The Effect of Attention, Humour, and Empathy Behaviours by a Healthcare Robot on User Perceptions and Behaviors

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***Abstract*— Developing social robot attentional behaviours is critically important if robots are to be successfully employed in healthcare environments. This submission presents the results of three separate studies examining the effect of robot attention, robot humour, and robot empathy behaviours, on human perceptions and behaviours; during human-robot interactions. Each of the three studies are briefly presented below.**

I. INTRODUCTION

The use of robots in healthcare environments is fast becoming a reality. While much research in social robotics is focused on developing the technical capabilities of a robot, developing the social behaviours of a robot is critical in achieving acceptable and comfortable human-robot interactions [1].

A. Attentional Behaviours

A fundamental social behaviour, in human social interactions, is the ability to engage, maintain and demonstrate attention. A number of attentional behaviours are involved in successful human interactions but have not been researched in HRI.

Self-disclosure. Self-disclosure is an important aspect of human social interaction, with research demonstrating the effectiveness of self-disclosure in increasing mutual eye gaze, smiling, perceived friendliness, and in facilitating closeness and rapport [2, 3]. While a handful of studies have investigated the effect of robot self-disclosure on participant anxiety [4] and likability [5, 6], no study could be found that has investigated the use of robot self-disclosure on participant ratings of engagement, attention, perceived robot empathy, or perceived robot attention.

Voice pitch. The use of voice pitch, is another important behaviour in attracting and sustaining attention in human interactions [7, 8]. Only one study to date has examined the effect of robot voice pitch on HRI [9]. Niculescu and colleagues found that participants rated a robot significantly better in terms of appearance, voice, social skills, and personality when a higher voice pitch was used, as opposed to a lower voice pitch. Participants also rated the interactions with the robot with the higher pitch as more exciting, enjoyable, and entertaining.

Forward lean. The ability of a robot to demonstrate attention when interacting with a human is another important social behaviour, particularly in a health care environment. When considering patient-clinician interactions, leaning towards a patient is one way in which to demonstrate attention or 'active listening' [10]. In a literature review by Hall, Harrigan and Rosenthal [11] examining physician-patient interactions, physician leaning towards a patient was found to be associated with increased patient perceptions of physician empathy. No research could be found examining the use of forward lean by a robot during HRI.

B. Humour Behaviours

Use of physician humour during physician-patient interactions is not only common (59%), but has been found to be associated with a number of positive patient outcomes such as increased rapport, communication, empowerment, perceptions of physician empathy, as well as decreases in patient psychological distress [12, 13, 14]. Thus far however, no study has examined the use of humour by a healthcare robot, in the context of a human-robot interaction.

C. Empathy Behaviours

Clinical empathy has been associated with many positive outcomes, including patient trust and satisfaction [15-18]. Physicians can demonstrate clinical empathy through verbal statements and non-verbal behaviours, such as head nodding [11, 19]. The use of verbal and non-verbal empathy behaviours by healthcare robots may also positively affect patient outcomes.

II. AIMS

A. Attentional Study

The primary aim of the attentional study was to investigate whether certain robot behaviours (i.e. self-disclosure, forward lean, voice pitch changes) would facilitate participant attention and positively influence user perceptions of robot empathy and robot attention. The secondary aim of this study was to investigate whether these same behaviours would positively influence user behaviors.

B. Humour Study

The primary aim of the humour study was to examine the effect of humour, used by a healthcare robot, on user perceptions of robot likability, intelligence, animacy, safety, empathy, anthropomorphism, personality, and user laughing behavior.

C. Empathy Study

The primary aim of the empathy study was to examine the effect of verbal and non-verbal empathetic behaviours by a healthcare robot, during a video-recorded interaction with a patient, on participant perceptions of robot empathy, trust, distrust, and satisfaction. Empathy was demonstrated by the healthcare robot through use of empathetic statements (verbal empathy) and head nodding (non-verbal empathy) behaviours.

III. METHOD

A. Attentional Study

Participants. 180 participants were recruited via emails to the University of Auckland students and social media sites.

Procedure. A randomised, between-subjects, experimental study was undertaken in which participants engaged in a 5-minute (approx.) scripted interacted with a robotic medical receptionist. In the voice pitch condition, the robot altered the pitch of its voice at

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three separate times during the HRI. In the forward lean condition, the robot leant towards the participant each time the participant spoke. In the self-disclosure condition, the robot offered two self-disclosure statements during the HRI (i.e. "I'm a little nervous about this task" and "No problem, I forget things to sometimes"). In all conditions, the rest of the script for the HRI was identical. Following the interaction, participants completed questionnaires aimed at determining engagement, perceived robot empathy, and perceived robot attention. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar.

Measures. *Participant Engagement.* In order to measure participant engagement, a 'Participant Engagement Tool' was created which utilised both a Likert scale and pair-choice items. The Likert scale was developed using an adaption of the 'stimulation' items from the McGill Friendship Questionnaire [20], along with an adaption of the engagement items used in the human-robot engagement study by Snider, Kidd, Lee and Lesh [21], was used.

Perceived Robot Attention. No measure could be found in order to measure human perceptions of robot attention. Therefore, in order to measure perceived robot attention, an adaption of the 'stimulation' items from the McGill Friendship Questionnaire [20] was used along with an adaption of the engagement items used in the human-robot interaction study by Snider, Kidd, Lee and Lesh [21].

Perceived Robot Empathy. Finally, in order to measure perceived robot empathy, an adaption of the McGill Friendship Questionnaire [20] was used, along with an adaption of the Consultation and Relational Empathy measure (CARE measure) [22].

User Behaviours. Video recordings were used in order to determine participant time spend (seconds) looking at the robot. Recordings were also coded in order to determine if participants smiled, laughed, and/or leant towards the robot during the interaction

Analyses. One-way ANOVA analyses were used to analyse the total Participant Engagement and total Perceived Robot Empathy scores. Fishers exact tests were used to analyse results of the (pair-choice) items in the 'Participant Engagement Tool'. A Kruskal-Wallis Test was performed to analyse total Perceived Robot Attention, due to data being found to violate normality. All analyses were performed using the Statistical Package for Social Sciences (SPSS), version 22.

B. Humour Study

Participants. 91 participants were recruited via emails to the University of Auckland students and social media sites.

Procedure. All participants took part in an initial scripted interaction with the robot, designed to minimize any novelty effects associated with interacting with the robot. This interaction involved participants asking the robot about the medical practice at which she 'worked' in order to decide if they should join as a patient. Following the initial interaction, study measures were completed (time-point one). Immediately prior to the second interaction with the robot, participants were randomized to either a humorous or neutral group. The second scripted interaction involved asking the robot for information about the influenza virus and how to go about booking in for an influenza vaccination. All conversation between the participant and the robot were identical for the second interaction, aside from the introduction of three humorous comments in the humour condition (e.g. "I caught a computer virus once and it was terrible, that will teach me for using a strange computers flash drive"). Study measures were completed once again following the second interaction (time-point two). Measures used at time-point one and time-point two were identical.

Measures. *Perceptions of the Robot.* The Godspeed questionnaire was used in order to measure perceptions of the robot's likability, intelligence, animacy, anthropomorphism, and safety [23].

Empathy. An empathy measure was created using questions from the McGill Friendship Questionnaire and the Consultation and Relational Empathy measure [20, 22].

Personality. An adaption of Asch's personality scale [24] was used in order to measure perceptions of the robot's personality.

Participant Laughing Behaviours. Participants were also discreetly observed in order to code any laughing behaviours. .

Analyses. ANOVA analyses were used in order to analyze data collected for each of the five dimensions of the Godspeed questionnaire as well as the empathy measure (controlling for time-point one scores). Fishers exact tests were used to analyse each personality item on Asch's personality scale, as well as differences in laughing behaviours between the humour and neutral groups.

C. Empathy Study

Participants. 100 participants were recruited using Amazon Mechanical Turk (AMT). AMT is a public, crowd-sourcing website which connects people, researchers, and businesses with individuals willing to take part in research and other work tasks. Potential participants (registered with AMT) were notified of the current study by AMT via their online profile.

Procedure. Participants were directed to complete a baseline demographics questionnaire. This questionnaire asked about age, gender, ethnicity, occupation, and any previous experience interacting with robots. All participants were then instructed to view the first of two separate online videos. The initial video was approximately 2 minutes in duration and presented an interaction between a patient ('Sam') and robot nurse ('Jane'). Following completion of time-point one measures, participants were randomised to view a second video. In this second video, the healthcare robot was seen to behave in one of the following ways:

1) The robot uses empathetic statements and head nodding during interaction with patient
2) The robot uses empathetic statements and no head nodding during interaction with patient
3) The robot uses no empathetic statements and head nodding during interaction with patient
4) The robot uses no empathetic statements and no head nodding during interaction with patient

The second video depicted a second interaction between the same patient ('Sam') and the same nurse robot ('Jane'). In this second interaction video, the patient is seen to ask the nurse robot to take their blood pressure as part of the health check. The patient is then seen to discuss their symptoms and emotional state with the robot nurse, including the fact that they are feeling tired, having trouble sleeping, and "really need the Doctor to get the bottom of things". In the head-nodding conditions, the nurse robot is seen nodding to the patient as the patient discusses their symptoms. In the verbal empathy conditions, the robot uses empathetic statements throughout the interaction, in response to the patient's disclosures around symptomology and emotional state. In the non-empathy verbal condition, only neutral statements are made. Care was taken to ensure that robot statements in both conditions were similar in length.

Measures. *Empathy.* An empathy measure was created using questions from the McGill Friendship Questionnaire and the Consultation and Relational Empathy measure [20, 22].

Trust and Distrust. The Jian et al. [25] trust scale was used in order to measure trust and distrust. The measure has been validated and shown to have two distinct subscales for trust and distrust [26].

Satisfaction. An adapted version of the Scale of Patient overall Satisfaction with Primary Care Physicians was used [27]. The satisfaction scale was adapted in the current study in order to ask participants questions relating to the video interactions they viewed as part of the studies online survey.

Analyses. Data were analysed by conducting four 2x2x2 ANOVAs with time point as a repeated measures variable and head-nodding and empathy statements as between subjects factors. The desire to interact again was analysed using a 3 way loglinear analysis ('question' x head-nodding x empathetic-statements) for each of the two time points.

IV. RESULTS

A. Attentional Study

Participants. In total, 181 participants took part in the study. Most participants identified as female (n=112, 61.9%). In regards to ethnicity, participants identified as NZ European (n=57), Chinese (n=37), Indian (n=29), Korean (n=5), Maori (n=4), Samoan (n=3), Tongan (n=1), and 'other' (n=49). Completed education level ranged from PhD or Masters level (n=26) to secondary school level (n=93). Most participants were students (n=139), followed by part-time employees (n=20), full time employees (n=19), and unemployed (n=4).

Participant Engagement. A one-way ANOVA of Participant Engagement (F (3, 177) = 1.420, p = .239) found no significant difference between the means of the neutral (M = 26.96, SD = 5.800), forward lean (M = 27.38, SD = 5.87), self-disclosure (M = 28.22, SD = 5.387), and voice pitch (M =25.84, SD = 5.261) conditions.

A Fishers Exact test found that participants in the voice pitch condition were significantly more likely to rate Nao as boring (as opposed to interesting) compared to the neutral, self-disclosure, and forward lean groups. χ^2 (3, n =179) = 10.255, p = .002). Participants in the voice pitch and neutral conditions were significantly more likely to rate Nao as unstimulating (as opposed to stimulating) compared to the self-disclosure and forward lean groups (χ^2 (3, n = 176) = 8.775, p = .029).

Perceived Robot Empathy. A one-way ANOVA of Perceived Robot Empathy (F (3,175) = 1.889, p =.133) found no significant difference between the means of the neutral (M = 41.95, SD = 6.38), forward lean (M = 44.23, SD = 6.716), self-disclosure (M = 43.83, SD = 7.325), and voice pitch (M = 41.33, SD = 6.925) conditions.

Perceived Robot Attention. A Kruskal-Wallis Test of Perceived Robot Attention (χ^2 (3, n = 181) = 1.081, p = .782 found no significant difference between the mean rank scores of the neutral (MR = 84.82), leaning forward (MR = 94.44), self-disclosure (MR = 94.63), and voice pitch (MR = 90.02) conditions.

User Behaviours. *Eye Gaze.* There was a significant difference between groups in regards to user eye gaze ($F_{3,173}$=8.13; P<.001), with participants in the forward lean (mean 78.80, SD 8.98) condition spending significantly more time looking at the robot compared with those in the neutral (mean 69.14, SD 10.96) and voice pitch (mean 73.30, SD 9.88) conditions. Participants in the self-disclosure (mean 76.30, SD 8.78) condition also spent significantly more time looking at the robot compared to those in the neutral condition.

Forward Lean. There was a significant difference between groups in regards to user forward lean behaviours (χ^2_3=22.1; P<.001; n=174), with significantly more participants in the forward lean condition leaning towards the robot, 67% (31/46), compared to those in the self-disclosure, 47% (20/42), voice pitch, 39% (17/43), and neutral, 18% (8/43) groups.

Smiling. No significant differences were found between groups in regards to participant smiling behaviors ($F_{3,173}$=0.801; P=.50).

Laughing. There was a significant difference between groups in regards to user laughing behaviours (χ^2_3=12.0; P=.01; n=174), with significantly more participants in the self-disclosure group laughing, 47% (20/42), compared to those in the forward lean, 21% (10/46), voice pitch, 20% (9/43), and neutral, 18% (8/43) groups.

B. Humour Study

Participants. The majority of participants were female (N = 73/91). Participants identified as New Zealand European (N = 26), Maori (N = 3), Chinese (N = 26), Korean (N = 3), Indian (N = 12), and "Other" (N = 21). The mean age of participants was 25.03 years (SD = 11.06).

Godspeed Questionnaire. Participants in the humour group rated the robot significantly higher in terms of likability (F(1, 89) = 7.74, p =.007, partial eta squared = .08.), animacy (F(1, 89) = 5.24, p =.024, partial eta squared = .06), and perceived safety (F(1, 89) = 5.19, p =.025, partial eta squared = .06). No significant difference were seen between groups in regards to intelligence (F(1, 89) = 0.60, p =.441, partial eta squared = .007) and anthropomorphism (F(1, 89) = 0.00, p =.989, partial eta squared = .00).

Empathy. Participants in the humour group rated the robot as significantly higher in terms of empathy (F(1,89) = 5.60, p = .020), partial eta squared = .06), than compared to participants in the neutral group.

Personality. The use of humor by the robot had a significant effect on the sociable personality factor, with participants in the humour condition rating the robot as significantly more sociable (F(1, 89)

C. Empathy Study

Empathy. A significant time by condition interaction was found for robot verbal empathy, F(1,96) = 16.01, p <.001), partial eta squared = .14, with participants in conditions in which the robot used verbal empathy, reporting significantly higher perceptions of robot empathy, compared to conditions in which verbal empathy was absent. There was no significant main effect of robot head nodding on empathy scores, F(1,96) = 0.70, p = .405) partial eta squared = .01), and no significant interaction effect of robot head nodding and verbal empathy on empathy scores, F(1,96) = 0.68, p = .410) partial eta squared = .01).

Trust and Distrust. A significant time by condition interaction was found for robot verbal empathy, F(1,96) = 13.78, p <.001), partial eta squared = .13, with participants in conditions in which the robot used verbal empathy, reporting significantly higher ratings of robot trust at time-point two, compared to participants in conditions in which the robot did not use verbal empathy. There was no significant main effect of robot head nodding on trust scores, F(1,96) = 1.75, p = .189), partial eta squared = .02, nor any significant main effect of verbal empathy on trust scores, F(1,96) = 1.32, p = .253), partial eta squared = .01.There were no significant interactions effects of robot head nodding and verbal empathy on trust scores F(1,96) = .22, p = .639), partial eta squared = .00.

For distrust, there was a significant time by condition interaction for robot verbal empathy F(1, 96) = 6.90, p =.010, partial eta squared = .07, with participants in the conditions in which the robot did *not* use verbal empathy, reporting significantly *higher* ratings of robot *distrust,* compared to participants in conditions in which the robot

did use verbal empathy (see Figure 6). There was no significant main effect of robot head nodding on distrust scores $F(1,96) = 2.36$, $p = .128$), partial eta squared = .02, nor any significant main effect of robot verbal empathy, $F(1, 96) = 1.57$, $p = .213$, partial eta squared = .02. There were no significant interactions effects of robot head nodding and verbal empathy on distrust scores $F(1,96) = 0.02$, $p = .901$), partial eta squared = .00.

Satisfaction. A significant time by condition interaction was found for robot verbal empathy, $F(1,96) = 10.44$, $p = .002$), partial eta squared = .10, with participants in the condition in which the robot used verbal empathy, reporting significantly higher satisfaction scores, compared to participants in conditions in which verbal empathy was absent. There was no significant main effect of robot head nodding on satisfaction scores $F(1, 96) = 0.82$, $p = .369$), partial eta squared = .01, and no significant interaction effects of robot head nodding and verbal empathy on satisfaction scores $F(1, 96) = 0.71$, $p = .403$), partial eta squared = .01.

V. Discussion and Conclusion

A. Attentional Study

Participants in the forward lean and self-disclosure conditions spent significantly more time looking at the robot, compared to those in the neutral condition. Participants in the forward lean condition were also more likely to lean towards the robot, while participants in the self-disclosure condition were more likely to laugh during the interaction with the robot. These user behaviours arguably demonstrate increased user attention and engagement in the forward lean and self-disclosure conditions. Those who interacted with the robot in the forward lean or the self-disclosure conditions also found the robot more stimulating that those who interacted with the robot in the voice or the neutral conditions, while those in the forward lean, self-disclosure, and neutral conditions found the robot more interesting compared to those in the voice pitch condition. Together, these results suggest that forward lean and self-disclosure are worth further investigation in the area of social and healthcare robotics.

B. Humour Study

Participants in the humour group rated the robot as significantly higher in likability, perceived safety, and animacy compared to the neutral group. No difference between groups was found in regards to anthropomorphism and intelligence. Participants in the humour group also rated the robot as being significantly higher in empathy and were significantly more likely to rate the humorous robot as sociable, compared to participants in the neutral group. Participant in the humour condition were also significantly more likely to laugh during the interaction with the humorous robot. Overall the findings of this study provide initial support for the use of humour as a relatively simple, yet effective robot communication behaviour, for improving user perceptions and human-robot interactions. Future researchers should consider the replication of this research with a patient population in a natural setting.

C. Empathy Study

Verbal empathy statements resulted in greater perceptions of the robot's empathy, trust and satisfaction, and lower perceptions of distrust. Head nodding had no significant effects on empathy, trust, distrust, or satisfaction scores, and there were no significant interaction effects of verbal empathy and head nodding on any outcomes.

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