

## From Isolation to Communication: A Case Study Evaluation of Robot Assisted Play for Children with Autism with a Minimally Expressive Humanoid Robot

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**Abstract** – The general context of the work presented in this paper is assistive robotics with our long-term aim to support children with autism. This paper is part of the Aurora project that studies ways in which robotic systems can encourage basic communication and social interaction skills in children with autism. This paper investigates how a small minimally expressive humanoid robot KASPAR can assume the role of a social mediator - encouraging children with low functioning autism to interact with the robot, and to break their isolation and importantly, to interact with other people. The article provides a case study evaluation of segments of trials where three children with autism, who usually do not interact with other people in their day to day activity, interacted with the robot and with co-present adults. A preliminary observational analysis was undertaken which applied, in abbreviated form, certain principles from conversation analysis - notably attention to the context in which the target behaviour occurred. The analysis was conducted by a social psychologist with expertise in using conversation analysis to understand interactions involving persons with an ASD. The analysis emphasises aspects of embodiment and interaction kinesics and revealed unexpected competencies on the part of the children. It showed how the robot served as a salient object mediating and encouraging interaction between the children and co-present adults.

### I. INTRODUCTION

In recent years, software and robotic based interactive learning environments have been studied increasingly in the therapy or education of people with autism [1-5]. The work presented in this paper is part of the Aurora project, rooted in assistive technology and human-robot interaction (HRI) research [6]. This project investigates the potential use of robots as therapeutic or educational ‘toys’ specifically for use by children with autism. The research focuses on ways that robotic systems can engage autistic children in simple interactive activities, such as turn-taking or imitative interactions. The overall aim is to encourage basic communication and social interaction skills.

In line with many other research activities in assistive robotics our work is strongly guided by the needs and preferences of individual subjects. This often involves working with a small group subjects in order to explore and evaluate the potential of a particular assistive robot and to assist its development, c.f. [7]. Given the nature of autism (a spectrum disorder) which implies huge differences among the

subjects, and the therapeutic/educational background, our work is guided by the individual needs and preferences of the children. Given this specific context, we conduct trials within a rather broad context (compared to studies in experimental HRI research), exploring the *interaction space* involving children with autism and a robot interacting in a familiar and relatively unconstrained environment. For some children, the robot’s simple movements and facial expressions encourage the development of basic imitation and turn taking skills [8]. For other children, even these simple skills are too advanced as a goal: for them the robot simply encourages tactile and playful explorations which by itself encourages sharing and communication with other people. This paper continues our research into the role of the robot as a social mediator encouraging autistic children to interact with the robot, and with other people.

In this paper we present a case study evaluation, where selected interaction sequences are presented in the form of video stills. Examination of these interactions between children and co-present adults reveals unexpected competencies on the part of these children. The paper will consider some of the ways in which the robot has facilitated the children’s interaction competencies with a particular focus on body movement and gaze and how the robot promoted non-verbal communication with co-present adults.

#### A. Autism

Autism here refers to Autistic Spectrum Disorders, a range of manifestations of a disorder that can occur to different degrees and in a variety of forms [9]. It 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, social communication and imagination [10]. People with autism usually exhibit little reciprocal use of eye-contact and rarely get engaged in interactive games. They have difficulties in understanding gestures and facial expressions, difficulties with verbal and non verbal communication, and are usually impaired in understanding others intentions, feelings and mental states.

The exact causes of autism are still unknown, and at present no cure exists. A variety of therapeutic and educational approaches are known. Any such therapeutic or educational contribution benefits some, but not all children with autism. Our approach to use robots is hoped in future to serve a complementary role: exploiting the fact that children with autism, like most children, show a great affinity towards robots, and using the robot as a useful and programmable toy [3].

### B. Current work

Previous research in the Aurora project illustrated the ability of a *mobile robot* to provide a focus of attention, and shared attention, in trials with pairs of children with autism [11]. More recently, Robins et al. explored robot-mediated joint attention in children with autism using a small humanoid robotic doll [12]. Extending the findings from these previous investigations, we further explored the possibility of robot mediated social interaction in children with autism, using a more ‘socially capable’ robotic platform – KASPAR, a minimally expressive child sized robot with facial and head expressions and expressive postures and gestures (see ‘robotic platform’ section below).

As people’s social behaviour can be very complex and subtle, for a person with deficits in mind-reading skills, as they have been shown in people with autism, social interaction can appear widely unpredictable, and very difficult to understand and follow. Our work indicates that KASPAR, which was designed as a minimally expressive humanoid robot, may give answer to some of these difficulties. It may provide a simplified safe predictable and reliable environment, and has been found to be very attractive to children with Autism and a suitable candidate for a tool to be used in education and therapy.

As autism can manifest itself to different degrees and in a variety of forms, not only might children in different schools have different needs, but also children in the same school might show completely different patterns of behaviour from one to another, and might have different or even some contradictory needs. Interaction with KASPAR is a multi-modal embodied interaction where the complexity of interaction can be controlled, tailored to the need of the individual child and gradually increased.

This article provides a case study evaluation, of segments of trials where three children with autism, from different schools, who usually do not interact or play with others (children or adults) at all, interacted with KASPAR and reached out to interact with the co-present adult. In one of the cases KASPAR also was used to mediate interaction with another child using the robot as a social mediator. A preliminary observational analysis was undertaken which applied, in abbreviated form, certain principles from conversation analysis - notably attention to the context in which the target behaviour occurred. The analysis was conducted by a social psychologist with expertise in using conversation analysis to

understand interactions involving persons with an ASD. Our analysis will highlight issues of embodiment and interaction kinesics, including the role and timing of nonverbal behaviour and body movements, in communicative and interactional dynamics. These play a fundamental part in human-human interaction and have also been highlighted recently as a challenge in human-robot interaction [8, 13].

## II. THE TRIALS

The trials described in this paper took place in two special schools for children with moderate learning difficulties in the UK and one trial took place in a medical centre in Germany.

As stated above, the aim of the current study was to investigate what effect the robot will have, and how it can mediate interaction between children with autism who usually do not interact, and other people. The trials were designed to allow the children to get used to the presence of the investigator, get familiar with the robot and to have unconstrained interaction with the robot with a high degree of freedom, should they wish to. We wanted to provide a reassuring environment where the repetitive and predictable behaviour of the robot is a comforting factor. In the main trials of this study, we have continued with the same approach where the children continue to have opportunities for free and unconstrained interactions with the robot and with each other.

### A. The Robotic Platform - KASPAR

KASPAR is a child-sized robot which acts as a platform for HRI studies, using mainly bodily expressions (movements of the head, hand, arms), facial expressions, and gestures to interact with a human. The robot has a static body (torso, legs and hands do not move and were taken from a child-sized commercially available mannequin doll) with an 8 DOF head and two 3 DOF arms. Important features of KASPAR head are minimal design, the inclusion of eyelids, and aesthetic consistency of the face [14, 15].

The overall design rationale of KASPAR’s head and face aims to approximate some important features of the appearance and movements of a human without trying to create an ultra-realistic appearance, i.e. not trying to imitate every detail of a human face (see Fig. 1 below). An emphasis on the features used for communication allows the robot to present facial feedback clearly by changing orientations of the head, moving the eyes and eye lids, and moving the arms. Furthermore, a reduction in detail de-personalizes the face and allows the interaction partner to project his/her own ideas on it and make it, at least partially, what they want it to be. This design rationale has been inspired by Scott McCloud’s work on comic design, cf. discussions in [14, 15].

These are both potentially desirable features for a robot to be used in different HRI scenarios, e.g when used in assistive technology with different user groups, such as people with autism, who generally have great difficulties in recognizing complex facial and gestural expressions.



Figure 1 - KASPAR's minimal expressive face

Initial observations of interactions of people with KASPAR indicate that subtle changes in expression coupled with simple gestures is already effective in conveying the message associated to a particular expression. KASPAR's existing facial expressions differ from each other by a minimal change around the mouth opening (see Fig. 1) that also subtly affects the overall face. Together with small changes in the tilt of the head and the direction of the eyes this already creates recognizable expressions (see Fig. 2).



Figure 2 - Some of KASPAR's facial expressions, and expressive gestures

Based on the results of our previous study into robot appearance suitable for children with autism, [12], the robot was dressed in a plain costume, and had simplified head features (i.e. short simple hair style, plain facial colouring, no facial hair).

### B. Trials set-up & procedures

The trials took place in two schools in the UK (Woodland school in London and St Elizabeth's school in Much Hadam) and in the University Clinic in Frankfurt, Germany. The trials were designed to allow the children to have unconstrained interaction with the robots with a high degree of freedom, and to build a foundation for further possible interactions with other people using the robot as a mediator ([8, 11, 16, 17]). In all schools, 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, connected to a laptop. The investigator was seated next to the table. The robot was operated remotely via a wireless remote control (a specially programmed keypad), 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. Two stationary video cameras were used to record the trials. The study in the UK lasted over several months and trials were designed to progressively move from very simple exposure to the robot to more complex opportunities for the children to get engaged in interactions with other people. The trial in the clinic in Frankfurt (Figure 3 below) was a one off trial.

## III. THE ROBOT'S EMBODIMENT AS A FACILITATOR OF INTERACTION COMPETENCIES

The robot demonstrated its role as a *social mediator*, an *embodied being*<sup>\*</sup> in the sense of providing an interactive context where social skills in children with autism were facilitated and encouraged. The concept of using a robot as a social mediator to facilitate interactions among people was initially proposed in [18], and first examples were documented in [11],[17]. This work is complementary to research into developing *sociable robots* that can ultimately possess sophisticated social skills [19, 20]. The robot's physical presence, movement and interactivity created a rich interactive environment – where body movement and gaze on the part of the child were made relevant by the actions of the robot. That is, the fact that the robot was an embodied entity that moved and responded to the actions of the child created an environment in which the child's own movement and gaze direction mattered

### A - Example I – Kelly.

Kelly<sup>†</sup> is a six years old girl with severe autism who lives in Germany. She does not talk and refuses all eye contact. She does not understand social interactions, she secludes herself from other people and even her mother is unable to reach her. Her mother described the situation in an interview: "... *She doesn't let anyone get through to her, she doesn't communicate, you can't get any sort of interaction, nothing ever comes back*".

Kelly was introduced to KASPAR in a one-off trial at the university clinic in Frankfurt where she regularly attends therapy sessions.. Her mother initially was very sceptic about any response from Kelly towards KASPAR and did not even think that Kelly will go anywhere near it.

Kelly, being at a distance, after overcoming her initial reservation to the new situation, i.e. facing an unfamiliar human-like toy (KASPAR) and an unfamiliar person (the investigator), indicated on her own initiative that she wanted to get closer to the robot (Figure 3). Kelly then explored KASPAR for some time, paying close attention to its face, and particularly to its eyes, and even tried to imitate it when it played the tambourine. Her Mother described it as "*extraordinary for her*".

Moreover, Kelly at one point stretched out her hand reaching for the experimenter's hand. (Fig 4) which was even more surprising to all adults present (experimenter, mother, therapist).

<sup>\*</sup> Note, we are using the term embodied 'being' for the robot referring to the situational, social context, we do not imply that the robot possesses sentience or any cognitive, emotional, or physiological properties characteristic of biological systems.

<sup>†</sup> Names of children used in this paper are synonyms.



Figure 3: Left – Kelly indicating her wish to come closer to KASPAR; Right – Kelly exploring KASPAR and imitating its drumming action.



Figure 4: Left - Kelly is exploring KASPAR's eyes; Right – Kelly is reaching for the experimenter's hand.

**Analysis:** In this sequence of interaction the child has revealed both an intensive interest in KASPAR and some initiation of physical contact with a co-present adult (the experimenter, a stranger). Certain attributes of KASPAR may have facilitated the child's engagement – for example the simple human features, the pleasant appearance and the relatively predictable movement on the part of KASPAR. Perhaps more fundamentally, KASPAR is embodied and has recognisable human features whilst being identifiably non-human. Being a three dimensional physical being – enables a physical engagement of a nature that is not possible with for example a computer image or virtual character. Likewise, having human properties (such as eyes, nose, mouth) yet being non-human allows for these familiar human features to be investigated – the cheek can be stroked, the nose squeezed etc – in a way that the child could not or would not be allowed to if this was a real human. In this way KASPAR provides an excellent embodied stimulus for physical engagement – in particular touching which was accompanied by gaze (directed at KASPAR).

Having provided a safe and stimulating embodied presence for the child, the child then uses just the same sort of interactional practice – touching and gazing at the thing being touched – with the experimenter's hand. KASPAR has created an environment in which touching and gazing has been made relevant and possible – his features are familiar, he can be touched and the child has been allowed to do so. It is from this specific initial interaction with KASPAR that the same touching and gazing activity is then used with the experimenter.

*B – Example II Leroy*

Leroy is a child with severe autism. Although at home he interacts regularly with other family members, at school he is not interacting on his own initiative with other people (not with other children nor with the teachers). In the playground he only plays by himself (e.g. riding a tricycle, throwing a small ball without aiming at any particular direction) ignoring all other children around him. Being observed during class time, he seemed totally 'lost' in his own world, ignoring the children and the teacher. When introduced to KASPAR, Leroy showed great interest in the robot. He regularly engaged in tactile exploration of the robot's surfaces (Figure 5 left), and he had a fascination in KASPAR's eyes and eyelids: often reaching and touching them. Interestingly, in a later stage this lead to touching and exploring his own eyes as well as exploring his teacher's eyes and face. Finally, after playing with KASPAR once a week for several weeks, Leroy started to share his excitement with his teacher (Figure 5 right), reaching out to her, (non-verbally) asking her to join in the game. He clearly used the robot to explore the environment and communicate (non-verbally) with the adults around him (both with the teacher and with the experimenter) as can be seen in Figure 6 & Figure 7 below.



Figure 5: Left - Leroy engages in a tactile exploration of KASPAR; Right – Leroy seeks to share his excitement with his teacher

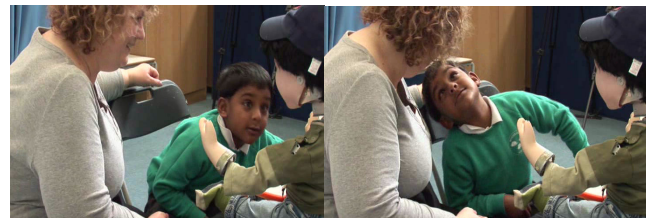


Figure 6: Leroy exploring very closely KASPAR's facial features, and then turns to his teacher and explores her face in similar way.



(a)

(b)



(c)

Figure 7: Leroy, being fascinated with KASPAR's eyes (image a) trying to communicate it to the experimenter (images a,b&c).

**Analysis:** As in the case of Kelly, Leroy demonstrates a tactile engagement with KASPAR – much of his interaction has involved touching and gazing at the robot. Again, as with Kelly, this touching and gazing behaviour has been found to generalise from KASPAR to co-present adults. In the case of Leroy, as figure 6 indicates, this has involved visual scrutiny of KASPAR followed by visual scrutiny of his co-present teacher. An additional feature that is evidenced in the sequence of photographs in figure 5 is that Leroy shows gaze use which appears to be overtly communicative – thus he turns to his teacher and displays positive affect (gazing at her and smiling) in response to his interaction with KASPAR. In this case KASPAR appears to have been treated as an object for joint attention – that is the child's smile and gaze at the co-present teacher appears to be in response to KASPAR. Leroy appears to be communicating a positive reaction to some action on the part of KASPAR to another person who was able to observe what KASPAR had done. Here, perhaps the noteworthiness and salience of having an object like KASPAR in immediate view of both child and co-present teacher allows for an ideal opportunity for sharing a response. KASPAR is an interesting, attention grabbing, interacting object which both child and teacher are very obviously (to each other) orientating to – this context facilitates joint attention as the shared focus is self-evidently present.

### C. Example III - Andy

Andy is a 16 years old teenager child with Autism who is not tolerating any other children in play or other task oriented activities, usually his focus and attention last only for very short time, he can be aggressive towards others, and can also cause self injury. However, when he was introduced to KASPAR, he was completely relaxed, handled KASPAR very gently, and kept focused his attention on KASPAR for as long as he was allowed, exploring KASPAR facial features very closely and exploring his own facial expressions at the same time (Figure 8). His attitude and interest in KASPAR remained strong over the whole period of trials.



Figure 8 - Andy controlling the robot himself, closely exploring KASPAR's and his own facial features.

As stated above, interaction with KASPAR is a multi-modal embodied interaction where the complexity of interaction can be controlled, tailored to the need of the individual child and gradually increased. As Andy usually does not let other children play with him it was as an objective, for the duration of the trials, to gradually direct Andy's interaction with KASPAR towards robot mediated play *with other children*. Andy, however, initially refused to sit at the table with KASPAR together with another child. Even with his therapist, Andy initially, although not minding the presence of the therapist, refused to let go the remote control of the robot, ignoring the therapist's requests and play with the remote control himself entirely focusing on the robot only. Gradually he accepted to play a simple imitation game with the therapist, mediated by the robot, which progressed into a turn-taking game alternating who controls the robot and who imitates the robot's expression (Figure 9 & Figure 10 left). During the games, Andy learned to look at his therapist to see how she imitates KASPAR, and when he explored KASPAR's face, he also looked at the therapist's face too which was extraordinary for him.

The therapist commented on it in an interview: “...*This is remarkable because usually he would always turn away from me*”.

This then was a good platform to introduce another child to Andy to play successfully the same simple imitation game. (Figure 10)



Figure 9 - Andy playing an imitation game with his therapist. Whilst controlling the robot, Andy checks the therapist's response (left) and corrects the therapist's gesture (right).

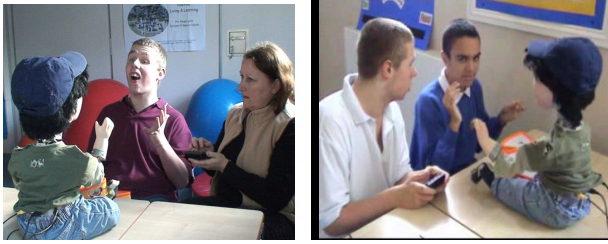


Figure 10 : Left - Andy let the therapist control the robot while he imitating the robot's gesture . Right - Andy plays with another child (right).

**Analysis:** Two features of Andy's interaction further illustrate ideas found in the case of Kelly and Leroy. First, Andy was found to move from an exploration of KASPAR to other co-present adults. In the case of Andy after initially gazing at KASPAR's face he subsequently initiated gaze at the therapist's face. Second, Andy was found to gaze at co-present others in response to the actions of KASPAR. In the case of Andy, the gaze was to another child and was part of an imitation game – Andy's gaze in figure 10 comes after he has made KASPAR move in a certain way which the other child was to imitate. Andy's gaze then checks the imitation of the other child. This gaze of Andy's shows a sophisticated awareness of precisely when the co-present child should have noticed and responded to a movement on the part of KASPAR. Again, Andy's gaze demonstrates an awareness of the co-present other's perceptions of KASPAR's movement (in this case a movement initiated by Andy).

### III. DISCUSSION OF RESULTS

The above brief analysis has suggested that there are features of KASPAR and the environment in which he is introduced to the children that may facilitate their embodied action and gaze with co-present others. It has been noted that KASPAR has the potential benefit of familiar human features (nose, eyes, mouth etc) whilst being obviously non-human and this may invite a direct physical engagement particularly touching and gaze. It should also be noted that the experimental context allowed for children to not only gaze at but also to touch KASPAR and – in the case of Andy to use a remote control to make KASPAR move.

The above analysis indicates that children were able to generalise their behaviour with KASPAR to co-present others – thus they could touch or visually examine not just KASPAR but also co-present others. This could be understood as being facilitated by both immediately prior experience with KASPAR (being able to touch and gaze at KASPAR) as well as the co-present adults' accommodating the child's actions (e.g. the experimenter and therapist allowing themselves to be touched or gazed at).

Furthermore the analysis indicates that children were able to gaze at co-present others in response to what KASPAR had done. In the case of Leroy this was a smiling gaze at a co-present teacher in response to some action on the part of

KASPAR, in the case of Andy this was a gaze at another child in the context of an imitation game at a moment where Andy had made KASPAR move and the other child was expected to imitate KASPAR. In both cases – albeit in somewhat different ways – the gaze at the co-present other demonstrated an awareness of the other's perceptions of KASPAR. That is, Leroy and Andy demonstrated an awareness that the other person was – or should have been – paying attention to some feature of KASPAR's behaviour. It was argued that in being a stimulating, interactionally responsive embodied entity (and being very prominently positioned) KASPAR was more likely to and *could be understood as* being more likely to have the attention of co-present others. This, therefore made it easier to treat KASPAR as being the object of attention for co-present others, which in turn facilitated the possibility of sharing affective responses and checking co-present other's actions at a relevant point in an imitation game.

### IV. CONCLUSION

This paper has argued that in interacting with KASPAR children (who are judged to be relatively low functioning on the ASD scale) can demonstrate some important interactional competencies. Not only do they show a level of direct, physical engagement with KASPAR but also they appear to generalise this behaviour at least to co-present others. Thus, children appear to use touching and gazing at KASPAR prior to touching and gazing at co-present others. Furthermore, children appear to show some awareness of co-present others' perceptions of KASPAR, turning to gaze at them following some potentially relevant action on the part of KASPAR that they are treated as having perceived.

This is an example of how (relatively) simple, low-budget, minimally expressive robots can facilitate interactive 'social' games that benefit the children and the wider social environment. This clearly emphasizes a 'bottom-up' approach where first specific needs of the children and the application environment were considered and which then led to the use of an appropriate robot (i.e. Kaspar) that matches the needs in this application domain. Thus, the behavioural and structural complexity of the robot is matched with the needs in the 'niche' application.

It has been noted in this paper that some of those familiar with the children have found aspects of these behaviours to be remarkable – with the children being described as not typically demonstrating such engagement with others, particularly unfamiliar others. There may indeed be features of KASPAR which could facilitate these interactions – supported by the actions of the co-present others (who allow themselves to be touched and gazed at) and aspects of the setting itself (which makes KASPAR visually prominent). It is also possible that in addition to facilitating interactional competencies the research with KASPAR which is reported here has facilitated the *display* of those competencies. That is, by examining interactions in this way we can better see and understand what children with ASD are capable of.

In the more general context of healthcare for children with autism this work also gives an example of how low-tech

solutions, appropriately designed for and adapted to the context of use and the needs of its users, can contribute to social education. It is planned to continue this study on a longer term and on a larger scale, to be able to monitor any possible long term effects and benefits to children with autism beyond the enjoyable playing time with a robot.

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