4th International Symposium on New Frontiers in Human-Robot Interaction
21–22 April 2015, Canterbury, UK
M. Salem, A. Weiss, P. Baxter, K. Dautenhahn (Eds.)

Presence of Life-Like Robot Expressions Influences Children's Enjoyment of Human-Robot Interactions in the Field

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Abstract. Emotions, and emotional expression, have a broad influence on the interactions we have with others and are thus a key factor to consider in developing social robots. As part of a collaborative EU project, this study examined the impact of life-like affective facial expressions, in the humanoid robot Zeno, on children's behavior and attitudes towards the robot. Results indicate that robot expressions have mixed effects depending on the gender of the participant. Male participants showed a positive affective response, and indicated greater liking towards the robot, when it made positive and negative affective facial expressions during an interactive game, when compared to the same robot with a neutral expression. Female participants showed no marked difference across two conditions. This is the first study to demonstrate an effect of life-like emotional expression on children's behavior in the field. We discuss the broader implications of these findings in terms of gender differences in HRI, noting the importance of the gender appearance of the robot (in this case, male) and in relation to the overall strategy of the project to advance the understanding of how interactions with expressive robots could lead to task-appropriate symbiotic relationships.

1 INTRODUCTION

A key challenge in human robot interaction (HRI) is the development of robots that can successfully engage with people. Effective social engagement requires robots to present engaging personalities [1] and to dynamically respond to and shape their interactions to meet human user needs [2].

The current project seeks to develop a biologically grounded [3] robotic system capable of meeting these requirements in the form of a socially-engaging *Synthetic Tutoring Assistant* (STA). In developing the STA, we aim to further the understanding of human-robot symbiotic interaction where symbiosis is defined as the capacity of the robot, and the person, to mutually influence each other in a positive way. Symbiosis, in a social context, requires that the robot can interpret, and be responsive to, the behavior and state of the person, and adapt its own actions appropriately. By applying methods from social psychology we aim to uncover key factors in robot personality, behavior, and appearance that can promote symbiosis. We hope that this work will also contribute to a broader theory of human-robot bonding that we are developing drawing on comparisons with our psychological understanding of human-human, human-animal and human-object bonds [4].

A key factor in social interaction is the experience of emotions [5]. Emotions provide important information and context to social events and dynamically influence how interactions unfold over time [6]. Emotions can promote cooperative and collaborative behavior and can exist as shared experiences, bringing individuals closer together [7]. Communication of emotion can be thought of as a request for others to acknowledge and respond to our concerns and to shape their behaviors to align with our motives [8]. Thus emotional expression can be important to dyadic interactions, such as that between a teacher and student, where there is a need to align goals.

Research with a range of robot platforms has demonstrated the willingness of humans to interpret robot expressive behavior – gesture [9], posture [10], and facial expression [1] – as affective communication. The extent to which robot expression will promote symbiosis will depend, however, on how well the use of expression is tuned to the ongoing interaction. Inappropriate use of affective expression could disrupt communication and be detrimental to symbiosis. Good timing and sending clear signals is obviously important.

Facial expression is a fundamental component of human emotional communication [11]. Emotion expressed through the face is also considered to be especially important as a means for communicating evaluations and appraisals [12]. Given the importance of facial expressions to the communication of human affect, they should also have significant potential as a communication means for robots [13]. This intuition has lead to the development of many robot platforms with the capacity to produce human-like facial expression, ranging from the more iconic/cartoon-like [e.g., 14, 15] to the more natural/realistic [e.g., 16, 17, 18].

Given the need to communicate clearly it has been argued that, for facial expression, iconic/cartoon-like expressive robots may be more appropriate for some HRI applications, for instance, where the goal is to communicate/engage with children [16, 15]. Nevertheless, as the technology for constructing robot faces has become more sophisticated, robots are emerging with richly-expressive life-like faces [16, 17, 18], with potential for use in a range of real-world applications including use with children. The current study arose out of a desire to evaluate one side of this symbiotic interaction – exploring the value of life-like facial expression in synthetic tutoring assistants for children. Whilst it is clear that people can distinguish robot expressions almost as well

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as human ones [16, 18], there is little direct evidence to show a positive benefit of life-like expression on social interaction or bonding. Although children playing with an expressive robot are more expressive than those playing alone [19], this finding could be a result of the robot's social presence [20] and not simply due to its use of expression. A useful step toward improving our understanding would be the controlled use of emotional expression in a setting in which other factors, such as the presence of the robot and its physical and behavioral design, are strictly controlled.

In the current study the primary manipulation was to turn on or off the presence of appropriate positive and negative facial expressions during a game-playing interaction, with other features such as the nature and duration of the game, and the robot's bodily and verbal expression held constant. As our platform we employed a Hanson Robokind Zeno R50 [21] which has a realistic silicon rubber ("flubber") face, that can be reconfigured, by multiple concealed motors, to display a range of reasonably life-like facial expressions in real-time (Figure 1).

Figure 1. The Hanson Robokind Zeno R50 Robot with example facial expressions

By recording participants (with parental consent), and through questionnaires, we obtained measures of proximity, human emotional facial expression, and reported affect. We hypothesized that children would respond to the presence of facial expression by (a) reducing their distance from the robot, b) showing greater positive facial expression themselves during the interaction, and c) reporting greater enjoyment of the interaction compared to peers who interacted with the same robot but in the absence of facial expression. Previous studies have shown some influence of demographics such as age and gender on HRI [22, 23, 24]. In our study, a gender difference could also arise due to the visual appearance of the Zeno robot as similar to a male child, which could prompt different responses in male and female children. We therefore considered these other factors as potential moderators of children's responses to the presence or absence of robot emotional expression.

2 METHOD

2.1 Design

Due to the potential of repeated robot exposure prejudicing participants' affective responses, we employed a between-subjects design, such that participants were allocated to either the experimental condition – interaction with a facially expressive robot, or to the control condition of a non-facially-expressive robot. Allocation to condition was not random, but determined by logistics due to the real-world setting of the research. The study took place as part of a two-day special exhibit demonstrating modern robotics at a museum in the UK. Robot expressiveness was manipulated between the two consecutive days, such that visitors who participated in the study on the first day were allocated to the expressive condition, and visitors who participated in the study on the second day were allocated to the non-expressive condition.

2.2 Participants

Children visiting the exhibit were invited to participate in the study by playing a game with Zeno. Sixty children took part in the study in total (37 male and 23 female; M age = 7.57, SD = 2.80). Data were trimmed by age to ensure sufficient cognitive capacity (those aged < 5 were excluded[4]) and interest in the game (those aged >11 were excluded) leaving 46 children (28 male and 18 Female; M age = 8.04, SD = 1.93).

2.3 Measures

Our primary dependent variables were interpersonal responses to Zeno measured through two objective measures: affective expressions and interpersonal distance. Additional measures comprised of a self-report questionnaire, completed by participating children, with help from their parent/carer if required, and an observer's questionnaire, completed by parents/carers.

2.3.1 Objective Measures

Interpersonal distance between the child and the robot over the duration of the game was recorded, using a Microsoft Kinect sensor, and mean interpersonal distance during the game calculated. Participant expressions were recorded throughout the game and automatically coded for discrete facial expressions: Neutral, Happy, Sad, Angry, Surprised, Scared, and Disgusted, using Noldus FaceReader version 5. Mean intensity of the seven facial expressions across the duration of the game were calculated. Participants' game performances (final scores) were also recorded. FaceReader offers automated coding of expressions at an accuracy comparable to trained raters of expression [25].

2.3.2 Questionnaires

Participants completed a brief questionnaire on their enjoyment of the game and their beliefs about the extent to which they thought that the robot liked them. Enjoyment of playing Simon Says with Zeno was recorded using a single-item, four-point measure, ranging from 'I definitely did not enjoy it' to 'I really enjoyed it'. Participants' perceptions of the extent to which Zeno liked them single-item on a thermometer scale, ranging from 'I do not think he liked me very much' to 'I think he liked me a lot'. They were also asked if they would like to play the game again. Parents and

[4] Additional reasons for excluding children below the age of 5 were questionable levels of understanding when completing the self-report questionnaires, and low reliability in FaceReader's detection of expressions in young children.

carers completed a brief questionnaire on their perceptions of their child's enjoyment and engagement with the game on single-item thermometer scales, ranging from 'Did not enjoy the game at all' to 'Enjoyed the game very much and 'Not at all engaged' to 'Completely engaged'.

2.4 Procedure

The experiment took place in a publicly accessible lab and prospective participants could view games already underway. Brief information concerning the experiment was provided to parents or carers and informed consent was obtained from parents or carers prior to participation.

During the game, children were free to position themselves relative to Zeno within a 'play zone' boundary marked on the floor by a mat (to delineate the area in which the system would correctly detect movements) and could leave the game at their choosing. The designated play zone was marked by three foam .62msq mats. The closest edge of the play zone was 1.80m from the robot and the play zone extended to 3.66m away. These limits approximate the 'social distance' classification [26]. This range was chosen for 2 reasons i) Participants would likely expect the game used to occur within social rather than public- or personal-distance ii) This enabled reliable recordings of movement by the Kinect sensor. The mean overall distance for the participants from the robot fell well within social-distance boundaries (2.48m).

At the end of the game, participants completed the self-report questionnaire, while parents completed the observer's questionnaire. Participant-experimenter interaction consistency was maintained over the two days by using the same experimenter on all occasions for all tasks.

Interaction with the robot took the form of the widely known *Simon Says* game (Figure 2). This game was chosen for several reasons: children's familiarity with the game, its uncluttered structure allows autonomous instruction and feedback delivery by Zeno, and its record of successful use in a prior field study [27].

The experiment began with autonomous instructions delivered by Zeno as soon as children stepped into the designated play zone in front of the Kinect sensor. Zeno introduced the game by saying, "*Hello. Are you ready to play with me? Let's play Simon Says. If I say Simon Says you must do the action. Otherwise you must keep still*." The robot would then play ten rounds of the game or play until the child chose to leave the designated play zone. In each round, Zeno gave one of three simple action instructions: 'Wave your hands', 'Put your hands up' or 'Jump up and down'. Each instruction was given either with the prefix of 'Simon says' or no prefix.

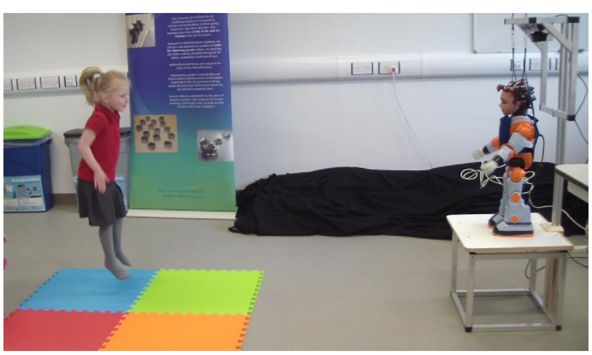

Figure 2. A child playing Simon Says with Zeno

The OpenNI/Kinect skeleton tracking system was used to determine if the child had performed the correct action in three seconds following instruction. For the 'Wave your hands' action, our system monitored the speed of the hands moving. If sufficient movement for the arms were detected following instruction then the movement was marked as a wave. For the 'Jump up and down' action the vertical velocity of the head was monitored, again with a threshold to determine if a jump had taken place. Finally for the 'Put your hands up' action, our system monitored the positions of the hands relative to the waist. If the hands were found to be above the waist for more than half of the three seconds following the instruction then the action was judged to have been executed. The thresholds for the action detection were determined by previous trial and error during pilot testing in a university laboratory. The resulting methods of action detection were found to be over 98% accurate in our study. In the rare cases where the child did the correct action and the system judged incorrectly then the experimenters would step in and say "*Sorry, the robot made a mistake there, you got it right*".

If children followed the action instruction after hearing 'Simon says' the robot would say, "*Well done, you got that right*". If the child remained still when the prefix was not given, Zeno would congratulate them on their correct action with "*Well done, I did not say Simon Says and you kept still*". Conversely, if the child did not complete the requested movement when the prefix was given Zeno would say, "*Oh dear, I said Simon Says, you should have waved your hands*". If they completed the requested movement in the absence of the prefix, Zeno would inform them of their mistake with, "*Oh dear, I did not say Simon Says, you should have kept still*". Zeno gave children feedback of a running total of their score at the end of each round (the number of correct turns completed).

If the child left the play zone before ten rounds were played, the robot would say, "*Are you going? You can play up to ten rounds. Stay on the mat to keep playing*". The system would then wait three seconds before announcing, "*Goodbye. Your final score was (score)*". This short buffer was to prevent the game ending abruptly if the child accidentally left the play zone for a few seconds.

At the end of the ten rounds, the robot would say, "*All right, we had ten goes. I had fun playing with you, but it is time for me to play with someone else now. Goodbye*."

The sole experimental manipulation coincided with Zeno's spoken feedback to the children after each turn. In the expressive robot condition, Zeno responded with appropriate 'happiness' or 'sadness' expressions, following children's correct or incorrect responses. These expressions were prebuilt animations, provided with the Zeno robot, named 'victory' and 'disappointment' respectively. These animations were edited to remove gestures so only facial expression were present. In contrast, in the non-expressive robot condition, Zeno's expressions remained in a neutral state regardless of child performance. Previous work indicates that children can recognize these facial expression representations by the Zeno robot with a good degree of accuracy [28].

3 RESULTS

A preliminary check was run to ensure even distribution of participants to expressive and non-expressive conditions. There were 9 female and 16 male participants in the expressive condition and 9 female and 12 male participants in the non-expressive condition. A chi square test was run before analysis to check for even gender distribution across conditions indicates no significant difference (X2 (1,48) = 2.25, p = .635).

3.1 Objective Measures

Overall, we did not observe any significant main effects of Zeno's expressiveness on objective measures of interpersonal distance or facial expressions between conditions. However, there were significant interaction effects, when gender was included as a variable.

There was a significant interaction of experimental condition and child's gender on average child's expressions of happiness $F(1,39) = 4.75$, $p = .038$. While male participants showed greater average happiness in the expressive robot condition in comparison to those in the non-expressive condition (19.1%, SE 3.3% versus 5.3%, SE 4.1%), female participants did not differ between conditions (7.4%, SE 4.3% versus 12.6%, SE 4.6%). Simple effects tests (with Bonferroni correction) indicated that the observed differences between conditions for male participants was significant (p = .012).

A contrasting interaction was found for average expressions of surprise $F(1,39) = 5.16$, $p = .029$. Male participants in the expressive robot condition showed less surprise than those in the non-expressive condition (6.1%, SE 3.2% versus 19.6%, SE 4.0%), whereas female participant expressions for surprise did not differ between conditions (11.9%, SE 4.2% versus 7.1%, SE 4.5%). There were no further significant interactions for any of the remaining expressions.

There was a near significant interaction for experimental condition and child's gender for interpersonal distance $F(1,41) = 2.81$, $p = .10$ (Figure 3). Male participants interacting with the expressive robot tended to stand closer (M = 2.28m, SE .10m) than did those interacting with the non-expressive robot (M = 2.57m, SE .13m), whereas female participants interacting with the expressive robot tended to stand further away (M = 2.59m, SE .14m) than those interacting with the non-expressive robot (M = 2.45m, SE .14m). A follow-up simple effect test indicates that the difference between conditions for male participants was also near significant (p = .086).

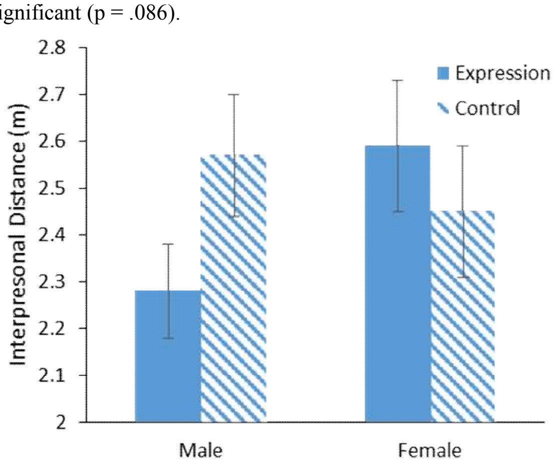

Figure 3. Mean interpersonal distance during game

Controlling for participant age or success/failure in the game made no material difference to any of the objective measures findings.

3.2 Questionnaires

No significant main effects of condition were seen for self-reported measures or observer reported measures. However, there were significant gender effects, and significant gender X condition effects. Gender had a main effect on children's beliefs about the extent to which the robot liked them $F(1,38) = 5.53$, $p = 0.03$. Female participants reported significantly lower ratings (M = 3.08, SE .34) than did male participants (M = 4.17, SE .31).

We observed a significant interaction of gender and experimental condition for participants' enjoyment in interacting with Zeno $F(1,38) = 4.64$, $p = .04$. Male participants interacting with the expressive Zeno reported greater enjoyment of the interaction than those who interacted with the non-expressive Zeno (M = 3.40, SE .18 versus M = 3.00, SE .23), whereas female participants interacting with the expressive Zeno reported less enjoyment than those interacting with the non-expressive Zeno (M = 3.22, SE .23 versus M = 3.78, SE .23). Simple effects tests did not indicate that the difference found between conditions were significant for either male participants (p > .10) or female participants (p > .10).

Results from the observer reports generated by the participants' parents or carers showed the same trends as those from the self-report results but did not show significant main or interaction effects. Controlling for participant age or success/failure in the game made no material difference to any of the questionnaire data findings.

4 DISCUSSION

The results provide new evidence that life-like facial expressions in humanoid robots can impact on children's experience and enjoyment of HRI. Moreover, our results are consistent across multiple modalities of measurement. The presence of expressions could be seen to cause differences in approach behaviors, positive expression, and self-reports of enjoyment. However, the findings are not universal as boys showed more favorable behaviors and views towards the expressive robot compared to the non-expressive robot, whereas girls tended to show the opposite.

Sex differences towards facially expressive robots during HRI could have profound impact on the design and development of future robots; it is important to replicate these experimental conditions and explore these results in more depth in order to identify why these results arise. At this stage, the mechanisms underpinning these differences still remain to be determined. We outline two potential processes that could explain our results.

The current results could be due to children's same-sex preferences for friends and playmates typically exhibited at the ages range tested (ages five to ten) [29]. Zeno is nominally a 'boy' robot and expressions may be emphasizing cues seen on the face to encourage user perceptions of it as a boy. As a result, children may be acting in accordance with existing preferences for play partners [30]. If this is the case, it would be anticipated that replication of the current study with a 'girl' robot counterpart would produce results contrasting with the current findings.

Alternatively, results could be due to the robot's expressions emphasizing the existing social situation experienced by the children. The current study took place in a publically accessible space, with participants in the company of museum visitors, other volunteers, and the children's parents or carer. Results from the current study could represent children's behavior towards the robot based on existing gender driven behavioral attitudes. Girls may have felt more uncomfortable than boys when in front of their parents whilst engaging in explorative play [20] with a strange person (in the form of their perceived proximity to the experimenter) and an unfamiliar object (the robot). Social cues from an expressive robot, absent in a neutral robot, may reinforce these differences through heightening the social nature of the experiment.

Behavioral gender differences in children engaging in public or explorative play are well established, and the link between these gender differences and the influence of direct parents/carers differential socialization of their children dependent upon the sex [31,32], is a further established link of developmental study. To better explore the gender difference observed in our study we must take into consideration existing observed behavioral patterns in children engaging in explorative play around their parents. Replication in a familiar environment away from an audience including children's parents may then impact on apparent sex differences observed in the current HRI study.

The current study is a small-sample field experiment. As with the nature of field studies, maintaining an exacting control over experimental conditions is prohibitively difficult. Along with possible confounds from the public testing space, the primary experimenter knew the condition each child was assigned to; despite best efforts in maintaining impartiality, the current study design cannot rule out potential unconscious experimenter influence on children's behaviors. In studies concerning emotion and expression, potential contagion effects of expression and emotion [33] could impact on participant's expressions and reported emotions. The current results therefore offer a strong indication of the areas to be further explored under stricter experimental conditions.

We aim to repeat the current study in a more controlled experimental environment. Children will complete the same Simon-says game in the familiar environment of their school, this time without an audience. Rather than allocation by day to condition, the study protocol will be modified to randomly allocate children to conditions, and the study will be conducted by an experimenter naïve to conditions. Testing at local schools offers better controls over participant sample demographics as children can be recruited based on age and having similar educational and social backgrounds. The environment of this study also removes any direct influence by the presence of parents/carers. Thus, a repeat of the current study under stricter conditions also offers opportunity to further test the proposed hypotheses for the observed sex differences in enjoyment in interacting with a facially expressive robot.

We have previously proposed that human-robot bonds could be analyzed in terms of their similarities to different types of existing bond with other human, animals, and objects [4]. Our relationships with robots that are lacking in human-like faces may have interesting similarities to human-animal bonds which can be simpler than those with other people—expectations are clearer, demands are lower, and loyalty is less prone to change. Robots with more human-like faces and behavior, on the other hand, may prompt responses from users that include more of the social complexities of human-human interaction. Thus, aspects of appearance that indicate gender can become more important, subtleties of facial and vocal expression may be subjected to greater scrutiny and interpretation. Overall, as we progress towards more realistic human-like robots we should bear in mind that whilst the potential is there for a richer expressive vocabulary, the bar may also be higher for getting the communication right.

5 CONCLUSION

This paper offers further steps towards developing a theoretical understanding of symbiotic interactions between humans and robots. The production of emulated emotional communication through facial expression by robots is identified as a central factor in shaping human attitudes and behaviors during HRI. Results from both self-repot and objective measures of behavior point towards possible sex differences in responses to facially expressive robots; follow-up work to examine these is identified. These findings highlight important considerations to be made in the future development of a socially engaging robot.

6 ACKNOWLEDGMENTS

This work is supported by the European Union Seventh Framework Programme (FP7-ICT-2013-10) under grant agreement no. 611971. We wish to acknowledge the contribution of all project partners to the ideas investigated in this study.

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