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ORIGINAL PAPER

Mental Schemas of Robots as More Human-Like Are Associated with Higher Blood Pressure and Negative Emotions in a Human-Robot Interaction

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Abstract Robots are often portrayed in the media as human-like, yet research suggests that people prefer to interact with robots that are not human-like. This study aimed to investigate whether people's mental schemas about robots' humanness were associated with their reactions to a robot. It was hypothesised that people who thought of robots as more human-like would be more anxious when subsequently interacting with a robot. Fifty-seven participants aged over 40 years were asked to draw their idea of a healthcare robot using standardised instructions before seeing the real robot. They reported their emotions at baseline and a medical student measured their blood pressure. The drawings were categorised as human-like or box-like by the researchers and drawing size was measured. Participants were then introduced to a robot that measured their blood pressure, and they reported their emotions during the interaction. Participants who had drawn a human-like robot had significantly greater increases in blood pressure readings and negative emotions from baseline in reaction to the robot compared to those who had drawn a box-like robot. Larger drawings of healthcare robots predicted higher ratings of negative emotions during the robot interaction. This study suggests that people who have mental schemas that robots are human-like experience heightened wariness in interactions with robots. Larger drawings of robots may indicate greater anxiety towards them. Assessing mental schemas of robot human-likeness is an important consideration for the acceptance of social robots. Standardised drawing instructions and scoring are a useful method to assess cognitions and emotions towards robots.

Keywords Human-robot interaction · Human-like · Mental schemas · Drawings · Blood pressure · Robot · Emotions · Health · Psychology · Acceptance

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1 Introduction

The majority of people experience robots primarily through the popular media. The way robots look and behave in books and films shapes the public's ideas about what a robot is and what it does. Movies such as Star Wars (1977) or Robocop (1987) commonly depict robots as life-like machines that have a human form and human-like traits; they are often metallic, with a head, body, arms and legs, intelligence and personality. Robots are sometimes depicted as being menacing and having superhuman abilities (for example, Terminator, 1984) or sometimes as emotionally conflicted and wanting to be more human-like (for example, Bicentennial Man, 1999). In the news media, reports sometimes show humanoid robots like Asimo (by Honda), as well as non-humanoid robots, such as the mechanical looking rovers used in space exploration.

The extent to which a robot appears human is a fundamental variable of robots portrayed in the media, and is important in shaping mental schemas (cognitive representations) of robots. In one study, forty-three members of the general population in Sweden were asked to draw how a robot would be in their own home [1]. The drawings showed likenesses to robots in film and literature, but differed in the extent to which they were drawn as human-like or machine-like. A study investigating the use of drawings to assess children's attitudes towards robots in England also showed that humanoid robots were often drawn [2].

Emerging research indicates that people have a preference for less human-like looking robots [3, 4]. Autistic children appear to respond better to a less human-like robot [5]. Similarly, people preferred a home-care robot without a face compared to one with a face [6]. Furthermore, it has been theorized that people feel uneasy if a robot looks uncannily human [7]. This is supported by research showing that children rate robots with a human-like appearance as having the most negative behavioural intentions compared to robots with other appearances [8]. A caveat of this work is it has been performed with Western populations, and preliminary work suggests that humanoid robots may be less upsetting to people in Japan than to people in the West [9].

Despite people seeing sophisticated social robots in the media, most people have never had the opportunity to interact with a social robot. This gives researchers the opportunity to study how people's mental schemas about the degree of humanness of robots might influence their feelings and reactions to a robot. It is possible that people who have preconceived ideas of robots as more human-like will feel more anxious in interaction with a robot, and this could be evident in their physiological reactions. If a person perceives a situation as a threat, his or her body responds with the fight or flight response, where the sympathetic nervous system is activated to release adrenaline and maximize the body's capacity to deal with the threat. His or her heart beats stronger and faster, pupils dilate, the mouth goes dry and the palms become sweaty.

The use of drawings as a research method is uncommon in robotics research, yet the study of people's drawings to assess emotions, cognitions and personality, has a long history in psychology. The Draw-A-Person test [10] is scored for the presence or absence of various features, and figure size. It is theorised that the bigger the size of the person drawn, the more significant he/she is to the subject. Children have been shown to draw Santa Claus larger at Christmas time than before Christmas [11]. Other work has developed standardised instructions and scoring for drawings that can be adapted for different topics, and has shown the height of heart attack patients' drawings of their own heart has been linked to greater heart-focused anxiety [12, 13]. Asking participants to draw a robot by applying established methods from psychological research may be a useful research tool for social robotic research, to reveal people's emotions and cognitions towards robots.

This study applied drawing methods from psychology to investigate whether people's mental schemas of robot humanness could predict their physiological reactions and emotions when exposed to a social healthcare robot. It was hypothesized that people would have a greater sympathetic nervous system response to a robot and report more negative emotions if they had mental schemas of robots as more human-like. Because drawing size has been associated with anxiety towards the drawn object in previous work, we also hypothesized that larger drawings would be associated with more negative emotions towards the robot and higher blood pressure in reaction to the robot.

2 Method

This paper reports an ancillary study within a larger study investigating healthcare robots [14]. Postal invitations were sent to 400 patients of a general practitioner in the locality of the University of Auckland, Tamaki Campus. Inclusion criteria were for people aged over 40 years, and being proficient in English. They were invited to participate in a study assessing people's reactions to a healthcare robot that took blood pressure. Those wishing to participate returned a consent form and were subsequently phoned and given an appointment at the University to take part in the study.

The sample consisted of 24 males and 33 females. The participants were predominantly European ($n = 50$) and seven were from other Ethnic groups. Participants completed a drawing task prior to their interaction with the robot; the instructions were adapted from psychological studies that use drawings as an assessment tool [13]. The instructions were "Please draw a picture of what you think a healthcare robot might look like. We are not interested in your drawing ability—a simple sketch is fine. We are interested in your ideas about healthcare robots." These instructions were provided at the top of the page followed by a 15 cm square box in which to draw their image. Inside the top of the box were the words "My picture of a health care robot".

Participants were also asked to complete the Positive and Negative Affect Schedule (PANAS), a widely used, valid and reliable, self-report scale that includes ten positive and ten negative emotions words [15]. For the PANAS, the participants rated how they currently felt towards using a healthcare robot during the interaction by scoring each emotion word from 1 'very slightly or not at all', to 5 'extremely'. The negative words were: distressed, upset, hostile, irritable, scared, afraid, ashamed, guilty, nervous, and jittery. The positive emotion words were: attentive, interested, alert, enthusiastic, excited, inspired, proud, determined, strong, and active. As per scale instructions, total positive affect was computed by summing all the scores for the positive words and total negative affect was computed by adding all of the scores of the negative words. The researcher took the participants' blood pressure before meeting the robot using an Omron blood pressure monitor (model M10-IT).

The participants were then introduced to a Peoplebot (Mobile Robots) that was interfaced with an Omron blood pressure monitor (model M10-IT). The robot was programmed with a human-like face on the screen and male

Fig. 1 The Peoplebot robot used in the study

U.S. voice (see Fig. 1). The robot provided written and spoken instructions on how to attach the blood pressure cuff and press the start button. The robot then reported the result both verbally and on the screen to the participant. After the robot interaction participants again completed the PANAS, with instructions to rate how they had felt while interacting with the robot.

As per psychological methods, the drawings were first examined for their content. The most striking observation was that people either drew a human-like or a box-like robot. Two independent raters subsequently categorised the drawings into human-like or box-like categories. Drawings were rated as human-like if they included a head, body and limbs (either arms, or legs, or both). There were no drawings of other kinds of robots, such as animal robots. In psychological studies, the size of the figure is measured to indicate its salience to the individual; often height is measured because it is the largest dimension, although width is sometimes also measured. In this study, the drawings of the robots tended to be either tall or wide, so the largest dimension of each drawing (in millimetres) was the best representation of robot size across the drawings. There was no difference between human-like and box-like drawings in their biggest dimension (human-like mean 87, SD 29; box-like mean 90 SD 32, $p = .74$).

Univariate ANCOVA were used to assess differences between groups in changes in blood pressure and reported emotions in reaction to the robot, controlling for baseline levels. Partial correlations were conducted to assess relationships between drawing size and changes in blood pressure, controlling for baseline blood pressure. Correlations were conducted between drawing size and emotions during the interaction.

3 Results

Participants' drawings of a healthcare robot showed that 26 participants imagined a robot to be a stationary 'box and an arm' type, and 22 participants imagined it to be more human-like. Nine participants did not draw a robot. Figure 2 shows some examples of participants' drawings.

To test the hypothesis that people who drew human-like robots would have higher physiological reactions to the robot than those who drew box-like robots, we first checked that there were no significant differences in blood pressure between groups at baseline. Baseline systolic and diastolic blood pressure readings did not significantly differ between those who drew a human-like robot (systolic mean 136.55, SD 21.14; diastolic mean 85.77, SD 12.07) or a box-like robot (systolic mean 132.00, SD 16.61; Diastolic mean 82.00, SD 12.63), p's $> .05$. We then conducted an ANCOVA looking at differences in changes in blood pressure in reaction to the robot between drawing-type groups, controlling for baseline readings. There was a significant difference between those participants who drew a human-like drawing and those who drew a box-type drawing in changes in diastolic blood pressure from baseline in reaction to the robot, controlling for baseline readings. Those who drew human-like drawings had greater increases in diastolic blood pressure (adjusted mean change = 2.78, standard error = 1.26) than those who drew box-like drawings (adjusted mean change = .74, standard error = 1.16). There was also a significant difference in changes in systolic readings between human-like (adjusted mean change = 5.79, standard error = 2.21) and box-like drawings (adjusted mean change = .82, standard error = 2.03). Table 1 and Fig. 3 show these results.

Partial correlations were run to test the hypothesis that larger drawings would be associated with higher blood pressure in reaction to the robot. The largest dimension of the drawings was not significantly correlated with changes in diastolic blood pressure readings, controlling for baseline readings (partial $r = .17$, $p > .05$), however there was a non-significant trend for larger drawings to be associated with greater increases in systolic blood pressure during the interaction (partial $r = .27$, $p = .07$).

We next examined differences between drawing-types in changes in self-reported emotions in reaction to the robot compared to baseline, using ANCOVA to control for baseline emotions. There were no differences in baseline positive emotions (human-like: mean 31.29, SD 6.87; box-like mean: 29.612, SD 9.13) or negative emotions (human-like: mean 11.67, SD 2.63; box-like mean: 11.41, SD 1.87) between drawing-type groups (p's $> .05$). There was a significant difference in changes in negative emotions in reaction to the robot compared to baseline between drawing groups.

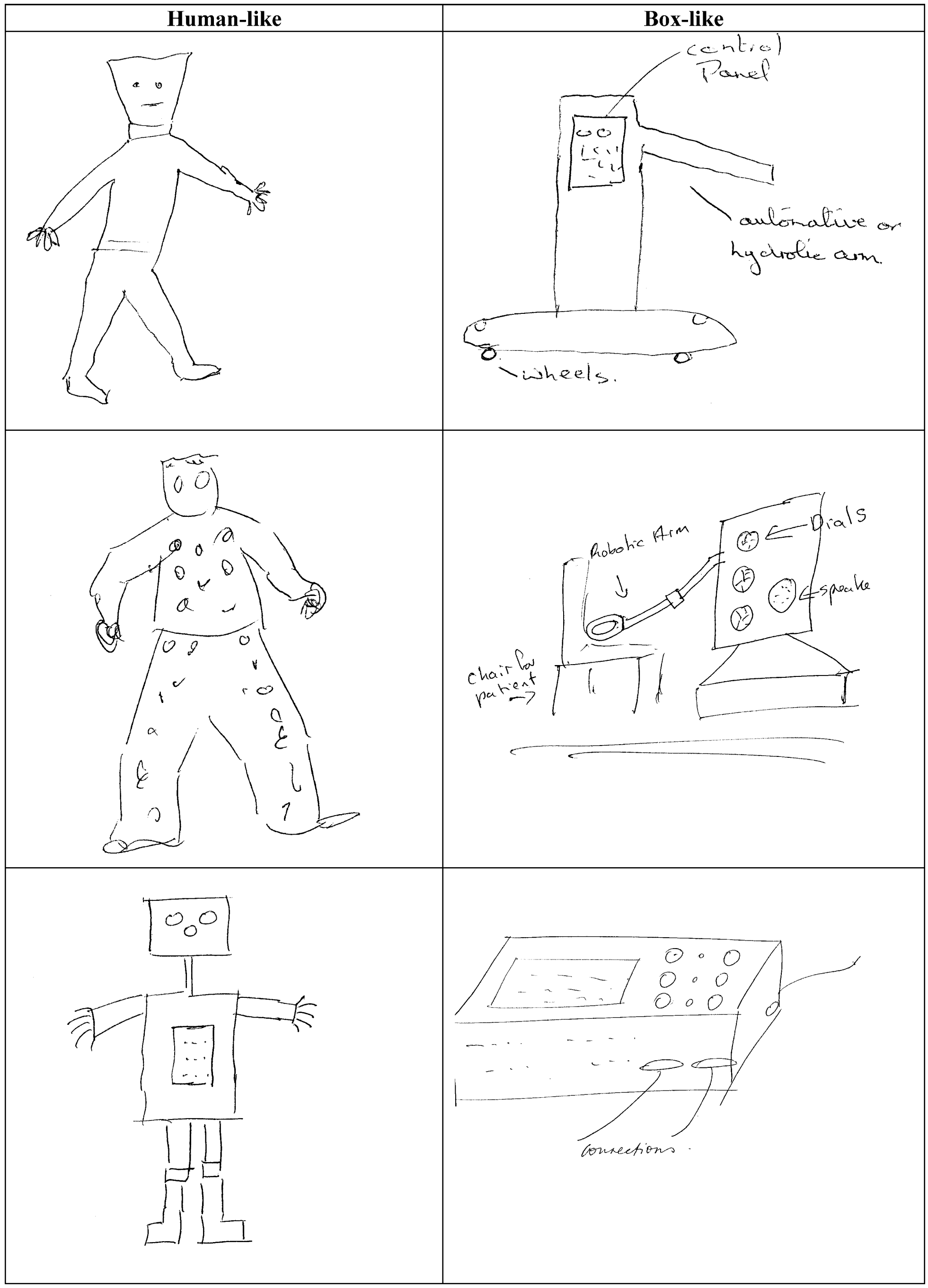

Fig. 2 Six participants' drawings of what a healthcare robot might look like

Those who drew more human-like drawings had greater increases in negative emotions in reaction to the robot (adjusted mean change 1.21, SE .36) compared to those who drew box-like drawings (adjusted mean change .05, SE .34), see Table 2. There was no significant difference in change in positive emotions in reaction to the robot between drawing-types, $p > .05$.

Correlations were run to test the hypothesis that larger drawings would be associated with more negative emotions towards the robot. The biggest dimension of the drawings was significantly correlated with negative emotions towards the robot during the interaction ($r = .29$, $p < .05$). There was no significant correlation between positive emotions during the interaction and drawing size ($r = -.17$, $p > .05$).

4 Discussion

People who drew robots as human-like had greater changes in systolic and diastolic blood pressure in response to the

Table 1 Results of ANCOVA analyses show that changes in diastolic and systolic blood pressure are predicted by both baseline blood pressure and whether participants drew a human-like or box-like robot

		Change in Systolic BP		Change in Diastolic BP	
	df	F	Sig.	F	Sig.
Baseline blood pressure	1	7.97	.007	23.18	.000
Drawing type	1	4.68	.036	4.16	.047
Error	45				

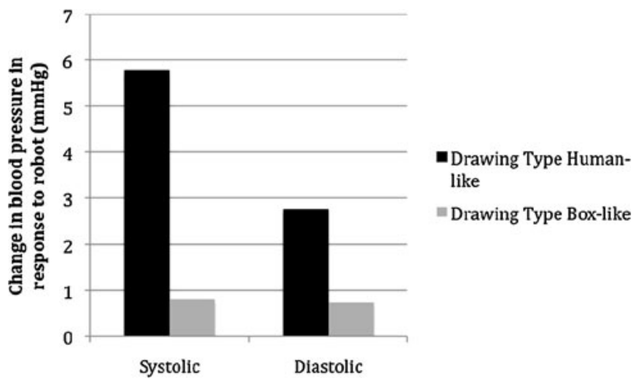

Fig. 3 People who drew robots as human-like had significantly greater increases in diastolic and systolic blood pressure readings than people who drew robots as box-like, in reaction to the robot

Table 2 Results of ANCOVA analyses show that changes in negative emotions in the robot interaction are predicted by both baseline negative emotions and whether participants drew a human-like or box-like robot

	df	F	Sig.
Baseline negative emotions	1	48.197	.000
Drawing type	1	5.433	.024
Error	45		

robot compared with people who drew box-like robots. Blood pressure is a measure of activation of the autonomic nervous system, and is highly responsive to stress and arousal. These results suggest that people who had mental schemas of robots as human-like experienced a greater activation of the autonomic nervous system in response to the robot. People who drew robots as human-like also reported greater increases in negative emotions during the interaction after controlling for baseline negative emotions. This supports the hypothesis that people who have mental schemas of robots as human-like experience more negative emotional reactions to robots than those have more machine-like schemas.

It is worth thinking about possible reasons why the people who drew a human-like robot had greater increases in blood pressure and negative emotions than people who drew a box-like robot. Since both groups met the same robot, the differences in reactions cannot be attributed to any differences in the robot itself, rather it is something about their pre-held mental schemas. Previous psychology research has shown that people are schema-driven in their perceptions of people and situations; they search for and pay attention to information that confirms their schemas (beliefs), while they ignore information inconsistent with their schemas [16]. Therefore, one possible explanation for these results may be that people who already held the schema that robots are human-like had their beliefs about humanness confirmed by the robot's face. It has been posited that a human-like appearance can lead people to infer that the robot has human-like abilities [17]. Perceptions of the robot as more human-like may cause heightened wariness and elicit a heightened autonomic nervous system reaction. Whereas, those who had more box-like schema may have had their beliefs confirmed by the robot's body; they therefore felt the robot was less human-like and felt more at ease. However, there may be other explanations for the findings, and further research is needed to test this theory.

This study shows that asking people to draw their ideas about robots is a useful method for exploring peoples' cognitions and emotions about robots. First, drawings can reflect people's preconceived ideas about the humanness of robots, a finding that is consistent with earlier studies [1, 2]. Second, the size of the drawings can give an indication of how people feel towards the robot. Larger drawings were associated with higher self-reported negative emotions during the interaction with the robot, with a trend for greater increases in systolic blood pressure. This is in agreement with previous research that has found that larger drawings are related to higher anxiety about an object [12].

This research makes a significant scientific contribution to the literature and has a number of strengths. As with questionnaires, it is important that standardised instructions and scoring methods are used when asking people to draw robots so that assessment methods are valid and reliable. This is the first study to apply standardised drawing instructions and scoring methods from psychological research to measure people's mental schemas about robots. No previous work on robot drawings has investigated how the size of the robots drawn is related to people's feelings about robots. The instructions and scoring methods published here can be usefully applied in future robotics research. There are some questionnaires available to assess anthropomorphism and liking of robots [18]; this research adds an alternative measure to the literature that can tap into cognitions and emotions.

This is the first study to demonstrate a relationship between people's mental schemas about how human-like robots are and their physiological reactions to a robot in a subsequent robot interaction. This has implications for the acceptance of robots, a key issue in social robotics. Many human factors, as well as robot factors, contribute to robot acceptance, and gains in acceptance may be made by considering how we can best match human preferences and expectations with the technical limitations of robots [19]. People report a preference for human-like robots in social roles, but prefer machine-like robots for more investigative roles, such as lab assistants [20]. This study supports the idea that users' preconceived ideas about robot humanness are an important consideration when employing social robots. This may be especially applicable in healthcare situations where a high degree of trust in the accuracy and reliability of the healthcare provider is required.

This is the only study asking people to draw a healthcare robot and so has particular implications for designers of healthcare robots for adults. Humanness is an important variable to consider, but also noteworthy was that there were no drawings of animal-like healthcare robots. This suggests that an animal-like healthcare robot would be counter to people's mental schemas, and may therefore be less acceptable to adult users than other forms. Interviews have suggested that animal-like robots may be most suitable for entertainment and social roles [21].

This work introduces the paradigm of a robot taking a participant's blood pressure itself as a direct way to assess physiological reactions to the robot compared to a human measurement. Indeed, one of the strengths of the study is that it includes both physiological measures and self-reported emotions. It has been recommended that robotics research include multiple types of measures, including psychophysiological [22]. Previous emotions research has been criticised for not including physiological measures [23]. Other strengths of this work include the use of an autonomous robot, rather than a Wizard of Oz design, and participants drawn from the community rather than university students (who tend to differ from the general population in younger age and higher education). This increases the generalisability of the results. The research is limited by a relatively small sample size, which may have limited the power of the study to detect relationships between self-reported emotions, drawings, and blood pressure. Nevertheless, the sample size is similar to, or larger than, other studies that have measured psychophysiology in robotics research [22]. More research is needed to replicate these findings, and to investigate whether the effects are increased when a robot that looks more humanlike is presented to participants. People have a tendency to anthropomorphise robots, and it has been suggested that robot designers can either leverage or constrain this tendency [24].

In conclusion, people who hold mental schemas that robots are human-like may experience heightened arousal and negative emotions in interactions with robots. Future research needs to further explore people's mental schemas of robots and their relationships to physiological, behavioural and self-reported responses to social robots.

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