Robots and Uncertainty: An investigation into the impact of the aesthetic visualisation on peoples trust of robots.

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Abstract. Human senses have evolved to pick-up on sensory cues. Beyond our perception, they play an integral role in our emotional processing, learning, and interpretation. They are what help us to sculpt our everyday experiences and can be triggered by aesthetics to form the foundations of our interactions with each other and our surroundings. Aesthetics, described by the ancient Greeks as sensation, is the ability to receive stimulation from one or more of our five bodily senses. In terms of Human-Robot Interaction (HRI), robots also have the 'potential' senses to interact with the environment and people around them. They can offer an 'embodiment' that has the potential to make the interaction with technology a more natural, engaging, and acceptable experience. However, for many reasons, people still do not seem to trust and accept robots. This paper explores that robots have unique opportunities to improve their facilities for empathy, emotion, and social awareness beyond their more cognitive functionalities. By applying various different design elements to design of the human robotic interaction, we have revealed that certain facial aesthetics seem to be more trustworthy than others (cartoon face versus human face etc) and also certain visual variables (i.e. blur) afforded uncertainty more so than others. Consequentially, this paper reports uncertainties in and between the visualisations greatly influenced participants willingness to accept and trust the robot. By understanding what aesthetic elements initiate what affective processes, this paper further enriches our knowledge of how we might design for certain emotions, feelings and ultimately more socially acceptable and trusting robotic experiences.

Keywords: aesthetics, robots, trust, human robot interaction.

1 Introduction

In a world where robotics is becoming more prominent, our ability to trust them has never been so important. With the robot's physical appearance drastically influencing our perceptions of trust, a greater awareness of how aesthetic elements may trigger what affect processes are imperative. Robots have an exceptional potential to benefit humans within a team, yet a lack of trust in the robot could result in underutilizing or not using the robot at all [1]. As Barnes [2] identified, the key to a successful relationship between man and machines is in how well they understand each other. Understanding can develop through the form and structure of the robot that in turn helps establish social expectations. In addition, a robot's morphology can have an effect on its accessibility and desirability [3]. The research presented in this paper explores how robot aesthetics can heighten participants ability to trust robots. Participants were introduced to an array of robot visualisations (face and chest) and asked to note their impressions towards each visualisation and whether they trusted the robot. This then enabled the researchers to investigate how emotional stimuli and aesthetic enhancements affects the ability to trust each robot. The study explored the impact of different aesthetic enhancements to the robot's appearance to afford trust. In detail, by using various design elements (i.e. colour, blurriness, tone) we were interested in better understanding how we design for the fundamental principles of aesthetic order in the human robotic interaction. We anticipate that uncertainties in and between the visualisations will greatly influence participants willingness to accept the robot (i.e. cohesion of messages, positive and balanced stimuli, non-invasive colours etc.). This paper highlights not only the impact of risks and uncertainties created by the visualisations on the human robot interaction but also the potential of robot aesthetics to commence a trusting relationship.

2 Human robot interaction

Human-Robot Interaction (HRI) is a field dedicate to understanding, designing, and evaluating robotic systems for use by or with humans.' [4]. Yanco and Drury [5] claims that Human-robot interaction is a subset of the field of human-computer interaction (HCI) and that HRI can be informed by the research in HCI. Scholtz [6] argues that there are many differences between HRI and HCI, dependent on dimensions in environment, system users and physical awareness. 'The fundamental goal of HRI is to develop the principles and algorithms for robot systems that make them capable of direct, safe and effective interaction with humans.' [7]. It is the 'effective' interaction which is of interest to the authors of this paper (i.e. the ability to build a trusting relationship through effective human-robot interaction). HRI quality may be strongly dependent on the capacity of the communication channel(s) to carry information between human and robot [8]. Robotic communication is based on three components, the channel of communication, communication cues and the technology that affects transmission. Information can be communicated through three channels: Visual, Audio, and environmental [9]. The authors of this paper will be focusing on the visual channel of communication and building affective visual communication cues. A socially interactive robot should be able to communicate its trustworthiness through the use of non-verbal signals including facial expressions and bodily gestures [10]. The face is capable of expressing a range of emotions that that others generally have little difficulty identifying [11]. Richert et al. [12] considers these human-like designs combined with the integration of natural users' interfaces could enhance the overall acceptance and interaction of these technologies. In more detail, Duffy [13] states a robot's capacity to be able to engage in meaningful social interaction with people requires a degree of anthropomorphism (human-like qualities). As Gurthrie citied in Daminao and Dumouchel [14] points out, the tendency to see human faces in ambiguous shapes provides an important advantage to humans, helping them to distinguish between friend or enemies and establish an alliance. A robot's appearance can instantly affect how a robot is interpreted by its users, and in turn how the user may interact with the robot [15]. In terms of human-robot interaction the physical appearance can have an important effect [16], yet before humans are able to effectively interact with robots, they must be able to accept and trust them

[17]. This trust is what is of real interest to the authors of this paper, in order to influence how we design for effective trusting relationships between human and robot through their physical and visual appearance.

3 Trust, Risk and Uncertainty

"Trust is a phenomenon that humans use every day to promote interaction and accept risk in situations where only partial information is available, allowing one person to assume that another will behave as expected." [18]. For many people, trust is the ability to hold a belief in someone and/or something can be counted upon and dependable, by accepting a level of risk associated with the interaction of another party [19]. A willingness to potentially become vulnerable to the actions of others, based on the expectation that the trusted party will perform actions essential or necessary to the trustor [20]. According to Gambetta [21], trust can be summarised as a particular level of subjective probability with which an agent assesses another in performing a particular action. That trust implicitly means the probability that an action by others will be beneficial enough to consider engaging in cooperation with them despite the risks. In situations such as trusting robots where a person's past behaviours and reputations are unknown, we acquire other sources of information to determine a person's motivations [22]. These other sources of information that are used to communicate understanding, include the use of empathy. As Lee [23] points out, an agent who appears to be empathetic are perceived as more trustworthy, likeable, and caring. As robots do not possess the ability to build traditional relationships with humans, they therefore rely heavily on visual appearance to portray their trust. As Lee [23] reported, human to human perceptions of trust is widely reliant on the empathy they have for one another. Research shows that a common way in which people convey empathy is in the use of their facial expressions [24]. In robot-human interaction, research has shown that facial features and expressions can portray important information about others trustworthiness [25]. Research by Merritt and Ilgen [26] shows that widespread implementation of automated technologies has required a greater need for automation and human interaction to work harmoniously together. The conclusion has supported that individuals will use machines more if it is trusted compared to those they do not. It has generally been agreed that where there is trust there is risk. As Gambetta [21] indicated, trust is a probability - as you determine the level of risk you can make alternations to the probability of trustworthiness. Lewis et al. [27] states that the introduction of anthropomorphism poses serious risks, as humans may develop a higher level of trust in a robot than is warranted. Additionally, risks do not always reflect real dangers, but rather culturally framed anxieties originating from social organisation [28]. Interestingly, research by Robinette et al. [29] shows in certain situations a person may over-trust a robot while mitigating risks and disregarding the prior performance of the robot. However, another dimension of trust is uncertainty. Wakeham [28] described being uncertain as having an obscured view of the truth, with a limit on what an individual might know. Uncertainty can cause a restriction in the ability to trust; with uncertainty you are unable to know all that can happen, resulting in trust becoming a leap of faith [30]. The decision whether or not to trust a robot based on the uncertainty presented can trigger ethically adjusted behavior that aims to avoid dangers and minimise potential risk [31].In more detail, research has shown how uncertainty influences people's ability to trust [32], yet in the same way trust is a way of dealing with uncertainty and objective risks [33].

4 Experiment design

This study was conducted through Qualtrics, a powerful online survey software. Considerations were made to ensure an adaptive survey design to facilitate responses from a range of device screen sizes. Participants were introduced to a series of ten blocks of questions, of which sixty-three questions related to the Canbot U03S robot's visual appearance (see figure 1), and twelve general robot acceptance questions. The survey URL link was disseminated through a series of strategic locations online, allowing researchers to target a global audience, all ages groups, and participants with and without past experience in robotics. In general, the study and questions asked had a strong visual component.

5 Study

Fig. 1. Canbot no aesthetic changes.

The study ran from 31/03/2020 to 15/04/20, and in this period seventy-four fully completed surveys were recorded. The participant group consisted fifty females and twenty-four males. There was a wide distribution of ages, with seventy-four percent of participants under the age of thirty-five years. Participants resided globally (i.e. Greece, Mami, Liverpool, Columbus, London, Montreal, Venezuela, Nottingham, Sweden, Birmingham, Australia (Perth), Falmouth, India). Of the seventy-four participants that undertook the study, twenty-eight (38%) had admitted to having experience with robotics and of having regular contact with robots (some participants indicating their jobs are to directly work with robots).

No changes	Cartoon Facial Expression: Dont Know	No	Yes
Dont Know	2	8	11
No	4	6	6
Yes	6	14	17

Fig. 2. Participants willingness to trust robots with/without cartoon facial expression.

The observations indicate that a participant's willingness to trust a robot was heavily impacted on the aesthetic elements that they were exposed to, and whether or not the participant had past experiences with robots. When asked about Figure 1, fifty percent of participants said they would trust this robot, twenty-eight percent were unsure, and the remaining twenty-two percent recorded that they would not trust the robot. Interestingly, anthropomorphism did not encourage more to trust the robot. Figure 2 shows how the introduction of the face impacted participants who first trusted the robot, twenty of the thirty-seven (fifty-four percent) of participants who first trusted were now non-trusting or uncertain to trust the robot. However, anthropomorphism did have a positive influence on those unsure to trust the first robot (Figure 1), with fifty-two percent changing their opinion from ‘unsure’ to 'yes' to trust. In the human-like visualisations, it seemed participants had different opinions on how robots should be designed for trust. One participant said, 'Less human-like as this makes them feel more deceptive' while another described human-features as 'creepy' and 'People may become intimidated by implementing human behaviours into a machine'.

Fig. 3. Heatmap of participants selected most trusted robot with facial alterations. When asked ‘what robot do you trust is giving you’re the correct answer to 997*1066?’.

In addition, the findings show different impressions towards facial features when faced with the decision to trust (i.e. What robot is providing you with the correct information?). Interestingly sixty-six percent of participants selected the second robot (Figure 3) as the most trusting, despite the introduction of a hybrid robot (Robot 4 -Figure 3). Robot five was the next most accepted (fifteen percent), yet on closer inspection participant's speed to answer this question was significantly higher (fifty percent increase) than other responses, thus indicating the potential use of a calculator to determine the correct answer to the equation. With further probing of the concept of trust participants said, 'Give them their own personality that isn't based on human expression' and that 'human features make the model 'creepy'. One participant notes that the introduction of realistic human face 'makes people uneasy'.

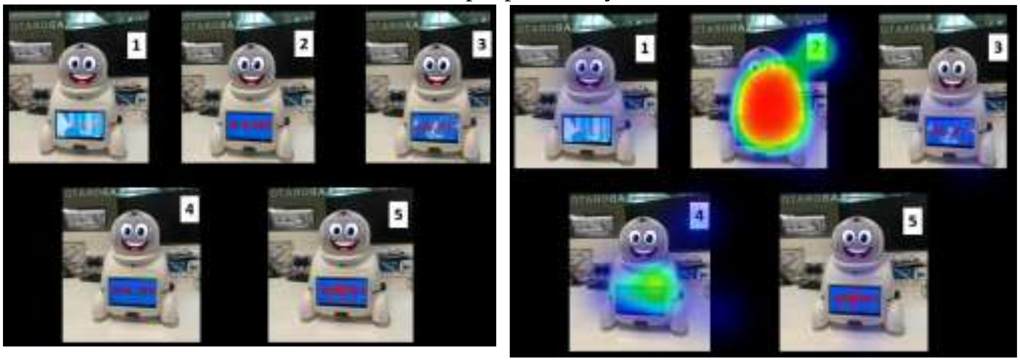

Fig. 4. Heatmap of participants selected most trusted robot with chest screen alterations. When asked 'what robot do you trust is giving you're the correct answer to 877*974?'.

Similar results were seen in Figure 4, with the alterations to the chest screen affording uncertainty to trust the robot to give the correct answer. Sixty-four percent of participants selecting the second robot as most trusting despite it providing incorrect information.

Moreover, participants felt that in order for a robot to be trusting there is a need for 'a screen that clearly shows the message that is being transmitted' and that 'I would expect the screen display to match with any expressions'. In terms of harmony between face and chest screen, one participant highlighted that 'It would be difficult to trust a robot with a face and another image within the robot screen. I would trust better with just one option.' In particular, when exposed to figure 5, participants felt that the facial expressions produced a contradicting message to the one upon the chest screen. With sixty percent of participants declaring the robot as untrustworthy and a further thirty-eight percent unsure whether or not to trust the robot. One participant could not trust the robot as 'I could not take anything this bot says seriously with that expression'. This highlights the true impact of the misaligned messages on participants ability to trust.

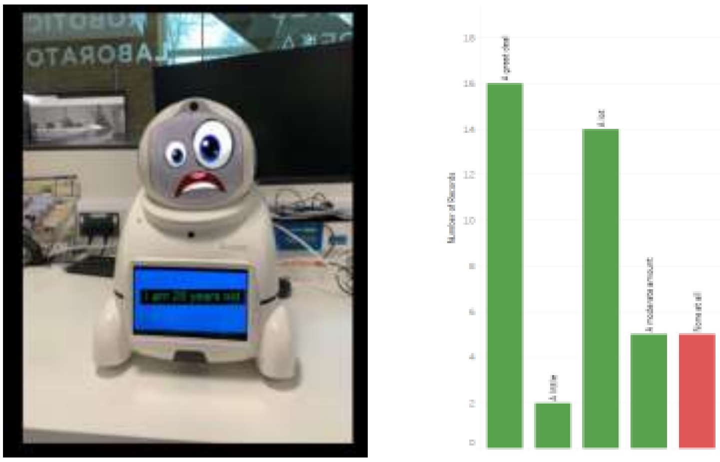

Fig. 5. Misaligned message influence on participants.

Finally, when exploring the design of the visual variables on the robot face visualisation. The blurry face visualisations (Figure 6), highlighted participants were more apprehensive to trust the robot. The findings show that participants were able to correctly identify the robot's emotional cue as ‘happy’ despite the introduction of blurriness. However, there were several terms used to describe the emotional change towards the robot felt by participants. ‘Uncertainty’, ‘uneasy’, ‘uncomfortable’, and ‘unsure’ indicated apprehension towards the ability to trust a robot while the facial expression was obscured. Moreover, participants noted that when designing for a robot the 'Use of colour but nothing too alarming or dark' and to ‘avoid dangerous colour e.g. black, red'. One participant felt colour was not a necessary factor for design as 'too many people are colour-blind'.

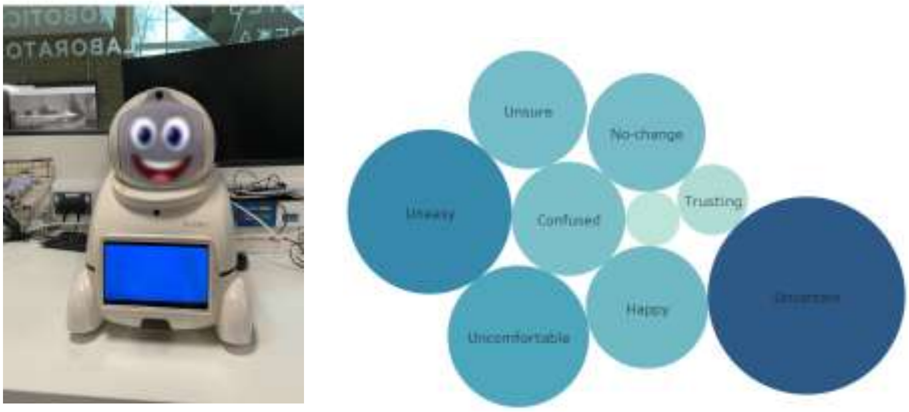

Fig. 6. Bluriness influence word chart**.**

6 Discussion

In this study we investigated the impact of the aesthetic order of facial and chest visualisations on participants willingness to trust robots. In particular, it considered the potential risks and uncertainty afforded by certain aesthetic orders to the human robotic trusting relationship. Our results showed the clear influence that past experience had on participants willingness to trust the original robot. Particularly, the visualisation with no modifications were found to have a substantial higher percentage of trust in those with past experience. Participants with no past experiences were relying solely on the visual appearance to determine their level of trust. These findings are in line with what Sanders [34] hypothesizes and found, in detail, how those participants with past robotics experience would lead to a higher trust of robots and a better positive attitude towards them. Interestingly, a blurred facial expression was a significant influence on whether participants trusted a robot. Also, the findings highlight the importance of cohesion between facial screen and chest screen. Participants were never asked whether or not they trust the robot as a whole, only if they trusted the information on the screen, yet the negative stimuli released by the facial expression had demonstrated a majority of participants declaring the robot as not trustworthy. When designing for a robot that can be trusted it is important to consider all elements, as stimuli from other visual outputs can potentially influence communication channels.

7 Conclusion and future work

This research has shown that robots have the unique ability to create an emotional connection with human through the use of facial expression and aesthetics. As documented, we have seen the introduction of anthropomorphism which creates a fine line between increasing trustworthiness and becoming ‘scary’. Nevertheless, the non-physical humanlike anthropomorphic designs (cartoon designs) encourage participants to further trust the robots, showing the unique ability to improve their facilities for empathy. Moreover, this research has shown that the face is not the sole visual aesthetic that can be utilised to initiate affective processes. The chest screen provides an additional entity to further enrich the potential to provide an engaging experience. Ultimately, the cohesion between the multiple screens is an important consideration for the design of socially acceptable robots. As is the design elements and principles and understanding how their aesthetic order can play such an important role in initiating a trusting robotic experience.

Going forth we feel there may be interest in replicating the study but utilising actual robots. We feel this study paves the way for future studies that involve aesthetic data physicalizations, where further sensory cues can be tested to evaluate their influence on our trusting ability of robots.

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