Investigating the Impact of Gender Development in Child-Robot Interaction

Anara Sandygulova and **Mauro Dragone** and **Gregory O'Hare** [1]

Abstract. In order to inform the important consideration when designing robotic applications for children, in this paper we describe and report the results of the preliminary study we conducted in a primary school. Our work investigates the impact of gender development by examining children's perceptions of robot's gender and age on levels of expressed happiness towards the robot. Our results suggest that children aged 8-12 years old relate differently towards robot's perceived gender and age and support the trends in gender development in child-robot interaction.

1 INTRODUCTION

Recent progress in all areas of service robotics, including works integrating speech, sensing, acting, and networking, have resulted in increasingly versatile and reliable service robots. One of the most promising application domain for such robots is to be deployed in public spaces such as hospitals, education institutions or rehabilitation centers. Robots of such applications are challenged with socially appropriate interactions with previously unseen users: they need to offer appropriate services and shape their interaction style according to the particular individual's needs and preferences, for example the elderly and children.

According to Dautenhahn [6], the most important abilities that robots need to demonstrate are *socialisation* and *personalisation* in order to meet the social, emotional and cognitive needs of people. She argues that individualisation is necessary due to the human nature: people have individual needs, likes and dislikes, preferences and personalities that a 'personalised robot companion' would have to adapt to: one and the same robot will not fit all people.

Our work focuses on investigating personalisation issues related to service robots employed in public spaces where they need to engage with a variety of previously unseen users, usually for short interaction episodes. In order to develop and test the effectiveness of dynamic personalisation in those HRI systems, we employ a ubiquitous robotic system comprising a humanoid Nao robot and a wireless sensor network installed on a toy kitchen. The system, detailed in [17], is able to gather information from a number of networked sensors to effectively and robustly estimate gender and age of the person in front of the robot, and consequently adapt its interaction style.

This paper explores the little explored issue of how children's perception of the robot changes with age. The goal is to investigate the impact of gender development on child-robot interaction. A literature in child psychology on trends in gender development [5] suggests that children at different development stages demonstrate different reaction regarding children's toys, activities, traits and play preferences. In the years between preschool and puberty, the free play of children occurs largely in sex-segregated groups, which is depicted as a group phenomenon, essentially unrelated to the individual attributes of the children [11]. Stereotypes tend to be rigidly held during childhood, so that sex differences are perceived to be extreme and binding [8]. In order to provide more acceptable, engaging and preferable interaction for children, the research question of our work is whether children follow the same tendency of sex-typing [8] in their interaction with the robot depending on its perceived gender. If so, what are the differences for girls and boys across different ages?

In order to address this question, we conducted an experiment with 76 children aged between 8 and 12 years old in a primary school. The goal of this evaluation was to compare three types of human-like robot voices in order to measure children's preferences. Children were in presence of a robotic system comprising of the Nao robot and a toy kitchen [16], where the robot invited them to play with the kitchen. We analysed and compared children's preferences in terms of expressed happiness by observing their facial expressions, children's verbal and non-verbal behaviour and the questionnaires. The results suggest that robot's perceived gender and age effect the levels of engagement and acceptance of the robot by children across different age and gender groups.

The remainder of this paper is organised in the following manner: Section 2 introduces the work on human-robot interaction, which explored the effect of the perceived robot's gender, followed by a review of the literature on child-robot interaction relating to age differences in robot's perception. Section 3 introduces hypotheses. This is followed by a description of the robotic system, structure and methodology used in the study. Section 4 presents the analysis of the results followed by the discussions, in Section 6, and our conclusions, in Section 7.

2 RELATED WORK

Child-robot interaction research has steadily increased in recent years [21], [19], [3]. During the study with the ASIMO robot [13], general features such as monotone robot-like voice and human-like voice were compared with children aged 4-10 years old. The results indicate that children learned more when ASIMO had a human voice. Also, learning styles and general features matter especially for children 4-6 years old.

Scheef *et al.* [18] found that young children of 4-7 years old tended to be very energetic around Sparky and kind to it regardless of gender. Older children (from 7ish to early teens) behaved differently according to gender: boys of that age were usually aggressive and girls were generally gentle with the robot. In an 18-day trial to investigate the use of robots as social partners to teach English to Japanese

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children, Kanda *et al.* [9] concluded that establishing rapport with children is essential when attempting to acquire information from them. In investigating whether or not children would share a secret with the robot, Fior *et al.* [7] found that 45.7% would be willing to share a secret and Bethel *et al.* [4] found that children aged 4 and 5 were as likely to share a secret with a NAO robot as with an adult.

The study by Tung [20] examined whether gender or age influences the social and physical attraction children feel toward humanoid robots with the results suggesting that girls are more accepting of human-like robots, especially female robots, than boys are.

A recent study by Ozogul *et al.* [14] investigated whether middle-school learners (11-13 years old), when given a choice in animated pedagogical agent, will select a young agent that matches their gender. The findings support the similarity attraction hypothesis with significant preference ($p < 0.001$) in children's choice for the computer-based animated agent that matched their age and gender.

3 Hypotheses

The goal of this experiment is to investigate children's preferences toward the robot's voice across different age groups and genders. How do children's non-verbal and verbal behaviour across different ages, as well as their opinion on the interaction with the robot, differ depending on the robot's human-like child versus adult voice? What is the difference across children's age groups in their willingness to interact with the robot depending on the robot's human-like male versus female voice?

These research questions produce the following hypotheses:

- H1: A match between the age expressed by the robot's human-like voice and the participant's age will have a positive effect on the interaction experience with the robot.
- H2: A match between the gender expressed by the robot's human-like voice and the participant's gender will have a positive effect on the interaction experience with the robot.

4 EXPERIMENT

4.1 Participants

The experiment was conducted in a primary school in Dublin with children aged between 8 and 12 years old. The experiment involved 76 children, 40 girls and 36 boys. There were 16 children aged 8 years old, 15 children were 9 years old, 20 children were 10 years of age, 20 children were of age 11 and 5 children were 12 years of age.

4.2 The Robotic System

The robotic testbed exploited for this experiment was designed with the aim to investigate human interactions with the ubiquitous robotic systems and to showcase and demonstrate various projects' results outside our laboratory in a wide range of settings, from outreach demonstrations in secondary schools and universities, to research exhibitions, industrial seminars and other project dissemination events. Deliberately, the testbed is designed to be easily transportable and re-configurable in order to adapt to different settings and requirements (see [16]). Figure 1 illustrates the components of the ubiquitous robotic system used for this experiment, namely:

- a humanoid NAO robot;

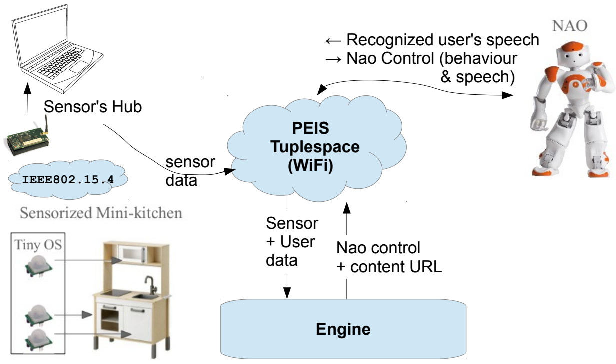

Figure 1. Software & Hardware Configuration

- a toy mini-kitchen (IKEA), equipped with a Wireless Sensor Network (WSN).

In the following sections, we briefly describe a middleware, and each of the system's elements, together with their software components.

4.2.1 *Middleware*

In order to leverage highly heterogeneous resources, encompassing, for instance, both wireless sensor and actuator networks (WSANs) and humanoid robots, we employ a middleware developed as part of the EU FP7 project RUBICON (Robotic UBIquitous Cognitive Network) [1]. Zero-configuration and interoperability among robots, wireless sensor nodes and traditional computers is ensured by using the PEIS kernel [10], a software suite previously developed as part of the Ecologies of Physically Embedded Intelligent Systems project.

4.2.2 *Smart Kitchen*

The mini-kitchen is a toy kitchen marketed by IKEA and normally used to encourage role play, as children can imitate grown-ups and play with all the normal functions installed in real kitchen furniture. The mini-kitchen has an oven, a cupboard, a microwave, a sink, and a cooker with simulated hobs, all in 72x35x50 cm. In order to gather knowledge on the status of the mini-kitchen, we have installed a number of sensors giving real-time information on the lighting conditions.

4.2.3 *NAO*

The NAO[2] is a child-sized, 58cm tall humanoid robot equipped with a vast array of sensors, including cameras, microphones, sonars and tactile sensors, and with 25 degrees of freedom. The NAO acts as a social interface toward the ubiquitous robotic system to communicate the status of the smart kitchen to the user. To this end, we wrote a C Peis component combining the NAOqi C++ SDK with the C Peis client. Our Nao-Peis component provides a Peis interface toward the Nao's behaviour system.

[2] www.aldebaran-robotics.com/en

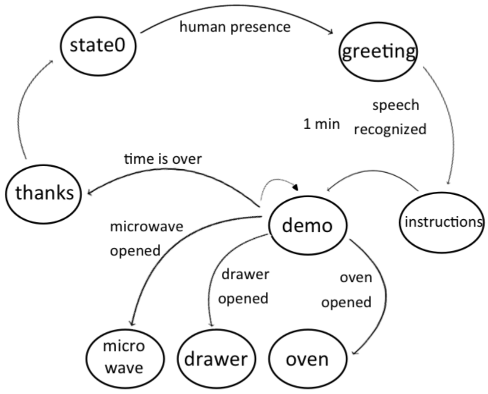

Figure 2. A Finite State Machine

4.2.4 *Engine*

The robotic system is controlled by a software engine that we designed to define and execute a finite state machine (Figure 2). Each state represents a possible event triggered by the other components of the robotic system: (i) the specific behaviours of the NAO robot, (ii) sensor and event updates from the kitchen, (iii) a Wizard-of-Oz control of the human presence through an iPhone application. Each time there is an event which triggers a state transition and a new state is reached, our engine instructs the PEIS to control the execution of the NAO behaviours.

Figure 3. Experimental Setup

4.3 Experimental Setup

Our experiment was setup in a small room which had a small entrance and two benches on the sides. Figure 3 presents the experimental setup: the smart kitchen is placed in the middle of the room with a NAO standing next to it on the left. There was a camera placed in front of the child capturing facial expressions for real-time happiness analysis that was logged for future processing. s

4.4 Scenario

The experiment was structured as an interactive game. Each child was instructed to sit in a chair facing the robot and the smart kitchen (see Figure 3). The experimenter controlled the launch of each experiment session through an iPhone application. This was done without the child's knowledge to give an impression of the robot's full autonomy. As the child is present in the room, the NAO wakes up by standing up and greets the child.

NAO: - Hello! (waving) My name is Josh/Rosie/Tracy. What is your name?
Child: (child says the name)
NAO: - It is very nice to meet you. It is my first time outside of the factory where I was created. My job is to help people be safe by reminding them to turn off things in the kitchen. Would you, please, help me practice for my new job? It's very easy to help (pause). You can open a microwave, an oven or under the sink cupboard one at a time. You are welcome to start (looking and pointing at the kitchen).
Child: (child opens either a microwave, an oven or a cupboard).
NAO: - The sensor inside the microwave/oven/cupboard (looking and pointing at a particular appliance) detected that you opened it. Could you, please, close it? If you want, try to open something else!
Child: (child plays with the kitchen for one minute)
NAO: - Thank you so much for your help! You've earned a "Super Star" sticker! Hope to see you soon. Bye-bye! (sitting down).

4.5 Stimuli

The independent variables of the experiment were robot voices: Josh, Rosie or Tracy. Josh is a US English voice of a boy. Rosie is a UK English voice of a girl. Tracy is an adult female voice of US English language. These voices are available from Acapela Inc. Participants were randomly assigned to interact with the NAO with either a Josh, a Rosie or a Tracy voice with applied counterbalancing in terms of gender and age group.

4.6 Procedure

The experiment sessions involved one participant at a time. Participants were instructed to take a seat in front of the robotic system (see Figure 3) and follow the robot's instructions. After the experiment, they were given a "Super Star" sticker by the experimenter. After the participants left the room, they were given a questionnaire to fill in on their own or with a help of their teacher depending on their age.

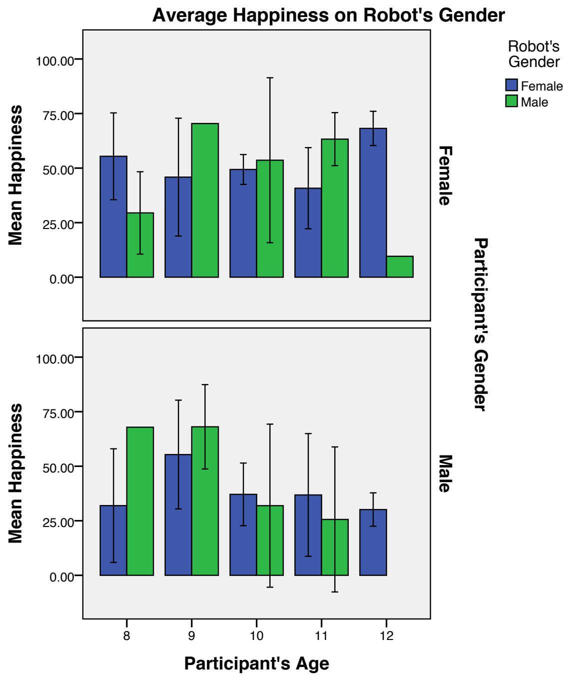

Figure 4. Average Happiness on Robot's Gender

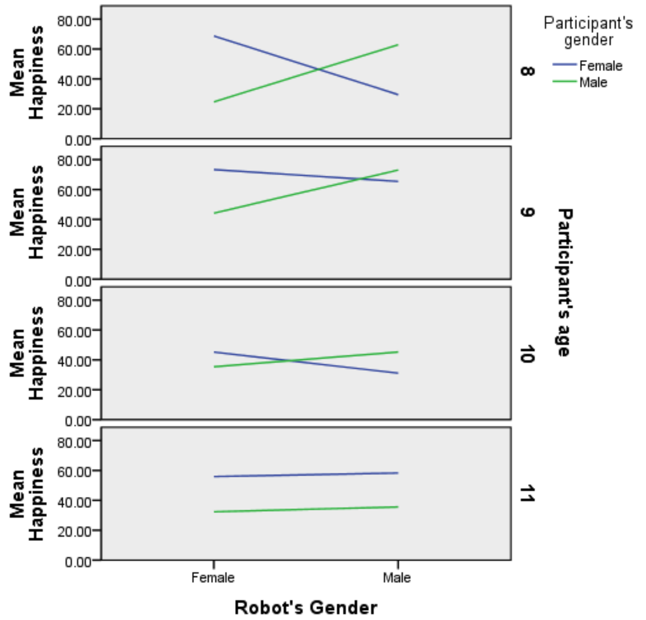

Figure 5. Average Happiness at Female and Male Robot Voice Conditions For Different Age Groups

4.7 Measurements

The participants were asked to complete the Godspeed [2] questionnaire (with items measuring likeability, intelligence and safety) immediately after the experiment. The questionnaire is very short and simple in order not to overwhelm the children. Wording is modified for children to understand, for example the word "intelligent" is replaced with the word "clever". In addition, some basic information about demographics is solicited such as age and gender.

In order to effectively evaluate children's attitude toward the interaction experience, there was a camera placed in front of the child capturing facial expressions for real-time emotion analysis using the Sophisticated High-speed Object Recognition Engine (SHORE)[3] software. This package gives the intensity values of the following emotional states: happiness, sadness, surprise and anger. For the purposes of this study, we only accounted for the expressed happiness of the participants. Moreover, at the intensity less than 50% the emotional state of the user is assumed to be neutral. The intensity score of the expressed happiness is recorded every second over the duration of the study from the moment the robot started speaking till the "Super Star" sticker is mentioned by the robot. This time period is the most trustworthy since the child's full attention is taken by the robot and it eliminates potential fallacious smiles caused in relation to the experimenter or due to the sticker. The final average score of the expressed happiness is then calculated for each participant.

5 RESULTS

The Godspeed questionnaire results showed internal consistency with Cronbach's alpha scores above 0.9 for all participants. However, there are no significant differences in how the children evaluated robot's likeability, intelligence and safety across three different conditions. This could be due to the limitations of the 5-point Likeart scale type of questionnaires to be used for assessing young children.

For that reason, we focus reader's attention on the results obtained from the analysis of the children's facial expressions, particularly their level of expressed happiness. A series of two-way ANOVA tests on different measurements were conducted in order to test for statistically significant differences between various combinations of the robot's gender and age conditions.

When comparing the average happiness score across age groups in relation to the robot's age, the results are not statistically significant. However, the average scores vary across age groups. For example, 8 and 9 years old children expressed slightly more happiness towards the child's voice of the robot and 11 and 12 years old towards the adult's voice. Children of 10 years of age expressed no difference for both age conditions of the robot's voice. These findings are exploratory and suggest that further experiments are needed.

We found a significant interaction between the effects of child's gender and robot's gender on the expressed happiness, $F(1, 12) = 4.935$, $p = 0.046$ for 8 years old children. However, the results for other age groups are not statistically significant. Figure 4 illustrates these results.

In order to analyse the correlation between children's and robot's genders only, we separated the results to only include children voices of both genders i.e. Rosie and Josh voices. The results we report here are for 50 children aged 8-11 years old (Figure 5). Again, we found a significant interaction between the effects of child's gender and robot's gender on the expressed happiness, $F(1, 7) = 19.198$, $p = 0.003$ for 8 years old children. However, the results for other age groups are not statistically significant: $F(1, 4) = 5.958$, $p = 0.71$ for children of 9, and $F(1, 9) = 1.475$, $p = 0.255$ for 10, and $F(1, 12) = 0.004$, $p = 0.952$ for 11 years old children.

[3] http://www.iis.fraunhofer.de/en/bf/bsy/produkte/shore.html

6 DISCUSSION

The results from this study indicate that children have different perspectives toward the robot's voice across age groups, which is supported by the literature in child psychology [5, 8, 11].

Child psychology on trends in gender development [5] suggests that by 7 years most children show full understanding of gender constancy. Until 7 and 8 years of age, gender stereotypes remain very rigid, for example stereotypes regarding children's toys, activities, colours, traits and play preferences. Stereotypes are stronger for boys than for girls. Segregation into same-gender playgroups remains high and continues until early adolescence. There is also a strong negative reaction to cross-gender behaviour, especially when it involves cross-gender appearance. This has been demonstrated in a statistically significant interaction ($p < 0.05$) between the effect of same-gender voices on likeability and engagement by the children. After 7 to 8 years of age, knowledge of gender stereotypes continues to increase, but stereotype rigidity gradually decreases. Children begin to understand the cultural relativity of gender norms. According to Cook [5], acceptance of cross-gender behaviour and appearance increases during middle primary school which supports the non-significant preferences toward the opposite-gender voices at 9-11 years old children. In addition to it, from 9 to 11 years of age, differences are found or increase in the emotional expressiveness, emotional perceptions, and self-esteem. Interestingly, the fact that girls show more and earlier stereotype flexibility than boys is also demonstrated: the difference between the mean values for girls is smaller than for boys at the age of 9. Our findings demonstrate that boys older than 10 were less expressive than girls of that age. This might be due to the fact that boys have more stereotypical preferences toward toys and activities than girls [12] with kitchen being a stereotypical girl's toy. According to [5], flexibility of gender stereotypes increases at least up to early adolescence. From 12 years and older, reactions to cross-gender behaviour and appearance become more negative, reversing the trend seen up until adolescence. These results are exploratory and suggest further investigation.

Concerning limitations of the experiment, it would be useful to assess the children's degree of extroversion or introversion in order to calibrate the expressed happiness variable. What is more, in future studies larger samples of subjects across the age groups and more age groups need to be investigated. In relation to the voices of the different accents, the US English and the UK English, we have consulted teachers and education professionals on their opinion whether the accent might influence the perception of the robot at that age. They thought that children are used hearing the US and the UK accents on television and should not perceive the particular accent as negative. Our concern was the perceived personality of the voice, which influenced our decision in selecting the voices. Testing a few voices of each gender and age group would eliminate this limitation.

7 CONCLUSIONS AND FUTURE WORK

This experiment provides strong support for continuing the research direction of the human-robot personalisation through verbal and non-verbal behaviours of the robot. Specifically, this paper describes an experiment with the ubiquitous robotic system where a humanoid robot NAO interacted with the children with either a child male, a child female or an adult human-like voice in order to investigate children's engagement and preferences toward the robot's gender and age. Our results suggest that children relate differently to the robot's age and gender at different age groups. This is important to consider when designing robotic applications for children in order to increase robot's perceived likeability, acceptance and engagement.

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