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Robots as Assistive Technology - Does Appearance Matter?

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Abstract

This paper studies the effect of a robot's design (appearance) in facilitating and encouraging interaction of children with autism with a small humanoid robot. The paper compares the children's level of interaction with and response to the robot in two different scenarios: one where the robot was dressed like a human (with a 'pretty-girl' appearance) with an uncovered face, and the other when it appeared with plain clothing and with a featureless, masked face. The results of these trials clearly indicate the children's preference in their initial response for interaction with a plain, featureless robot over interaction with a human like robot.

1 Introduction

Robots, virtual environments and other computer based technologies are increasingly being used in rehabilitation and education [12, 7, 18, 17]. The work presented in this paper is part of the Aurora project that studies the potential use of humanoid and non-humanoid robots in education and therapy of children with autism [1, 4, 6]. People with autism have impaired social interaction, social communication and imagination (referred to by many authors as the triad of impairment, e.g. [20]). This can show itself in difficulties in forming social relationships, the inability to understand others' intentions, feelings and mental states, difficulties in understanding gesture and facial expressions, having a limited range of imaginative activities, etc. In addition people with autism usually show little reciprocal use of eye-contact and rarely get engaged in interactive games. The Aurora project focuses on the development of new interactive robotic systems that encourage basic communication and social interaction skills. Contrary to people's social behaviour, which can be very subtle and widely unpredictable, the use of robots allows for a simplified, safe, predictable and reliable environment where the complexity of interaction can be controlled and gradually increased. Part of our investigation is to see how we can encourage social interaction skills using simple imitation and turn-taking games e.g. [5, 14]. We are also investigating how the robots can be used as objects of shared attention, encouraging interaction with peers and adults e.g. [19, 15]. Such contacts with other humans could provide meaning and significance to otherwise mechanical interactions with the robots.

2 Current work

This paper reports initial findings, focusing on aspects of the robot's design in influencing the facilitation of interaction of children with autism with a small humanoid robot. Ferrara and Hill [8] reported that children with autism prefer simple designs and a predictable environment in their interaction with toys, and that they approached social objects (they used various types of dolls) more readily if they were simple in appearance. They concluded that these are more appropriate starting points for therapeutic intervention where the complexity of the therapeutic toys can be slowly increased. More recently, Michaud and Théberge-Turmel explored various robotic designs e.g, an elephant, a spherical robotic 'ball', a robot with arms and tail and other designs, all small in size, that can best engage children with autism in playful interactions helping them develop social skills [11]. An important implication of our findings for the use of robots in therapy and education of children with autism relates to the question of whether one should use humanoid robots that closely resemble human beings (e.g. possessing a lot of facial features such as eyes, mouth, eye brows etc). Previous work does not clearly show whether robots that interact with children should have humanoid appearance, as suggested by Breazeal and Foerst [3], and Kozima and Yano [10], or rather possess machine-like, clearly non-humanoid robots, as argued e.g. by Dautenhahn [4]. Although robots equipped with human-like features appear more like ordinary humans, the complexity of their appearance might be overwhelming or even frightening to autistic children. In our investigation into the effects

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of the robot's design, we conducted two studies: A study with a life size 'Theatrical Robot' (a person who was dressed and acted like a robot) and a study with a small humanoid robotic doll. The study with the life size robot is reported in a separate paper [13] but can be summarized as follows: Results showed that the children responded notably more socially towards the life-size robot when it had a plain/robotic appearance, as compared to an appearance with full human features. In the current paper we investigate whether these results can be confirmed in studies with a small humanoid robot that has previously been used in our work [5, 14]. We focus on investigating how the children respond in two experimental conditions with different appearances of the robot. Autism research has shown that children react with avoidance towards novel stimuli in general, and strangers in particular which are treated as objects rather than people [9]. We hypothesize that the children will react more socially towards a plain/robotic version than towards a more human-like appearance.

2.1 A study with a humanoid robotic doll

Recently we conducted a longitudinal study [14], where children with autism were repeatedly exposed to a small humanoid robot over a period of several months. The aim of that study was to investigate to what extent repeated exposure to a humanoid robot, over a long period of time, using interactive imitation and turn taking games, can help to increase basic social interaction skills in children with autism. We also integrated the appearance of the humanoid robot and examined the effect that different appearances of the robot, e.g. plain robot, or pretty-girl doll robot, had on the level of interaction of the children with the robot. Inspired by the results of our trials with the 'theatrical robot' [13] we prepared a robotic outfit (plain clothing with a featureless head) for our humanoid robotic doll, in addition to its pretty-girl outfit, and conducted some of the trials with these two different appearances. This longitudinal study was extended six month later, with additional trials, focusing specifically on the issue of the robot's appearance, providing additional data for the results presented in this paper. In all trials, different behavioural criteria (including Eye Gaze, Touch, Imitation and Near (proximity)) were evaluated, using mainly quantitative analysis techniques based on the video data of the interactions.

3 The trials

The trials took place in a mainstream primary school in Essex, UK which also caters for nine pupils with various learning difficulties and physical disabilities. We designed our trials in such a way as to minimize the anxiety and distress the children might experience, caused by a change of routine, being in a novel situation with a new and unusual toy (the robot), and a new person (the investigator). At the same time we wanted to provide a reassuring environment, where the predictability and repetitive behaviour of the robot is a comforting factor. The approach in all the trials has been designed to allow the children to have unconstrained interaction with the robot with a high degree of freedom, and to build a foundation for further possible interactions with peers and adults using the robot as a mediator [19, 15]. Four autistic children age 5-10 from the Enhanced Provision unit were selected by their teacher to participate in the trials. Each child participated in as many trials as was possible for him during that period, e.g 13 trials with the humanoid robot each on average.

3.1 The Robot

The robot used in these trials is Robota - a 45cm high, humanoid robotic doll [2]. The arms, legs and head of the robot are plastic components of a commercially available doll. The main body of the doll contains the electronic boards (PIC16F870, 4MHz and 16F84, 16MHz) and the motors that drive the arms, legs and head giving 1 DOF to each. For a complete description of Robota's hardware see [2].

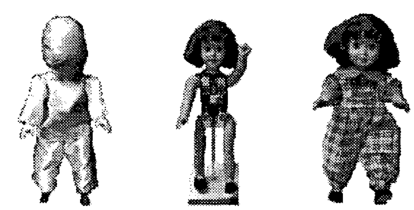

Figure 1: The robot in its two different types of appearance (the centre figure shows the 'undressed' version revealing the robotic parts that control its movement)

Robota was originally developed as a robotic toy with the capability to connect to an array of various sensors, and to support a rich spectrum of multi-modal interactions with children, involving speech, music and movements. However, in the current trials, in light of the children's impairment (e.g lack of speech, inability to be still and have a long enough focus of attention, and maintaining gaze on another's face etc.), Robota's features of speech processing, motion tracking, and learning were not used. In the current set of trials, the robot has been programmed to operate in two basic modes:

a) as a 'dancing toy' where it moves its arms, legs and head to the beat of pre-recorded music. We used three types of music - children's rhymes, pop music and classical music - following the teacher's advice as to the children's preference.

b) as a puppet, whereby the investigator is the puppeteer and, unknown to the children, moves the robot's arms, legs or head by a simple press of buttons on his laptop (Wizard-of-Oz approach).

3.2 Trials set up & procedures

The trials were conducted in a familiar room often used by the children for various activities. The room size is approx. 4.5m, with a carpeted floor. The room had one door and several windows overlooking the school playgrounds. The robot was positioned on a table, at one end of the room against the wall, and was connected to a laptop. The investigator was sitting next to this table operating the laptop when necessary. Two stationary remotely operated video cameras were used to record the trials. The children were brought to the room by their carer, one at a time. Each trial lasted as long as the child was comfortable with staying in the room. The trials stopped when the child indicated that he wanted to leave the room or if he turned bored after spending 3 minutes already in the room. The average duration of trials was approximately three minutes. The main study with the humanoid robot expanded over several months and trials were designed to progressively move from very simple exposure to the robot to more complex opportunities for interaction. There were three phases to this:

A. The familiarisation Phase - where the robot was operating in its 'dancing' mode, moving its limbs and head to the rhythm of pre-recorded music. This phase was designed mainly for the children to familiarise themselves with the robot, and they were left to do what they chose to do.

B. The learning phase - Here the teacher showed the child how the robot could imitate his movements. The robot was operating in its 'puppet mode', where, unknown to the child, the investigator as puppeteer caused the robot to accurately respond to the child's arm, leg and head movements.

C. Free interaction/imitation - In these trials the children were left to interact and play imitation games on their own initiative if they chose to do so. On these occasions the robot was operated as a puppet by the investigator again. The investigator was able to recognise even subtle expressions of the child and quickly respond to the child's movements, and also to introduce further complexity of turn-taking and role-switching into the simple imitation game.

Figure 2: The three phases of the trials (familiarisation, learning & free imitation)

This set of trials, where the children were given the opportunity to have free interaction with the robot, was repeated a few months later as an extension study, with the focus on the different appearances of the robot. In these trials, the robot was operating in his puppet mode, with the investigator acting as the puppeteer.

Figure 3: Free interactions during the extension study

4 Data Processing and Analysis

In our trials we defined four elementary behaviour criteria that we evaluated throughout the period of trials, based on the video footage. These behaviours were:

a. Eye Gaze (when directed at the robot)

b. Touch (when the child touched any part of the robot)

c. Imitation (this included direct imitation of the robot's movements, delayed imitation and response to the robot's movement, and attempted imitation of the robot's movement)

d. Near (this included the child approaching the robot and staying in close proximity to the robot regardless of the child's other behaviours)

4.1 Quantitative Analysis

The video data from each and every trial for a given child was segmented into one second intervals. The trials were coded by scoring the above defined elementary behaviours for every second of the trial, cf. [16]. The coded data for each trial was then summed up and yielded the total number of occurrences of each behaviour during a specific trial and the total duration the child was engaged in each behaviour during that trial. As some of the trials varied in duration, the total duration of a behaviour was transformed to a proportional representation of the duration of behaviour relative to the duration of that specific trial. The quantitative analysis of the data produced graphs showing the different responses of the children to the robot's appearance (i.e. the different duration of the interaction). The analysis of the data also showed the changes in the children's behaviour (during child robot interaction) over a period of time. However these findings are outside the scope of this paper and can be found in [14]. We can see in figures 4 & 5 examples how one child (Don) has a different level of interaction with the robot, in terms of behavioural criteria of Touch and Near, depending on the robot's appearance. This data was taken during the longitudinal study when the child had many exposures to both robot's different appearances.

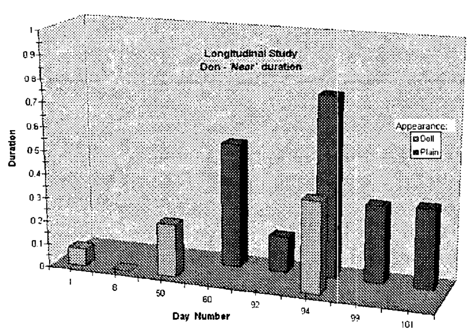

Figure 4: Don's duration of *Touch* in both scenarios (The vertical axis is a proportional representation of the duration of behaviour relative to the duration of that specific trial)

Extension Study: As mentioned earlier, six months later the trials have been repeated twice again (weeks 1&2 in the graphs below) with the exact same set up, with the specific aim of studying the children's reaction to the different appearances of the robot. The

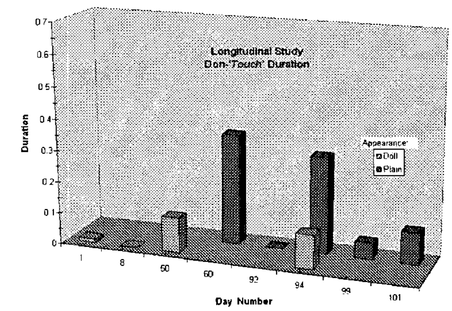

Figure 5: Don's duration of *Near in both scenarios*

graphs show samples of the results. Figures 6&7 show individual children's levels of interaction in all four behavioural criteria (gaze, near, touch, imitation), and how they differ according to the robot's appearance.

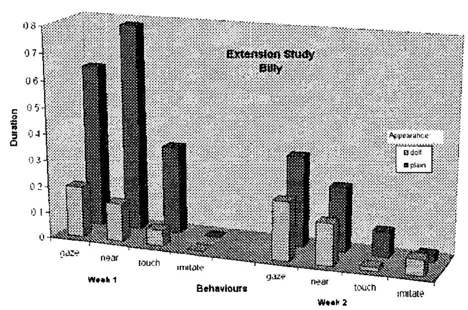

Figure 6: Billy's behaviour during the interaction

Figure 8 below gives example of how the robot's appearance during the Extension Study affects the level of eye-gaze towards it in all children.

4.2 Qualitative analysis

Our approach of repeated trials over a long period of time allowed the children time to explore not only the interaction space of robot-human, but also human-human interaction. In some cases the children started to use the robot as a mediator, an object of shared attention. They opened themselves up to include the investigator in their world, actively seeking to share their experience with him as well as with their carer (as seen in figure 9). Although with a very small sample base, it is interesting to note that in most of the cases, this has happened when the robot wore its plain robotic costume, and in the case of two of the children,

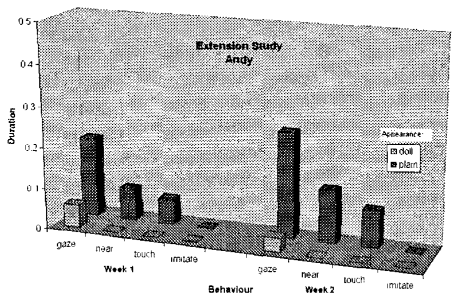

Figure 7: Andy's behaviour during the interaction

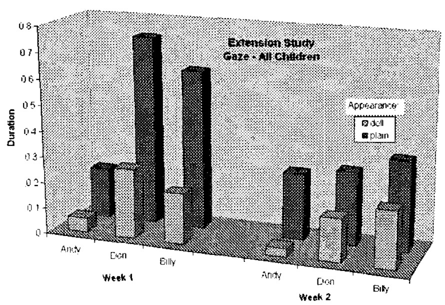

Figure 8: Eye-Gaze levels of all children

this happened when they saw this outfit for the very first time (after seeing the 'pretty-girl' outfit several times before). As it is such a small sample base, it is impossible to decide if, and to what extent, the children's behaviour in these cases can be attributed to the robot's plain appearance. However these results might be a good basis for further longitudinal studies. A comprehensive qualitative analysis of some of these segments of trials where the children used the robot as a mediator and object of shared attention can be found in a separate publication [15].

5 Discussion of results

The result of the two studies (both the longitudinal study, and the extension study) clearly indicate that initially the children showed preference for interaction with the robot with its plain robotic appearance over the 'pretty doll' appearance (although over time, during the longitudinal study, they became accustomed to both appearances of the robot). It also might be possible that the plain appearance was a salient feature in causing the children to use the robot as a mediator and interact with the adults around (this needs further investigation).

Figure 9: Robot as a mediator, an object of joint attention

6 Conclusion

The results of these studies into the effect of the robot's appearance on the level of interaction with it by children with autism, confirm the results of the study we conducted with the life size 'Theatrical Robot' [13]. Autism does not occur to the same degree and in the same form in all cases, so, as robotic systems are developed to aid in the therapy and education of children with autism, it is unlikely that they can be used generically to satisfy all needs and requirements. To conclude, the results from this research can possibly contribute to the search for a better and more tailored robotic design that will elicit specific basic interaction skills in children with autism.

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