”Where is Your Nose?” - Developing Body Awareness Skills Among Children With Autism Using a Humanoid Robot

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***Abstract*—This article describes an exploratory study in which children with autism interact with KASPAR, a humanoid robot, equipped with tactile sensors able to distinguish a gentle from a harsh touch, and to respond accordingly. The study investigated a novel scenario for robot-assisted play, namely to increase body awareness with tasks that taught the children about the identification of human body parts. Based on our analysis of the childrens behaviours while interacting with KASPAR, our results show that the children started looking for a longer period of time to the experimenter, and a lot of interest in touching the robot was observed. They also show that the robot can be considered as a tool for prolonging the attention span of the children, being a social mediator during the interaction between the child and the experimenter. The results are primarily based on the analysis of video data of the interaction. Overall, this first study into teaching children with autism about body parts using a humanoid robot highlighted issues of scenario development, data collection and data analysis that will inform future studies.**

Keywords: *Assistive Technologies; Socially Assistive Robots; Human-Robot Interaction; Body Awareness.*

I. Introduction

Three critical factors for the healthy physical and psychological child’s development are touch, movement and interaction with other humans. Touch is one of the earliest senses developed in human embryos and the most developed sense at birth [1]. Thus, touch plays a key role in the physical, emotional, and psycho-social development. Touch deprivation early in life leads to severe consequences, like complete emotional isolation or lack of trust in others [1]–[3]. Children need up to four hours per day of physical play to accomplish satisfactory sensory stimulation for their proprioceptive and tactile systems in order to develop normally [4]. On one hand, touch can convey affectioned feelings, on the other, it can express pain or discomfort.

Touch can be divided into cutaneous, kinesthetic, and haptic systems [5]. The cutaneous system is constituted of mechanoreceptors set in the skin. This system composes the tactile sense, processing stimulations on the skin. The kinesthetic system is constituted of receptors situated in the muscles, tendons, and joints. The kinesthetic sense allows humans to identify positions and movements of upper and lower limbs and muscle tensions. The haptic sensory system concerns both cutaneous and kinesthetic receptors, but it is associated with an active procedure [5]. Children learn early on to understand and to identify different types of physical contact in order to communicate with other children and adults, building trust relationships, based on the exchange of support and mutual confidence, developing their social relationships.

According to Piaget infants develop object permanence through touching and handling objects [6]. Object permanence is the understanding that objects continue to exist even when they cannot be seen, heard, or touched [7]. Caregivers typically offer organized environments where children can explore, touch and manipulate different materials and where they can be able to ask questions, use their creativity and learn new concepts. Children have to build their own learning experience, with the focus on the reasoning processes [8].

In this study, we used a humanoid, minimally expressive child-sized robot with a static body - KASPAR ([9] for technical details), able to move its arms and head in order to simulate gestures in social interaction. KASPAR has simplified and minimalistic human-like features. The robot’s behavioural repertoire includes expressive postures, it can approximate the appearance and movements of a human without trying to create an ultra-realistic appearance. KASPAR is equipped with tactile sensors that allow it to automatically respond to a gentle or rough touch from the child. The tasks used this study aim to teach the children to identify their body parts, and increase their body awareness. As we can see in the Section II, robots have already been used with children with autism to develop their social and communicative skills with encouraging results. In the present study, the robot is going to be used as a mediator between the child and the experimenter but also as a tool of teaching. Our main research interest is to understand if the robot can help to elicit interactions between an autistic child and another person, and whether it can facilitate the ability to acquire knowledge about human body parts. We want to verify if the robot can help children with ASD (Autism Spectrum Disorder) to learn appropriate physical social engagement. The experiments consisted of 7 sessions with 8 children diagnosed with autism, using qualitative and quantitative measures to evaluate the triadic interaction between the children, the robot, and the experimenter. In this article, we present the analysis of the observations of the first and the last session with the 8 children. To our knowledge this is the first article that studies how to use robots in order to teach children with autism about body parts. Due to the novelty of the subject a main purpose of the article was to develop scenarios, means of data collection and to learn how to analyse the data. This paper is organized as follows. In Sect. 2 will be presented research projets that also use tactile human-robot interactions. Sect. 3 features the procedures during the experiments. The results and the discussion are described in Sect. 4 and 5. Sect. 6 provides the conclusions and future work.

II. Tactile Interaction

As mentioned earlier, touch plays a vital role in human-human interaction. Since it is our goal to transmit extra information to the robot, so it can react predictable and convincing to a human tactile interaction, the robot needs to be equipped with tactile sensing capabilities. The robot's behaviour must appear natural, in order to generate enjoyable interactions.

There are several research projects concerned with the physical contact between humans and robots, presenting various types of sensors to detect these interactions, for example the cheap and robust sensors that can measure force or pressure, changing its resistance, called force-sensing resistors (FSR) [10]. The information provided by tactile sensors aims to increase quality and interpretation of sensor data. We can measure improvements in tactile sensing according to data quality, assessed relatively to detection sensitivity, noise and physical toughness and also its signal interpretation, assessed relatively to computational cost and measurement accuracy [10]. The detected contact should be used to produce compliant robotic behaviours.

Robots for human-robot interactions (HRI) within the current tactile HRI literature can have different shapes [10]. The baby seal Paro [11], the teddy bear Huggable [12], the robotic cat NeCoRo [13], and the child-sized robot KASPAR [9] are some examples of different artificial pets and humanoid robots designed to engage people based upon relational touch interactions. This kind of affective interaction is a growing area of research, especially concerning the target group of people with special needs.

Tactile data contributes to the determination of the Paro's internal state, driving the choice and implementation of a limited number of hand-coded behaviours, similar to those of a real seal [14]. Huggable, the robot teddy bear able to orient itself towards the direction of the human touch through motion in its neck and shoulders. A soft multi-modal sensory skin plus the fur covering its entire teddy-bear-shaped body are able to classify multiple human touch types and perform tactile interactive behaviours [12]. The robotic cat NeCoRo is used to analyse personrobot communication, responding to human voice, movements, and touch. Its multiple sensors, together with artificial intelligence technology produce a real-life-looking robotic cat capable of a playful and natural communication with humans [13]. KASPAR is a robot that has been used e.g. in call-and-response games, where its goal was often to imitate the human partner [9]. In the ROBOSKIN project, researchers develop a robotic skin to provide tactile feedback which was added to KASPAR. One goal is to improve human-robot interaction capabilities in the application domain of robot-assisted play [15].

III. Procedures

The experiments were performed in four different phases: familiarisation, pre-test, practice, and post-test (fig. 1).

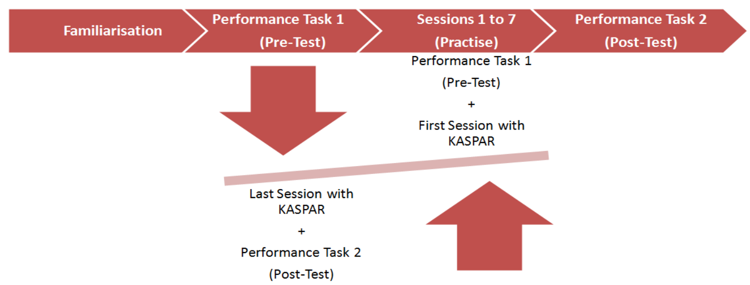

Figure 1. Phases of the study, in this paper only the pre- and post-test, and the analysis of the first and last session of the practice phase will be presented

Before starting the experiments with the robot, the children and the experimenter took part in a familiarisation phase. The goal of this phase was to get acquainted with the children and to integrate the experimenter in the school environment. The experimenter spent one day at the school, in the classroom where the children normally do their activities. A pre-test served as baseline to be compared with the results of a post-test. The task tested in these two phases was the performance task. The post-test phase had the same conditions of the pre-test phase in order to evaluate if the children were able to improve the performance of the task done in the pre-test. In the practice phase, three different activities were introduced according to the children's accomplishment. The next sub-section presents the different tasks associated with each phase.

Each session with the robot was introduced with a Picture Exchange Communication System (PECS) card, that the children usually use in their daily routine to start new activities. The PECS card used for this experiment depicted the KASPAR robot (Figure 2).

A. *Tasks*

In the performance task, carried out in the pre- and post-test, the children were asked to choose the right place for the different body parts, and place them on a drawing of a little human figure printed on a cardboard (Figure 3). The

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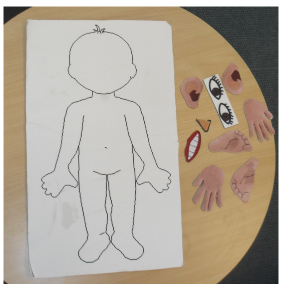
Figure 2. PECS card of KASPAR

performance task used in the pre- and post-test took the TEACCH program [16] already used in the classroom by the teachers into consideration.



(a) Beginning of the Task

(b) Task Accomplished

Figure 3. Performance task done in the pre- and post-test

In the practice phase, with 7 sessions of approximately 10 minutes each, there were three different activities, focusing on body awareness skills. The complexity of the activities was different, so whenever the children managed to accomplish the first activity, in the next session they would perform additionally the next more complex activity. If a child did not manage to progress, more sessions were done with the basic activity. The evaluation of the right transition moment to the next level for each child was done by the experimenter based on the opinion of the teachers. At this stage the robot's response was triggered remotely by the experimenter.

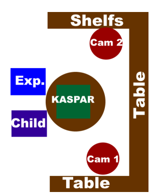
- Activity A: The robot identified one part of its body saying: ”This is my head”. Then, it asked: ”Can you please show me your head?”. If the answer of the child was correct, the robot responded with a positive reinforcement like ”That's right!” or ”Well Done!”. If the answer was not correct, the robot encouraged the child to try again, e. g. ”Almost. Try again!”. The human body parts to be identified were: head, tummy, nose, ears, eyes, hands toes, and mouth.
- Activity B: The robot identified a sequence of human body parts on its own body. For example: head and tummy. Next, it asked the child to point at the same body parts and in the same sequence on her own body. Then, the following step was to use three body parts (e.g., head, tummy and toes). The same type of reinforcement of Activity A was used.
- Activity C: This activity involved the learning from the previous activities together with joint attention and interaction with the experimenter. The robot asked the child to sing together a song about human body parts, and the experimenter encouraged the child to do the gestures that accompanied the song. If the child did not have verbal communication, he was asked to do the same gestures of experimenter (moving their body parts according to the song). The song was chosen based on simplicity and the practical learning approach is normally used in the school to teach other contents.

B. Participants

The eight participants in the experiments were boys with ASD aged six to ten years old. Four of the participants were high-functioning (Group A), the others were low-functioning (Group B), according to the diagnosis of the children. The experimenter was in the room to introduce the robot, and to intervene in case of difficulties. She was also involved in the activity as a facilitator of the interaction, providing guidance and ensuring that the children did not become agitated or damage the robot during the activity. A signed informed consent form was obtained from the parents of each child. This work was granted ethics approval by the University of Hertfordshire.

C. Settings

The experiment took place in a familiar room in the school often used by the children for their activities (Figure 4). The robot was connected to a laptop and placed on a table in the centre of the room. The children were sitting or standing facing the robot.



(a) Room Setup Schematic

(b) Positioning of the participants in the room

Figure 4. Room Setup

The two cameras were placed in such a way that one recorded the face of the child and the other the experimenter during the experiments.

D. Touch Feedback

The robot was equipped with 8 FSR sensors positioned on the right head, left head, right shoulder, left shoulder, right wrist, left wrist, right hand, left hand, right foot, and left foot of the robot. These FSRs only distinguished a gentle from a harsh touch. If the child touched the robot, activating the sensor below the threshold limit, it answered a sentence such as ”You are so gentle. Thank you.”. If the child touched the robot and activated the sensor above the threshold limit, it answered with a sentence such as ”Ouch, you are hurting me.”.

The threshold limit was defined in experimental pre-tests. The goal of this feedback is to automatically produce a response to the children's tactile interaction, teaching appropriate physical social engagement, reinforcing suitable behaviours when using touch to interact with another agent.

E. Evaluation Tools

As a qualitative measure, we used a structured interview. As quantitative measures, we used questionnaires, a behavioural analysis, where the children's behaviours were identified and coded with video analysis, and the comparison between the pre- and post-test.

1) Questionnaires: The questionnaire aimed to measure the development of children assessing their skills regarding tactile interaction. The questionnaire was delivered at two different points during the trials. First, before the trials with the children to establish a data baseline for each child. Then, the last evaluation was done at the end of the study, to evaluate the changes in the behaviours of the children. The items were with a 5 point Likert-scale. Three teachers completed the corresponding questionnaires for the children. For each question, space was available for comments, providing information not covered by the response categories. The questions were mainly related to tactile interaction and the knowledge about body parts, such as, 'Does the child use his/her hands to explore novel/unknown objects?' or 'Can the child point or identify parts of his/her body in any way?'.

2) Structured Interview: The structured interview was done with one of the teachers, showing her extracts of the videos of each child. In this interview, we were interested in the perspective of the teacher on the children's behaviours. Mainly, we wanted to know, how the teacher would describe the reactions of the children towards the robot and what usual or unusual behaviours the children showed in the video. Also, the children's social behaviour seen in the video was compared with the behaviour of the children towards teachers and other children in the classroom (tactile interaction, eye gaze, playing with others, among others). After discussing this, the main differences in the children's behaviour in the two videos were discussed, as well as whether the robot could have had an influence on the specific behaviours performed by the children. The interviewed teacher knew only four of the eight children very well and thus only commented on these. Despite this fact, we considered her comments very relevant and included them in this article.

3) Behavioural Analysis: The sessions were examined via video analysis (using the Observer XT 11 program by Noldus). The behaviours coded were the following: looking, touching, following, pointing, imitation, prompts, and identifying body parts. For each coded behaviour (except for looking) the coders marked whether the child showed the behaviour spontaneously or whether the behaviour was prompted by the experimenter. If the child was, for example, touching the experimenter for no specific reason, the behaviour was classified as spontaneous. If the child touched the experimenter after the experimenter said "Where is my nose?", the behaviour was classified as prompted. A behaviour ended if the child stopped exhibiting that behaviour or showed another behaviour, directly related (for example, looking at KASPAR/looking at the experimenter). When the child exhibited behaviours that are not specified in our list, they were not coded. For eye contact turning away ended the behaviour. Turning back immediately and making eye contact again counted as a new behaviour. To ensure inter-rater reliability 10% of the videos were re-coded by a second independent coder (Cohen's kappa k = .63).

4) Comparison between pre- and post-test: When comparing the pre- with the post-test, special attention was paid to the time taken to accomplish the performance task. Some of the children needed help to finish the task, but this help was only provided when it was verified that the children were not able to solve the performance task.

IV. Results

The collected data from the questionnaires, the behavioural analysis, and the comparison between pre- and post-test were statistically analysed, and a descriptive evaluation was made based on the structured interview.

A. Questionnaires

To determine how the responses of the teachers on the written questionnaires matched for the same questions, we examined the numerical differences between the responses to the two sets of questionnaires, using a paired sample t-test. We found that there were significant differences between the two sets of data regarding the exploration of unknown objects by the children using their hands ($p = 0.033$), and the verbal identification of at least one part of the child's body ($p = .033$). In addition, we also discovered that there were significant differences between the first and last session, for pointing to at least one part of their body when asked to do so ($p = .011$), and when identifying body parts in any way ($p = 0.041$). As comments, teachers added that one child has changed and that he is now able to listen and understand body parts. Another child changed to being more focused compared with his previous state and he was enjoying the body part activities much more.

B. Structured Interview

The interviewed teacher had prior knowledge about the robot's functionalities. During the interview the teacher classified the following behaviours as improved:

- "Child 1 held attention for a longer period of time";
- "When Child 3 touched KASPAR's face, he was completely engaged with the robot. And he was touching KASPAR's body parts and face, because he was happy. KASPAR was definitely facilitating the interaction between you [the experimenter] and Child 3, because he wanted to engage with you [experimenter]. His eye contact was just amazing.";
- "Child 5 was interacting, and I said previously I did not see him interacting with someone, but today he and Child 1 spoke to each other. And I stopped the lesson, for them to continue, because they were speaking to each other.".

C. Behavioural Analysis

To compare the data from the video analysis of the first and the last session we used a paired sample t-test. As mentioned above, one of the coded behaviours was the direction of the eye gaze of the children when they were interacting with the robot. We found significant differences, comparing the first and the last session, for the children looking at KASPAR ($p = .001$), at the experimenter ($p = .004$), and elsewhere ($p = .032$). The results (Fig. 5) show, that the average time the children looked at the robot decreased (75.04% - 51.01%), at the experimenter increased (4.29% - 16.01%) and to no particular place also increased (20.66% - 32.97%).

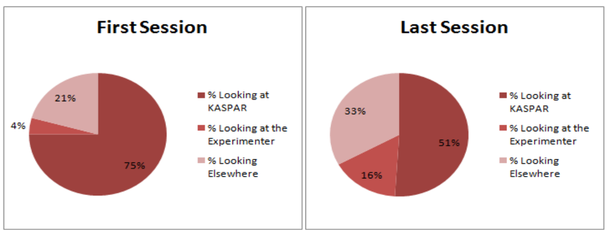


Figure 5. Percentage of eye gaze in the first and last session of the Practice Phase

Comparing the Group A (High Functioning) with Group B (Low Functioning), we found significant differences between the average time Group B looked at KASPAR in the first and in the last session ($p = .048$). There are no significant differences between the average of time that Group B looked at the experimenter or elsewhere. The average time the children in Group B looked at the experimenter increased from 4.32% to 15.3% group.

In Group A, we found significant differences in the average time of looking at KASPAR ($p = .025$), at the experimenter ($p = .033$), and looking elsewhere ($p = .417$), comparing the first and the last session. The average time that the children in Group A looked at the experimenter increased from 16.7% to 49.4%.

Concerning the tactile interaction of the children in the first and last session, there were no significant differences of the number of times the children touched the robot or the experimenter, gently ($p = .281$) or roughly ($p = .381$). Despite having no significant differences when evaluating tactile interaction, more than 90% of the times the children touched the robot gently (Fig. 6).

We video coded the following behaviours: the children following a pointing gesture with head movement of the experimenter (following), the children pointing at something with an index finger to attract the attention of the experimenter (pointing), and the children imitating vocalisations or gestures of KASPAR/experimenter (imitation). There are no significant differences between the first and the last session in any of the interaction parameters (pointing, following, and imitation). The behaviours that were shown most were imitation and pointing.

Regarding the success of the children while performing the

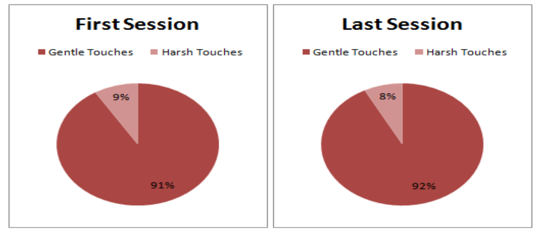


Figure 6. Percentage of gentle and rough touches during the interaction with KASPAR in the first and last session of the Practice Phase

proposed activities Figure 7 shows that the children managed to complete Activity A more than 70% of the times in both the first and the last session. There were no significant differences between the first and the last session.

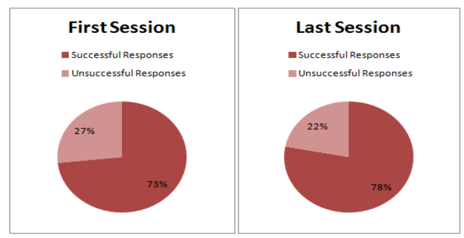


Figure 7. Percentage of Success of the Activity A in the first and last session of the Practice Phase

D. Comparison between pre- and post-test

When comparing the pre- and post-test there were no significant differences in the time children took to complete the performance task ($p = .365$). The average time the children took was 156 seconds in the pre-test and 124 seconds in post-test. 75% of the children managed to perform the task in less time in the post-test than in the pre-test.

V. Discussion

We observed that from the first session with KASPAR to the last, children directed their eye gaze increasingly less towards KASPAR. Instead the time they spent looking at the experimenter and at no particular place increased. The latter can be explained with the familiarisation of the children with the situation, but looking four times longer at the experimenter can be interpreted as KASPAR successfully functioning as social mediator. Comparing Group A and Group B, we found that the results follow the trend of the entire group. Despite the increase in time the children in Group B looked at the experimenter, they did so only 15% of the time in the last session. In Group A on the other hand this time increased up to almost 50% of the last session. The difference between the two groups show that children at the high functioning end of the autistic spectrum are much more attentive to the social partners face then children at the low functioning end. In both groups this attentiveness seemed to have been promoted by the activity with KASPAR. An increasing familiarity with

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the experimenter could be an alternative explanation of these results, which nevertheless would be a desirable outcome of the triadic interaction between the robot, the experimenter and the child.

The fact that the difference between the first and the last session regarding the tactile interaction of the children with KASPAR was not significant, could have different reasons. One explanation could be that all the children were even in the first session gentle in more then 90% of their tactile interactions. This by itself is interesting, since the teachers reported that this initial gentleness was surprising to them. Based on this descriptive quantitative data it is possible to argue that the exposure of the children to the interactive situation with KASPAR already induced a more careful behaviour. However a more detailed evaluation of the tactile data from all sessions is needed to understand how the children interact with the robot.

Even without analysing quantitatively the number of times that the children performed interaction behaviours (pointing, following, and imitating), it is interesting to notice that imitation is the most pronounced behaviour. Previous studies with KASPAR [17] show that children on the high functioning end of the spectrum are able to imitate KASPAR's movements, and that it was easier for them to imitate and understand the partial movement of the body of KASPAR than the total movement of IROMEC, a mobile robotic platform. This indicates that KASPAR can be useful to facilitate interaction behaviours.

According to the data from the interview and the questionnaires some of the children that initially were not able to identify any of the body parts on themselves, showed an improvement on their knowledge. The teachers also indicated that the children transferred some of the knowledge learned during the sessions with KASPAR to the classroom. They gave in general very positive feedback

VI. Conclusion and Future Work

This paper presents a study in which children with autism interacted with a humanoid robot. The children learned about body parts and at the same time the robot was equipped to respond accordingly to tactile interaction from the children. We wanted to test whether the robot could facilitate the interaction between the child and another person in the experiment, and to acquire knowledge about human body parts. Another point of interest was to see if the robot could help children with ASD to learn appropriate physical social engagement. Our results show that from the first to the last session with the robot, the children increased the time they looked at the experimenter. An evaluation by teachers of the children shows, that they improved the ability to identify parts of the their body with their own hands. Additionally, some of the children that initially were not able to identify any of the body parts on themselves, showed an improvement of their knowledge. In this paper we used a robot to enable the learning of body parts by children with autism and due to the novelty of the topic, we wanted to construct and test different scenarios in this respect. A more detailed analysis of the data is still ongoing and will enable with a better interpretation of the findings. Due to the preliminary nature of the data analysis, no causal conclusions can be drawn at this point. It is necessary to point out that it is, due to the school environment design of the study, not possible to exclude that any observed improvements could be due to other activities at school or at home. Further research is needed to confirm the extent in which the robot was instrumental in causing these changes.

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