Developing Interaction Scenarios with a Humanoid Robot to Encourage Visual Perspective Taking Skills in Children with Autism – Preliminary Proof of Concept Tests

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Abstract. The study described in this article is part of our contribution to the Horizon 2020 Babyrobot project, where we have created different play scenarios for children with autism to playfully explore elements that are important in developing Visual Perspective Taking (VPT) skills. Individuals with autism often have difficulty with Theory of Mind (TOM) and the understanding that other individuals have their own thoughts, beliefs, plans and perspectives. Visual Perspective Taking is the ability to view the world from another individual's perspective, e.g. understanding that other individuals have a different line of sight to oneself, and also understanding that two or more people viewing the same object from different points in space might see different things. It is believed that TOM and VPT may share common cognitive processes.

Our study aims to help children with autism develop their VPT skills using the Kaspar robot. Using a robot to teach children about VPT has a distinct advantage in the fact that what the robot can see can be shown directly to the children using the cameras in the robot's eyes and a screen to show the robot's perspective. This article presents the preliminary test of these concepts during interaction sessions with children. It also presents the testing and further development of the play scenarios specifically in aspects related to VPT.

Keywords: Robot assisted therapy · Visual Perspective Taking (VPT) · Autism

1 Introduction

The study described in this article is part of our contribution to the Horizon 2020 Babyrobot project, where we have created different play scenarios for children with autism to playfully explore elements that are important in developing Visual Perspective Taking (VPT) skills.

Autism is a lifelong developmental disorder that affects the way a person communicates and relates to people around them. The main impairments that are characteristic of people with autism lie in the areas of social interaction, communication and imagination [1, 2]. People with autism usually exhibit little reciprocal use of eye-contact and rarely get engaged in interactive games. They often have difficulties in understanding gestures and facial expressions, difficulties with verbal and non-verbal communication,

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and usually have an impaired ability to understand others intentions, feelings and mental states [3].

Individuals with autism often have difficulty with Theory of Mind (TOM) and the understanding that other individuals have their own thoughts, believes, plans and perspectives [4, 5]. Visual Perspective Taking is the ability to view the world from another individual's perspective, understanding that other individuals have a different line of sight to oneself, and also understanding that two or more people viewing the same object from different points in space might see different things [6]. It is believed that TOM and VPT may share common cognitive processes.

In recent years an increasing number of research studies have shown the potential use of humanoid robots, e.g. Robota, Nao, Kaspar, Milo to engage children with autism in playful interactions aimed to help develop various skills and mediate interactions with peers and adults [7–14].

Our current study in the Babyrobot project is a novel study that aims to help children with autism develop their VPT skills using the Kaspar robot. Using a robot to teach children about VPT has a distinct advantage in the fact that what the robot can see can be shown directly to the children using the cameras in the robot's eyes and a screen to present the robot's perspective on.

2 Exploratory Pilot User Studies

As stated above, for our study in the Babyrobot project we have created different play scenarios for children with autism to playfully explore elements that are important in developing Visual Perspective Taking (VPT) skills [15]. During the development of the interaction play scenarios and the definition of their tasks, we have conducted several experimental pilot studies to test the feasibility of some of the new concepts that were included in these tasks, as well as the intended setup procedures. The tasks in these play scenarios were designed to progressively move from very simple games that children play with the robot to more complex opportunities for interactions. These exploratory user studies allow us to test and tune the setup and procedures so we could later on facilitate and provide the best opportunities for the children to have enjoyable interaction sessions with the robot whilst at the same time also proceeding with the specific tasks, progressing from one level to another.

Three exploratory user studies have been carried out and are described below:

1. A study to test if low functioning children with autism can understand the concept that what they see on a computer screen next to the robot represents what the robot sees through its eyes.
2. A usability study in the lab with a typically developing child to test the full setup and procedures of all the tasks.
3. A pilot study to test the setup and procedure with three children with autism aged 9–11 in special education school.

2.1 The Trials

The trials were designed in such a way so as to minimize the anxiety and distress the children might find themselves in, allowing the children to get used to the presence of the investigator, get familiar with the robot and initially to have unconstrained interaction with the robots with a high degree of freedom, on their terms to begin with (providing it is safe for the child and safe for the robot), and to build a foundation for further possible interactions with the experimenter when he introduces the specific interaction tasks. Our objective was to provide a reassuring environment where the repetitive and predictable behaviour of the robot is a comforting factor and where the children could have opportunities for free interactions with the robot and with the present adults (i.e. teacher, experimenter) should they choose to, whilst being introduced from time to time to specific tasks of the game scenarios.

2.2 The Robotic Platform - Kaspar

Kaspar is a child-sized robot which acts as a platform for Human-Robot-Interaction studies, using mainly bodily expressions (movements of the hand and arms) and gestures to interact with a human. It is a 60 cm high robot fixed in a sitting position (see Fig. 1 left). The main body of the robot contains the electronic boards, batteries and motors. Kaspar has 18 FSR pressure sensors placed on several points on the hands, arms, shoulders, torso, head and feet to detect tactile interaction. The robot has 11° of freedom in the head and neck, 5 in each arm and 1 in the torso. The face is a silicon-rubber mask, which is supported on an aluminum frame. Its eyes are fitted with video cameras and can move up & down, and left & right, eye lids that can open and shut and a mouth is capable of opening and smiling. It has several pre-programmed behaviours for generic play sessions that include various postures and facial expressions, hand waving, drumming on a tambourine that is placed on its legs and singing children's nursery rhymes.

Fig. 1. The Kaspar robot (left); Wireless keypad for manual control (right)

2.3 Trials Setup and Procedure

The trials in schools took place in two schools in different towns in Hertfordshire, UK. The trials were designed to allow the children to have unconstrained interaction with the robot. The trials were conducted in a familiar room often used by the children for various activities. Before the trials, the humanoid robot was placed on a table, and was connected to an additional screen that was placed next to it showing what the robot is seeing through the cameras in its eyes. The investigator sat next to the table. The robot was operated remotely via a wireless remote control (a specially programmed keypad, (see Fig. 1 right), either by the investigator or by the child (depending on the child's ability). The children were brought to the room by their carer and the trials stopped when the child indicated that they wanted to leave the room or if they became bored and lost interest. Two stationary video cameras were used to record the trials. The second trial in the school, which was designed to test the full procedure of the interaction play scenarios and their tasks (the mini games related to various aspects of VPT), had additional equipment setup (e.g. a Kinect sensor and another laptop for the Wizard of Oz operation) and two more researchers were present. In this setting, the main researcher who had an active part in the interactive game scenarios sat together with the child and the robot. Unknown to the child, another researcher, controlled the robot remotely from a distance (WoZ) in the parts of the interaction games (tasks) that are related to aspects of VPT. The tasks are mini games related to various aspects of visual perception, e.g. bringing toys to the line of sight of the robot, moving the robot's head so it could see a toy that it asked for, recognizing objects that the robot can see in an 'I Spy' type game, etc. The use of WoZ mode intended to replace the autonomous or semi-autonomous responses of the robot that are currently under development and which will be used in future studies (e.g. recognizing objects such as soft toys that are part of the game scenarios and responding according to the games scripts).

2.4 Proof of Concept Testing in a Nursery for Children with Autism

As Visual Perspective Taking revolves around the understanding (or lack of) of what the other person can or can't see, an additional screen was used in the first few tasks to display what the robot can see through its eyes. It was therefore very important to first test out this new aspect to see if low functioning children with autism can understand the concept that what they see on screen next to the robot represents what the robot sees through its eyes.

Three young children age 3–5 diagnosed with autism took part in this study. In addition to free interaction with the robot, the experimenter introduced several games that involved moving toys into and out of the robot's field of view, asking the child if the robot can see the toys, or letting the child control the robots head direction so it could see the toys. The experimenter showed the child how to check what the robot can or can't see by looking at the screen. The three children that participated in this study all possessed different levels of cognitive ability. One child could not understand throughout the session the concept that the screen displays what the robot sees. Another child had difficulty grasping this concept initially, but towards the end of the session, with the help of the experimenter, began to understand this concept. Figure 2 shows how first the experimenter demonstrated it (left), the child then brought the toy to the robot's eyes (center) and then checked on the screen (that was situated next to the robot) what the robot saw (right - this image is the view from the robot's eye). The child later got excited each time he controlled the robot's head directing it towards a toy and saw the toy appear on the screen (Fig. 3). The third child understood this concept very quickly and the experimenter had to engage the child in other games with the robot to keep the child interested and sustain the interaction.

Fig. 2. The child is learning that the screen shows what the robot is seeing.

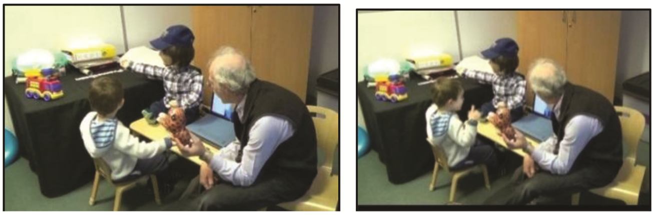

Fig. 3. The child directs the robot's gaze towards the red toy on the left, and then checks the screen. (Color figure online)

2.5 Usability Study with a Typically Developing Child

This study aimed to test the setup, procedures and usability of the whole set of the play scenarios prior of any study with children with autism. A 7-year old typically developing child, accompanied by his mother, visited our lab and volunteered to play with the robot following all the pre-defined tasks in the game scenarios. Figure 4 below shows some of the different tasks tested e.g. bringing a toy into the field of view of the robot; moving the robot's head towards a toy and confirming it on the screen (Fig. 4 - top); and the more advanced tasks where some toys were placed behind partitions, and the robot and the child each seeing different toys (Fig. 4 - bottom).

Fig. 4. A typically developing child tests the play scenarios in a laboratory setting, providing feedback to the research team on the setup and procedures.

2.6 A Pilot Study with Children with Autism in a Special School

This was the first pilot study to test the procedure of the interaction scenarios and their tasks in a Wizard of Oz set up (as described above) with children with autism in a special education secondary school. Three children aged 9–11 participated in this pilot. Here again the children all varied in their cognitive and interaction abilities. Two children were only partially verbal whilst one was very articulate.

- The first child (partially verbal) was initially hesitant to interact with Kaspar, but after several minutes choose to come into the room to interact with Kaspar and appeared to enjoy interacting with the robot. The child managed to complete the first task, but did not have time to progress further in this session. However, the child chose, on his own initiative, to come back during his lunch break and began the second task in this second interaction. Figure 5 below shows how the child placed the toy too close to the robot face (left) and finally the child moving the toy to a correct distance following the robot's feedback.

Fig. 5. A child with autism explores the correct distance to place the toy in front of the robot's eyes.

- The second child (partially verbal) was much more subdued, with the teacher explaining that the child does not use language at all unless he is very comfortable with the people he is around, which can take many weeks. The child gradually became more comfortable with the researcher and the robot, and by the end of the session had started to say few words. This child managed to complete the first task only (Fig. 6).

Fig. 6. The child was initially reluctant to interact, but gradually became more comfortable.

- The third child was very talkative and collaborated more freely with the researcher and the robot. This child managed to successfully complete the first three tasks and would likely have been able to progress further given more time (Fig. 7).

Fig. 7. A child with autism freely collaborates with the experimenter during the interaction with the robot.

3 Discussion and Future Work

Overall the pilot studies provided a proof of concept that the VPT tasks developed do indeed work and provided positive indication that the games flowed well and the children were able to complete the games with ease. Concepts implemented in the robot setup to help teach children aspects related to VPT can work (e.g. the use of a screen positioned next to the robot, showing the robot's field of vision). It was important to confirm that some low functioning children with autism can learn after some attempts, and eventually understand the concept that what they see on the screen next to the robot represents what the robot see through its eyes, or realising that a picture they see on one side of a cube that faces them is not the picture that the robot sees on the side of the same cube that is facing the robot. However it also confirmed some of the challenges that this attempt of using the robot to help teach skills related to VPT presents:

- The structured game scenarios required some degree of flexibility. Following a rigid script, as we originally intended before the proof of concept studies, is very unlikely to lead to sustained engagement with the children. We addressed this challenge by integrating some of the previously developed and more generic games for Kaspar that could be initiated by the child, (e.g., tactile interaction, singing or drumming etc.) to the core VPT games to help keeping the children engaged and focused. Flexibly alternating between core VPT games and 'fun games' (also considering the individual children's preferences and interests) was therefore an important lesson learnt.
- As we are working with low functioning children with autism, some also with impaired language, the information and instructions that are passed to the children need to be very focused, and phrased in simple language. Speech is often required to be repeated several times. This experience allowed us to simplify Kaspar's speech.

- Some children do not have speech and if they do, it is very hard to understand – this is a challenge to future plans for the implementation of a speech recognition feature on the robot.
- Some children have a more erratic/unpredictable behaviour making it a challenge to develop an accurate child tracking feature on the robot. Dealing with noisy and highly unstructured school environments poses a significant challenge to any attempts to introduce autonomous features of Kaspar.
- Children's abilities are varied. Some children will not be able to accomplish all of the tasks outlined. This can be expected and will be documented in the children's learning journeys. The learning journey's will reflect how the individual children progressed through different levels, if when not completing the final, most complex tasks.

We are currently in the final stages of the development and implementation of various technologies that will allow the robot to operate in an autonomous/semi-autonomous mode, to facilitate the interaction in these game scenarios [16]. Alongside this, based on the positive results of the preliminary test of proof of concepts presented in this article, we are currently finalizing the plans and preparation for a larger study utilizing these concepts and play scenario with our humanoid robot Kaspar to encourage the development of Visual Perspective Taking skills in children with autism.

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