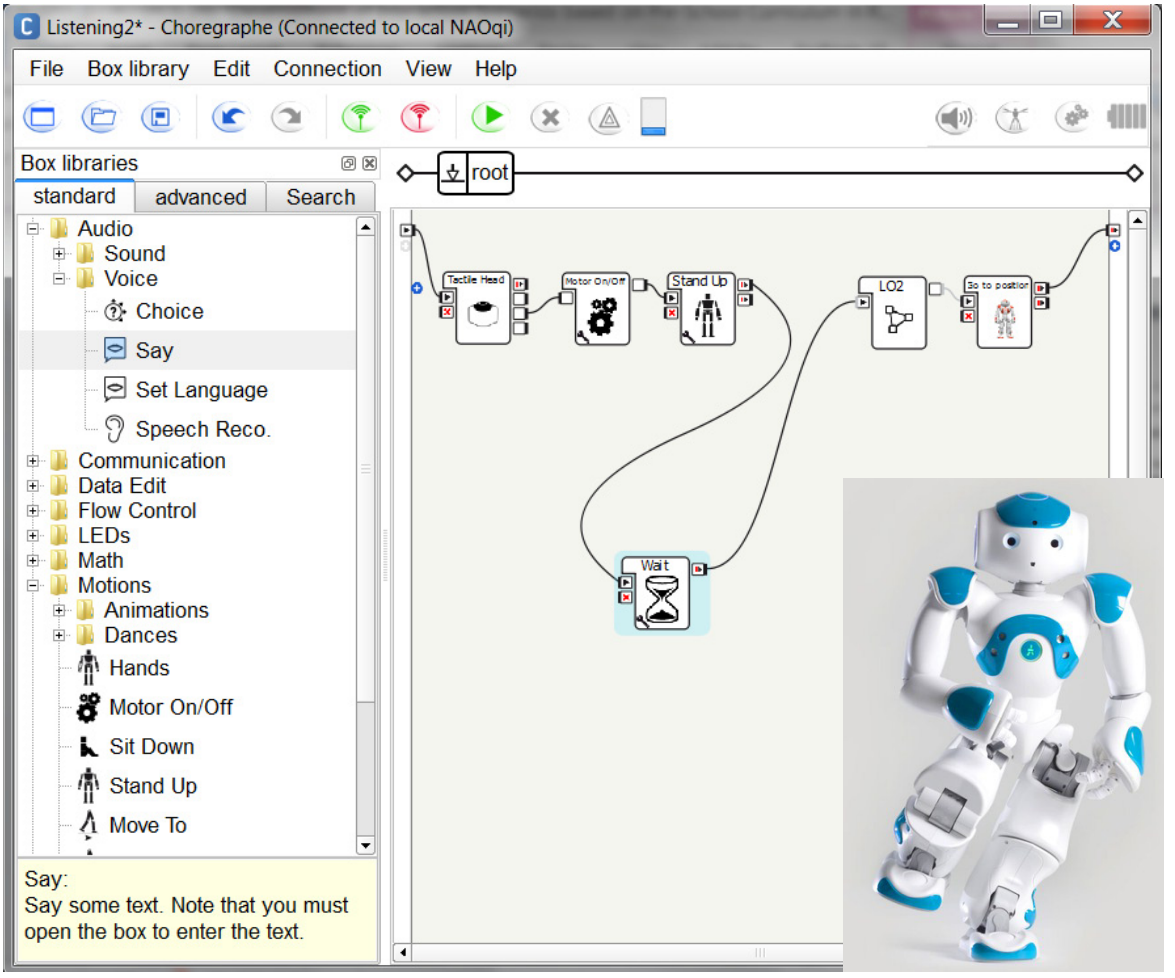

Fig. 2. The humanoid robot NAO by Aldebaran Robotics (insert picture) and the Choregraphe program to construct the interaction scenarios

Using the Choregraphe software, 6 interaction scenarios were designed with different levels of difficulty using the humanoid robot NAO. Content of each scenario was based upon observations on therapy activities at the clinic, informal interviews with special education teachers and also intensive review studies. The robot used and an example of the programming environment in Choregraphe is shown in Figure 2. Robot's movement is one of the key factors in to attract the children's attention during the child-robot interaction. Therefore, the robot's motion is choreographed carefully to correspond to the target outcome of each lesson unit. Also, the two-way interactive dialogue needs to be composed using short and simple sentences.

2.2. Input from clinician on robot choreography and interaction content

When the 6 scenarios of robot behaviors were completed, we sought inputs from a clinical specialist in rehabilitation to get better insights on the contents of the interaction. Each robot program was demonstrated and the clinician gave inputs regarding the robot's physical movements and also interaction dialogues. Comments obtained during this consultation are summarized in Table 3.

Table 3: List of inputs from clinician on the content of the interaction scenarios

Scenario	Description of Existing Scenario	Input from Clinician
Respond To Own Name	-There are 3 sequences: NAO introducing itself, NAO asks for child's name and NAO calls out child' name -NAO gave instructions at the beginning of the session -Movements of NAO include NAO waving its hand at the start and the end of the interaction	-Only 2 sequence: NAO will directly introduces itself and then calls out for the child's name -Eliminate the sequence of robot asking for child's name -Need to make interaction simpler with lowest difficulty level (this is the first lesson) -Focus only the child's response when his/her name being called
Listen And Respond To One Word or Simple Instruction	-Initially to teach children about greetings -NAO begins with simple introduction -NAO asks the child to repeat after it says "Good Morning" -NAO asks for the names of the child's mother and father -NAO will praise the child if the question is answered	-Asking a child to repeat "Good Morning" is not a one word or simple instruction -Suggests the use a simple instruction through simple body movements such as 'raise-up hand' and 'shaking head' -Removes the question about the name of the child's parent because it is a difficult question
Listen to Songs and Perform Simple Related Activities	-NAO begins with simple introduction for the child to sing along and follow its movements -Initially there are 3 popular nursery songs: 'Good Morning to You', 'Good Morning' and 'Goodnight Sleep Tight' -Each consists of NAO playing music through its speakers with simple body movements -NAO praises the child at the end	-3 songs are too many for children with autism, it could cause the children to lose their focus -Suggest to use only 2 songs -To standardize for each scenario to only have 2 set of questions or activities -Remove 'Good Morning' song
Imitate Sounds that Give Meaning	-NAO begins with simple introduction -Consists of 2 sequences -First sequence contains of NAO voicing 4 phrases used in greetings: (i) 'Good morning', (ii) 'Good afternoon', (iii) 'Good evening' and (iv) 'Good night'. Then NAO asks child to repeat the phrases -Second sequence involves a set of 3-words phrases: (i) 'Good morning mother', (ii) 'Good afternoon father' and (iii) 'Good evening' -NAO praises child for correct answers	-Greetings is not one the 'sounds that give meaning' -Instead, can follow the therapy approach by using simple, familiar in everyday life to be imitated by the autistic children such as the sounds of vehicles or animals -Chosen sounds are the bell sound 'Ding Dong' and the cat sound 'Meow' - NAO praises child for correct answers
Give Single Word Answer 'Yes' and 'No'	-NAO begins with simple introduction that child need to answer 'Yes' or 'No' for each question -Consists of 2 sequences. First, NAO asks questions related to greetings: (i) 'Do you like morning?' (ii) 'Do you like afternoon?' (iii) 'Do you like evening?' (iv) 'Do you like night?' -Secondly, NAO asks questions about family: (i) 'Do you like your mother?' (ii) 'Do you like your father?' (iii) 'Do you have a brother?' (iv) 'Do you have a sister?' -NAO will praise when the child responses	-Questions are difficult and unsuitable -Propose to replace with questions usually used by clinicians in therapy -Suggest using pictures of familiar objects and placing them at the left and right of NAO. NAO will ask question regarding to the picture and the children need to answer 'Yes' or 'No'. -The pictures show number one and a car and the questions are: (i) 'Is this number one?' and (ii) 'Is this a car?' -NAO will praise the children if they answered it correctly.

Table 3 (continues): List of inputs from clinician on the content of the interaction scenarios

Scenario	Description of Existing Scenario	Input from Clinician
Name Objects in the Environment	-NAO begins with simple instruction -Three items are placed in front of NAO -The first item the left side is a bottle, second item in the middle is a book and third item is a pen -NAO asks children to remember names of each item and be able to say it aloud when asked	-Suggest to standardize to 2 questions only -2 objects will be placed at the right and left side of NAO. The first object is a ball and the second one is a car both are familiar objects. Questions are: (i) 'What is the item on my right?' and (ii) 'What is the item on my left?' -NAO praises child for correct answers

2.3. Improvements on interaction scenarios and assessment method

Robot programming for each interaction scenario was improvised based on suggestions put forward by the clinician. At this stage, we had also incorporated an assessment method. The convention of 'S' for success, 'F' for failure and 'R' for repeat will be used to evaluate the response from the children during the robot-assisted lessons. For example, in Scenario 1, a score of 'S' will be given if the child says 'Yes' or show response after his/her name is being called and score 'F' if the child does not show response to the question. 'R' means that the robot will repeat the question 3 times if the child did not answer the question. The 'R' cycle is applicable to all 6 scenarios where the robot was programmed to automatically repeat the questions thrice in the case that no response is detected.

2.4. Evaluation by a Special Education teacher

The final stage of development for the robotic programs is the evaluation process by a special education teacher. A questionnaire was developed with the purpose to evaluate whether the six interaction scenarios are suitable to be tested on children with autism children and also by obtaining feedback from expert to improve their overall contents.

The questionnaire consists of a total of 45 questions. For each item, the respondent need to rate on the 5-point Likert Scale of between 1 to 5 (from strongly disagree to strongly agree) to convey her opinion on the appropriateness of the contents. The 5-point Likert Scale is the most common scale used in questionnaires to measure the degree of agreement to a set of statements based on respondent's preferences. Respondents are asked to indicate their level of agreement with a given statement by way of an ordinal scale.

Table 4: The 5-point Likert Scale for the questionnaire

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

Overall, results from the questionnaire show that the respondent agreed that the content of the interaction scenarios are suitable and that the language incorporated in the child-robot interaction are understandable by preschool-age children. Language plays an important role in communication so that the children can understand what NAO is saying. NAO dialogues need to be delivered clearly, concisely, and directly to the child. The respondent also approved that NAO gives praises when a child answers a question. This complies with the ABA method where there will be a reward when a child executes a certain behavior correctly.

For Scenario 1, the respondent agreed with the movements of NAO waving its hand at the child while introducing itself with its eyes blinking. This nonverbal language cue may increase the child's focus on the interaction with robot. The child will also be motivated to communicate because children with autism will generally not engage in communicative interactions unless they are motivated to do so. However, the respondent chose the neutral score when asked about the position of the robot which is in standing mode during interaction.

For Scenario 2, the respondent gave an overall score of 4 for most of the questions. Basically, this scenario has increased slightly in terms of difficulty compared to Scenario 1. She agreed that the robot need to perform the same actions as it gives general actions command to the children, for example when asking the child to raise up his/her hand. This action provides visual assistance for the children, so that the children can perform the instruction easily

by imitating the robot's movement.

For Scenario 3, in terms of songs selection the respondent gave a rating of 2 which meant that the songs 'Good morning to you' and 'Good night sleep tight' were unsuitable. She recommended to change replace them with other familiar songs because it work better especially to the kids who need simplicity due their nature and special needs. For Scenario 4, the sounds that have been proposed were the sounds of the doorbell 'Ding Dong' and also the sound of an animal which is the cat's 'Meow'. The respondent agreed that these sounds are suitable. Children with autism should be able to imitate the sounds theoretically because both are considered familiar.

For Scenario 5, the questions 'Is this number one?' and 'Is this a car?' are suitable for pre-school children with autism. Finally, for Scenario 6 the respondent agreed that a ball and a car are suitable objects that can be used because it is simple to be pronounced by the pre-school children. For the position and the movement of the humanoid robot NAO, both are rated as 4 which are agreed. The respondent supported that the robot should be in standing up position with its hand pointing to the object while it asking related question to the child. The movement of the robot might help the children to understand boy gestures that are related to instructions.

3. Conclusion and Future Works

This paper presents a set of newly developed robotic scenarios according to its level of complexity meant for assisting children with autism in learning. The programs are based on the pre-school curriculum for children with special needs by the Ministry of Education Malaysia. The robot has been choreographed with body movements and interaction dialogues to fit the purpose as a learning tool in the classroom. The interaction scenarios were presented to a rehabilitation specialist for consultation on their contents. Improvements were carried out and then the programs were demonstrated to a special education teacher for evaluation. Evaluations have been done using a questionnaire. Overall, the teacher agreed on the appropriateness of contents of the interaction scenarios to be tested on children with autism in the pre-school age.

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References

1. S.K. Saha,*" Introduction to Robotics"*. 2010, 7 West Patel, New Delhi: Tata-McGraw Hill Publishing Company Limited.
2. C. Liu, K.C., N. Sarkar, and W. Stone, *"Affect Recognition in Robot Assisted Rehabilitation of Children with Autism Spectrum Disorder*," in *Robotics and Automation IEEE International Conference* 2007. p. 1755-1760.
3. C. Kasari, S. Freeman, and T. Paparella, *"Joint Attention and symbolic play in young children with autism: a randomized controlled intervention study"*. 2006. **47**: p. 611-620.
4. Brugha T, McManus S, Meltzer H, Smith J, Scott FJ, Purdon S, Harris J, and Bankart J, *"Autism spectrum disorders in adults living in households throughout England: report from the Adult Psychiatric Morbidity Survey*, in *NHS Information Centre for Health and Social Care"*. 2009, Department of Health Sciences, University of Leicester, Autism Research Centre, University of Cambridge.
5. Indu Joshi, M. Percy, and Ivan Brown, *Advances in Understanding Causes of Autism and Effective Interventions.* 2003. **9**: p. 2-3.
6. B. Robins, P. Dickerson, P. Stribling, and K. Dautenhahn, *"Robot-Mediated Joint Attention in Children with Autism: A case study in Robot-Human Interaction*, in *Interaction Studies*". 2004. p. 161-198.
7. B. Robins, K. Dautenhahn, and J. Dubowski, "*Does appearance mattter in the interaction of children with autism with a humanoid robot"*. Interaction Studies," 2006. **7**: p. 479-512.
8. B. Ingersoll and L. Schreibman, *"Teaching reciprocal imitation skills to young children with autism using a naturalistic behavioral approach: effects on language, pretend play, and joint attention"*. 2006. **36**: p. 487-505.
9. M. A. Ma'sum, M. S. Alvissalim, F. Sanjaya, A. Andros, and W. Jatmiko, "*An affordable compact humanoid robot for autism spectrum disorder interventions in children"*. in *Body gesture based control system for humanoid robot*. 2011. Boston,USA: IEEE Engineering in Medicine and Biology Society. Conference.
10. K. Karlsson, *" A computer based approach on autism*". 2009, University of Akureyri.