Human-robot interaction: The impact of robotic aesthetics on anticipated human trust

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Background

Human senses have evolved to recognise 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. In terms of Human-Robot Interaction (HRI), robots have the possibility to interact with both people and environments given their senses. They can offer the attributes of human characteristics, which in turn can make the interchange with technology a more appealing and admissible experience. However, for many reasons, people still do not seem to trust and accept robots. Trust is expressed as a person's ability to accept the potential risks associated with participating alongside an entity such as a robot. Whilst trust is an important factor in building relationships with robots, the presence of uncertainties can add an additional dimension to the decision to trust a robot. In order to begin to understand how to build trust with robots and reverse the negative ideology, this paper examines the influences of aesthetic design techniques on the human ability to trust robots.

Method

This paper explores the potential that robots have unique opportunities to improve their facilities for empathy, emotion, and social awareness beyond their more cognitive functionalities. Through conducting an online questionnaire distributed globally, we explored participants ability and acceptance in trusting the Canbot U03 robot. Participants were presented with a range of visual questions which manipulated the robot's facial screen and asked whether or not they would trust the robot. A selection of questions aimed at putting participants in situations where they were required to establish whether or not to trust a robot's responses based solely on the visual appearance. We accomplished this by manipulating different design elements of the robots facial and chest screens, which influenced the human-robot interaction.

Results

We found that certain facial aesthetics seem to be more trustworthy than others, such as a cartoon face versus a human face, and that certain visual variables (i.e. blur) afforded uncertainty more than others. Consequentially, this paper reports that participant's uncertainties of the visualisations greatly influenced their willingness to accept and trust the robot. The results of introducing certain anthropomorphic characteristics emphasised the participants embrace of the uncanny valley theory, where pushing the degree of human likeness introduced a thin line between participants accepting robots and not. By understanding what manipulation of design elements created the aesthetic effect that triggered the 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.

1 # Human-robot interaction: The impact of robotic
2 # aesthetics on anticipated human trust.

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Abstract

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Introduction

In a world where robotics is becoming more prominent, our ability to trust them has never been so important. With a robot's physical appearance drastically influencing our perceptions of trust, a greater awareness of how design elements and their aesthetic effect may trigger what affective 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 underutilising or not using the robot at all (Floyd et al., 2014). As Barnes and Jentsch (2010) identified, the key to a successful relationship between man and machines is in how well they can work and adapt to each other. This 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 (Fong et al., 2003). 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 enabled the researchers to investigate how design elements and their combined aesthetic arrangement can act as emotional stimuli and the ability to trust each robot. In detail, by using various design elements (i.e., colour, blurriness, and tone), we were interested in better understanding how we design for the fundamental principles of aesthetic order in human-robotic interaction. We anticipate that uncertainties in and between the visualisations will greatly influence a participant's willingness to accept the robot (i.e., The 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.

Literature Review

Human-robot interaction

Human-Robot Interaction (HRI) is a field dedicated to understanding, designing, and evaluating robotic systems for use by or with humans. (Huang, 2016, p.1). Yanco and Drury (2002) claim 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 (2002) argues that there are many differences between HRI and HCI, dependent on dimensions in the 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.' (Feli-Siefer & Mataric, 2010, p.86). 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 (Steinfelt et al., 2016). 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 (Green et al., 2008). 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

128   gestures (Stoeva & Gelautz, 2020). The face is capable of expressing a range of emotions that
129   others generally have little difficulty identifying (Hancock et al., 2007). Richert et al. (2018)
130   considers these human-like designs combined with the integration of natural user interfaces could
131   enhance the overall acceptance and interaction of these technologies. In more detail, Duffy (2003)
132   states a robot's capacity to be able to engage in meaningful social interaction with people requires
133   a degree of anthropomorphism (human-like qualities). As Gurthrie cited in Daminao and
134   Dumouchel (2018) points out, the tendency to see human faces in ambiguous shapes provides
135   an important advantage to humans, helping them to initially distinguish between friend or enemy
136   and establish an alliance. A robot's appearance at the first interaction can affect how a robot is
137   interpreted by its users, and in turn how the user may interact with the robot (Lupetti, 2017). In
138   terms of human-robot interaction the physical appearance can have an important affect (Canning
139   et al., 2014), yet before humans are able to effectively interact with robots, they must be able to
140   accept and trust them (Billings et al., 2012). This trust is what is of real interest to the authors of
141   this paper, in order to influence how we design for effective trusting relationships between human
142   and robot through their physical and visual appearance.
143
144   **Aesthetic Interaction**
145   'Aesthetic interaction is not about conveying meaning and direction through uniform models; it is
146   about triggering imagination, it is thought-provoking and encourages people to think differently
147   about interactive systems, what they do and how they might be used differently to serve
148   differentiated goal' (Petersen et al., 2004, p.271). Aesthetics can be classified as a core principle
149   of design which encompasses a design's visually pleasing qualities, functionality, and emotional
150   considerations (Interaction Design Foundation, n.d.). For many people, an understanding of a
151   robot is achieved through the senses and the reading of bodily form and gestures, facial and chest
152   screens, and sounds as opposed to only the reading of a screen. As a result, it is very important
153   for us to be able to consider the aesthetic processes involved in our interaction with robots.
154   Research shows that aesthetics can afford the construction of associations and meanings through
155   feelings, intuitions, thoughts, memories, etc. (whilst we interact with computers), which we can
156   then stitch together to form a deeper understanding and appreciation of what we are seeing/
157   experiencing (Carroll, 2010). Indeed, the aesthetic interaction can promote a relationship between
158   the user and the computer (i.e., robot) that encapsulates a person's full relationship – sensory,
159   emotional, and intellectual. In doing so, it can entice an 'engaged interaction' which can change
160   the user's perceptions and interpretations (Carroll, 2010). In our human-robotic interactions, the
161   authors of this paper feel that the aesthetic provides many opportunities to enhance our human-
162   robotic experiences particularly our trust and acceptability of robots. As Prinz cited in Holmes
163   (2017) points out, our conscious experience consists of perceptions with shades of feelings–
164   objects (such as robots) can be comforting or scary, sounds are pleasing or annoying, our body
165   feels good or bad – which all can play a crucial role in guiding our behaviours. According to Moors
166   et al. (2013), the basic premise of appraisal theories is that emotions are adaptive responses,
167   which reflect our appraisals of features of the environment/events that are significant for our well-
168   being. Essentially, emotions are elicited by evaluations (appraisals) of how events and situations
169   relate to our important goals, values, and concerns. Scherer (2009) suggests that there are four
170   major appraisal objectives that an organism needs to reach to adaptively react to a salient event:
171   relevance (i.e. how relevant is this event for me?), implications (i.e. what are the implications or

172 consequences of this event and how do they affect my well-being, and so on?), coping potential
173 (i.e. how well can I cope with or adjust to these consequences?), and normative significance (i.e.
174 what is the significance of this event for me-concept and for social norms and values?).
175 Interestingly, each emotion has a unique appraisal structure. For example, the aesthetic emotion
176 interest involves two appraisals (Silvia, 2005): appraising an event as new, complex, and
177 unfamiliar (a high novelty-complexity appraisal) and as comprehensible (a high coping-potential
178 appraisal). Interest causes an emotional and motivational state that facilitates exploration,
179 engagement, and learning (Silvia, 2008); it reflects both the emotional and cognitive aspects of
180 engagement (Ainley, 2012). In terms of the aesthetic emotion of knowledge, firstly, the emotions
181 stem from people's appraisals of what they know, what they expect to happen, and what they
182 think they can learn and understand (Silvia, 2009). Secondly, the emotions, for the most part,
183 motivate learning, thinking, and exploring, actions that foster the growth of knowledge (Silvia,
184 2009). It is generally agreed that the aesthetic information process starts with input from a
185 stimulus, then continues through several processing stages (i.e. Connected to more profound
186 memorial instances) and ends in the final decision-making (i.e. an evaluative judgement of the
187 stimulus) (Markovi´c, 2012). Locher (2015) describes the aesthetic experience as occurring in two
188 stages. Firstly, an initial exposure to the artefact where a viewer spontaneously generates a global
189 impression/gist of the work and secondly, where aesthetic processing ensues (i.e. directed focal
190 exploration to expand knowledge and contribute to a viewer's interpretation, aesthetic judgement,
191 and emotions regarding the artefact). Zajonc (1980), claimed that it is possible for us to like
192 something or be afraid of it before we know precisely what it is and perhaps even without knowing
193 what it is. Since this, there have been many researchers who have begun to explore automatic
194 affective processing; the premise is that beings are able to establish good and bad stimulus before
195 establishing contact with the stimulus (DeHouwer & Hermans, 2001). In light of this, the evaluation
196 is subject to the interaction between an event and the appraiser (Lazarus,1991). Importantly, the
197 emotions are elicited according to the way a person appraises a situation (Ellsworth, P. C., &
198 Scherer, 2003). Significantly, however, research shows that certain aesthetic elements can
199 trigger cognitive and affective processes into motion to influence aesthetic appraisals and more
200 especially how a person aesthetically appraises a situation (Blijlevens et al., 2012). In fact, stimuli
201 that evoke aesthetic responses are always composites of multiple elements that do not ordinarily
202 occur together, and when they do, their joint effect is different in kind from the separate effects of
203 the individual elements (Mechner, 2018). In terms of visual elements such as colour, line, form,
204 and composition priming certain emotions, Melcher and Bacci (2013) found that there is a strong
205 bottom-up and objective aspect to the perception of emotion in abstract artworks that may tap into
206 basic visual mechanisms. In his book, James (2018) considered aesthetic emotions to be the
207 immediate and primary sensory pleasure resulting from exposure to a stimulus. Therefore, we
208 ask, can these aesthetic emotions/interactions, in turn, influence how robots are received and
209 how we make decisions to trust them? Indeed, apart from the logical schemes and sense
210 perception, there is also a powerful 'felt' dimension of experience that is prelogical, and that
211 functions importantly in what we think, what we perceive, and how we behave (Cox & Gendlin,
212 1963). What is of real importance to the authors of this paper is the interplay between the
213 aesthetic, cognitive, and affective processes in how we make decisions to trust a robot; in
214 particular, how the in-take of aesthetic information from a robot's facial and/or chest visualisation
215 can influence how we trust the robot.

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217 **Trust, Risk and Uncertainty**
218 "Trust is a phenomenon that humans use every day to promote interaction and accept risk in
219 situations where only partial information is available, allowing one person to assume that another
220 will behave as expected." (Cahill et al., 2003, p.53). For many people, trust is the ability to hold a
221 belief in someone and/or something can be counted upon and dependable, by accepting a level
222 of risk associated with the interaction of another party (Paradeda et al., 2016). A willingness to
223 potentially become vulnerable to the actions of others, based on the expectation that the trusted
224 party will perform actions essential or necessary to the trustor (Mayer et al., 1995). According to
225 Gambetta (2000), trust can be summarised as a particular level of subjective probability with
226 which an agent assesses another in performing a particular action. That trust implicitly means the
227 probability that an action by others will be beneficial enough to consider engaging in cooperation
228 with them despite the risks. Indeed, trust can be evaluated as a probability; however, it is
229 nevertheless a cerebral contract between trustee and trustor that develops within relations
230 between humans (Coeckelbergh, 2012). In terms of the robot aesthetic, the authors of this paper
231 feel that we have a unique opportunity to enrich further our knowledge of how designing for trust
232 may afford a unique robotics experience. In situations such as trusting robots where a person's
233 past behaviours and reputations are unknown, we acquire other sources of information to
234 determine a person's motivations (DeSteno et al., 2012). These other sources of information are
235 used to communicate understanding, which can be done through the use of empathy. As Lee
236 (2006) points out, an agent who appears to be empathetic is perceived as more trustworthy,
237 likeable, and caring. Robots do not possess the ability to build traditional relationships with
238 humans; therefore, they rely heavily on visual appearance to portray their trust. As Lee (2006)
239 reported, human to human perceptions of trust is widely reliant on the empathy they have for one
240 another. Research shows that a common way in which people convey empathy is in the use of
241 their facial expressions (Riek & Robinson, 2008). In robot-human interaction, research has shown
242 that facial features and expressions can portray important information about others
243 trustworthiness (Valdesolo, 2013). For this paper, it highlights the importance of considering the
244 design elements to initiate positive affective processes. Research by Merritt and Ilgen (2008),
245 shows that widespread implementation of automated technologies has required a greater need
246 for automation and human interaction to work harmoniously together. The conclusion has
247 supported that individuals would use machines more if they are trusted than those they do not. It
248 has generally been agreed that where there is trust, there is a risk; as Gambetta (2000) indicated,
249 trust is a probability; as you determine the level of risk, you can make alternations to the probability
250 of trustworthiness. Lewis et al. (2018) states, the introduction of anthropomorphism poses serious
251 risks, as humans may develop a higher level of trust in a robot than is warranted. Additionally,
252 risks do not always reflect real dangers, but rather culturally framed anxieties originating from
253 social organisation (Wakeham, 2015). Interestingly, research by Robinette et al. (2016) shows
254 that in certain situations, a person may over-trust a robot while mitigating risks and disregarding
255 the prior performance of the robot. However, another dimension of trust is uncertainty. According
256 to Wakeham (2015), who described being uncertain as having an obscured view of the truth, with
257 a limit on what an individual might know. Uncertainty can cause a restriction in the ability to trust;
258 with uncertainty, you are unable to know all that can happen, resulting in trust becoming a leap of
259 faith (Nooteboom, 2019). The decision whether or not to trust a robot based on the uncertainty

260 presented can trigger ethically adjusted behaviours that aim to avoid dangers and minimise
261 potential risk (Tannert et al., 2007). Viewing uncertainty from a psychological perspective presents
262 both subjective uncertainty and objective uncertainty. Subjective uncertainty represents a
263 person's feelings, while objective uncertainty is concerned with information a person has (Schunn
264 & Gregory, 2012). In more detail, research has shown how uncertainty influences people's ability
265 to trust (Glaser, 2014), yet in the same way, trust is a way of dealing with uncertainty and objective
266 risks (Frederiksen, 2014).
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Materials and Methods

269 This study was conducted at Cardiff Metropolitan University from the 31st of March 2020 to the
270 15th of April 2020 and was designed to capture the perception of participants feelings and attitudes
271 towards trusting robots. The study was conducted using the powerful online survey software:
272 Qualtrics. Participants were selected through stratified random sampling to target both
273 participants with past robotic experience and those without. Through distributing the questionnaire
274 on social media, special robotic interest groups, and online forums, the authors were able to obtain
275 participants from a diverse participant pool. A total of seventy-four participants from the age of 16
276 plus years (50 Female & 24 Male) completed the study from a varied demographic. Participants
277 resided globally (i.e., Europe, Africa, Asia, Australia, North America, and South America) and
278 captured an assortment of participants. The questionnaire took approximately thirty minutes in
279 duration. All graphics were generated using Adobe Photoshop, and the study and questions
280 asked had a strong aesthetic visual component.
281 The study mainly consisted of quantitative questions in order to provide summaries through
282 descriptive statistics. Additionally, an assortment of questions required participants to engage in
283 qualitative questions, which then enabled analysis to enrich interpretations and uncover
284 similarities. The questions were separated into two categories to target both the general
285 acceptance of robotics and specific questions relating to the Canbot U03 robot. In order to not
286 influence a participant's feelings and past experience with robots, the Canbot U03 was not shown
287 during the first block of questions. Participants were provided with a brief definition of trust at the
288 start of the questionnaire "To Believe that someone is good and honest and will not harm you, or
289 that something is safe and reliable" (Cambridge Dictionary, 2021, trust entry).
290 Once participants had concluded the initial preparatory questions, they were introduced to the
291 opening visual of the Canbot U03 robot. Participants were presented to a Canbot U03 (see Figure
292 1) with no visual modification and asked whether or not they would trust this robot based on its
293 visual appearance (i.e., only based on the design features). To address the concepts of a
294 participant's ability to trust the Canbot U03 robot, participants were asked to envisage situations
295 in their everyday life where they may encounter a robot. A short list of possible situations and jobs
296 roles were provided to participants (i.e., Teacher, doctor, receptions, bus driver, etc.)."
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319   Figure 1
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321   Participants were then presented with a series of questions with different aesthetic modifications
322   throughout. The first modifications came with the Canbot U03 robot presented with a series of
323   cartoon facial expressions portraying different emotions. Participants were prompted to identify
324   the robot's emotion and whether or not they felt the robot was more or less trusting than before.
325   To detail, questions such as the following were asked to participants: *How trustworthy is this*
326   *robot's appearance?, What emotion do you think the robot is feeling?, Does this visual*
327   *change affect your ability to trust the robot?, How does the robot make you feel with this*
328   *appearance*? Participants were also asked to provide descriptions on the following questions:
329   *What characteristics do you believe only robots should have? How do you design a robot*
330   *that people would trust?*
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343   Figure 2:
344   The following block of questions prompted participants to consider the anthropomorphic
345   characteristics of the robot (see figure 2). Participants were introduced to a series of robots that
346   related to having human features; these questions probed participants for their feelings towards
347   these powerful visual modifications.
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349   The next section of questions was related to how the design element colour influenced the
350   participant's opinions and description of the robot. This required participants to associate words

351   (i.e., dangerous, happiest, trusting, unpredictable, and unrealistic) with an array of Canbot U03
352   robots with different colours hues. Participants were presented with eight robot visualisations (see
353   figure 3), all with varying colour hues (i.e., Pink, orange, blue, yellow, etc.) and prompted to
354   associate the expressive wording with an individual Canbot, no Canbot or all Canbots.
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371   Figure 3:
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373   Participants were also introduced to a range of visualisations with contrasting images such as
374   conflicting facial expressions and chest screen imagery (i.e., Happy facial expression + Danger
375   symbol on the chest). Participants were asked a series of questions such including: ***Which***
376   ***Canbot would you describe as most uncertain?, What impact did the cohesion of screens***
377   ***have on your decision? and Does the facial expression overrule the icon on the chest***
378   ***screen when considering the Canbot's emotions?*** These questions aimed to understand how
379   the level of cohesion between the chest and facial screens can influence a participant's
380   willingness to trust the robot.
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382   Finally, to further probe the concept of risk, participants were presented with mathematical
383   problems that would be too complex for human calculation (i.e., 887x974 & 997x1066).
384   Participants were then be asked to identify which Canbot (A-H) displayed the correct solution
385   upon their chest screen. This question required participants to determine the answer they deemed
386   correct based solely on trusting the robot's physical appearance. Optional text boxes were
387   provided throughout the questions to allow participants to expand and express opinions on the
388   robot's appearances.
389
390   The Ethics Board at Cardiff Metropolitan University approved the study (CST_2020_Staff_0002),
391   and participants involved were all provided and signed an online consent form to participate in
392   the study and for the academic use of the non-identifiable data.
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394   **Results**

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396   The observations indicate that a participant's willingness to trust a robot was heavily impacted
397   by the aesthetic elements they were exposed to, and whether or not the participant had past
398   experiences with robots. When asked about Figure 1, fifty per cent of participants said they
399   would trust this robot, twenty-eight per cent were unsure, and the remaining twenty-two per cent
400   recorded that they would not trust the robot. Interestingly, anthropomorphism did not encourage
401   more to trust the robot. Figure 2 (Robot B) shows how the introduction of the face impacted
402   participants who first trusted the robot, twenty of the thirty-seven (fifty-four per cent) of
403   participants who first trusted were now non-trusting or uncertain about trusting the robot.
404   However, anthropomorphism did positively influence those unsure of trusting the first robot
405   introduced, with fifty-two per cent changing their opinion from 'unsure' to 'yes' to trust (see figure
406   4). In the human-like visualisations, it seemed participants had different opinions on how robots
407   should be designed for trust. One participant (P72) said, 'Less human-like as this makes them
408   feel more deceptive' while another described human features as 'creepy' and 'People may
409   become intimidated by implementing human behaviours into a machine'.
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427   Figure 4:
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429   When probed further into how designing for trust, participants said, 'Give them their own
430   personality that isn't based on human expression 'and that 'human features make the model
431   'creepy'. One participant notes that the introduction of a realistic human face 'makes people
432   uneasy'. When adding human eyes to the robot visualisation (see figure 2) participants were
433   asked their feelings on the realistic eyes. 80 per cent of participants expressed their dislike of this
434   appearance, making them feel 'confused, scared, worried and surprised'. One participant noted
435   'the need for distinction between human and robot' and 'the inclusion of human likeness may be
436   intimidating'.
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438   When asked **Would you trust this robot?** and **What do you think this robot feels?**

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454   Figure 5:
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456   In the blurry face visualisations (figure 5), it appeared participants were more apprehensive about
457   trusting the robot. The findings show that half of the participants were able to correctly identify the
458   robot's emotional cue as 'happy' despite the introduction of blurriness. In contrast, the other half
459   of the participants were torn between 'confused, angry, uncertain, uneasy, and uncomfortable' for
460   the robot's emotion. The introduction of the dissimilar stimuli of the happy facial expression and
461   the blurriness presented participants with uncertainties through the contrasting messages each
462   present (i.e., Happy face – trust, blurriness – uncertain). The results were clearer when prompting
463   participants away from identifying which emotion the robot depicted to how these changes made
464   them feel. The participants concerns were expressed when asked about how the Canbot made
465   them feel, with the majority of responses including terms such as uncertain, uneasy, and
466   confused.
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482 In addition, the findings show different impressions towards facial features when faced with the
483 decision to trust (i.e., What robot is providing you with the correct information?). Interestingly sixty-
484 six per cent of participants selected robot B (Figure 6) as the most trusting, despite the introduction
485 of a hybrid robot (Robot D - Figure 6). Robot five was the next most accepted (fifteen per cent),
486 yet on closer inspection the participant's speed to answer this question was significantly higher
487 (fifty percent increase) than other responses, thus indicating the potential use of a calculator to
488 determine the correct answer to the equation.

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500   Figure 7:
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502 Similar results were seen in Figure 7, with the alterations to the chest screen affording uncertainty
503 to trust the robot to provide the correct answer. We asked participants to indicate which of the six
504 robots posed the correct answer to the equation 997*1066 by clicking on the chosen robot. Figure
505 7 displays the frequency distribution of clicks over the six distinct robot images. Sixty-four per cent
506 of participants selected robot B (the robot with limited visual modifications) as most trusting
507 despite providing incorrect information. Interestingly, robot B presented the incorrect answer to
508 the mathematical equation.

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510 Moreover, participants felt that in order for a robot to be trusting, there is a need for 'a screen that
511 clearly shows the message that is being transmitted' and that 'I would expect the screen display
512 to match with any expressions'. In terms of harmony between face and chest screen, one
513 participant highlighted that 'It would be difficult to trust a robot with a face and another image
514 within the robot screen. I would trust better with just one option.' In particular, when exposed to
515 figure 8, participants felt that the facial expressions produced a contradicting message to the one
516 upon the chest screen. With sixty per cent of participants declaring the robot as untrustworthy and
517 a further thirty-eight per cent unsure whether or not to trust the robot. One participant could not
518 trust the robot as 'I could not take anything this bot says seriously with that expression'. This
519 highlights the true impact of the misaligned messages on participants ability to trust.

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Discussion

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538 In this study, we investigated the impact of the aesthetic order of facial and chest visualisations
539 on participants willingness to trust robots. In particular, it considered the potential risks and
540 uncertainty afforded by certain aesthetic orders to the human-robotic trusting relationship. Our
541 results show the clear influence that past experience had on a participant's willingness to trust
542 the original robot. Particularly, the visualisation with no modifications was found to have a
543 substantially higher percentage of trust in those with past experience. Participants with no past
544 experiences were relying solely on the visual appearance to determine their level of trust. These
545 findings are in line with what Sanders et al. (2017) hypothesised and discovered, in detail, how
546 those participants with past robotics experience would lead to a higher trust of robots and a better
547 positive attitude towards them.
548 Interestingly, we found that a blurred facial expression significantly influenced whether
549 participants trusted a robot. The blurred facial and chest screen visualisations afforded uncertainty
550 and resulted in a participant's unwillingness to trust a robot.
551 Figure 7 displayed the extent that physical appearance had on the decision participants made to
552 trust a robot. With a participant's ability to roughly estimate the correct answer not largely adopted
553 by participants, we can only conclude that the physical appearance was the determining factor in
554 the decisions. Interestingly, over half the participants selected robot B, which presented the
555 incorrect answer to the mathematical equation.
556
557 Based on previous research that shows colours can influence various moods (Kurt & Osueke,
558 2014), we predicted similarly that the aesthetic element colour could initiate different affective
559 responses when applied to a robot. We tested that hypothesis by introducing participants to an
560 array of robot visualisations that applied an assortment of distinct colour changes. We found that
561 comparably participants were following known psychology of colour associations when selecting
562 what feelings and terms they associated to the robots with the assortment of colours. For example,
563 figure 9 displays the words participants associated with the array of colours and other visual
564 modifications. As we hypothesized, certain colours had followed the known associations of related
565 words, such as when participants were promoted to associate the red coloured robot to a
566 particular word. Following the commonly known western culture word associations with the colour

567 red (i.e., dangerous, excitement, festive, etc.) (Cousins, 2012), we evaluated its affect while
568 present on a robots outer shell and found a similar result of red being associated with the term
569 dangerous.
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596   Figure 9:
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598 However, it is important to consider how cultural beliefs and geographical regions may also have
599 an influence on a person's perceptions of colour. A particular colour hue can have multiple
600 meanings and interpretations to people in different regions of the world (Kurt & Osueke, 2014). It
601 is critical that when designing a robot to afford trust that these cultural backgrounds, geographical
602 location, and beliefs are carefully considered when selecting a robot's hue to be fit for purpose.
603 Additionally, it is important that this same level of consideration is taken for other design elements,
604 in order to evaluate how the different designs are perceived in different regions, backgrounds,
605 and faiths.
606
607 The research has also highlighted the importance of cohesion between the facial screen and
608 chest screen. In the question prompting participants to consider the information on the chest
609 screen (see figure 7), the participants were never asked whether or not they trusted the robot as
610 a whole, only if they trusted the information on the screen. However, the negative stimuli released

611 by the facial expression demonstrated that most participants declared the robot as not trustworthy.
612 Moving forward, when designing a robot that can be trusted, it is important to consider all
613 elements, as stimuli from other visual outputs can potentially influence an independent
614 communication channel.
615

Conclusion and future work

617

618 This research has shown that robots have the unique ability to create an emotional connection
619 with humans through the use of facial expressions and aesthetics. As documented, we have seen
620 the introduction of anthropomorphism which creates a fine line between increasing
621 trustworthiness and becoming 'scary'. Nevertheless, the non-physical humanlike
622 anthropomorphic designs (cartoon designs) encouraged participants to trust the robots further,
623 showing the unique ability to improve their facilities for empathy. Moreover, this research has
624 shown that the face is not the sole visual aesthetic that can be utilised to initiate affective
625 processes. The chest screen provides an additional entity to further enrich the potential to provide
626 an engaging experience. Ultimately, the cohesion between the multiple screens is an important
627 consideration for designing socially acceptable robots. As is the design elements and principles
628 to understand how their aesthetic order can play such an important role in initiating a trusting
629 robotic experience.
630

631 Going forth, we feel there may be interest in replicating the study but utilising actual robots. We
632 acknowledge there is still a substantial amount of research required to fully understand how we
633 form trusting relationships between human and robot. However, we feel this study paves the way
634 for future studies that involve aesthetic physicalisation, where further sensory cues can be tested
635 to evaluate their influence on our trusting ability of robots. Additionally, this research touched upon
636 how design elements may influence different participants from different cultural backgrounds,
637 geographical locations, and beliefs. We feel it would be of interest to further explore the potential
638 to develop culturally appropriate robots.
639 Moreover, it would be interesting to further expand on the use of aesthetic designs to evaluate
640 how further modifications (i.e., different colour tones, design elements, design principles, etc.) can
641 affect and in some cases, increase a participant's willingness to trust a robot.
642 Finally, we believe there would be value in understanding how the trusting relationship between
643 human and robot may develop over time. Whilst this study provides details on the initial
644 engagement/interaction, there may be interest to explore aesthetic designs in different situations
645 and time scales.
646 Throughout this research, we have explored how we can build trusting relationships with robotics
647 through aesthetic designs. In future work, better consideration of human-centered design
648 perspectives must be explored when considering building trust. The research explores
649 participants not trusting robotics as injudicious when the reason not to trust is still a valid and
650 acceptable response in certain situations.
651

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653

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659

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661

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Figure 1

Original image of the Canbot-U03 robot

Figure 2

Canbot-U03 robot with human eyes modification.

Figure 3

Multiple Canbot-U03 robots with different colours hues.
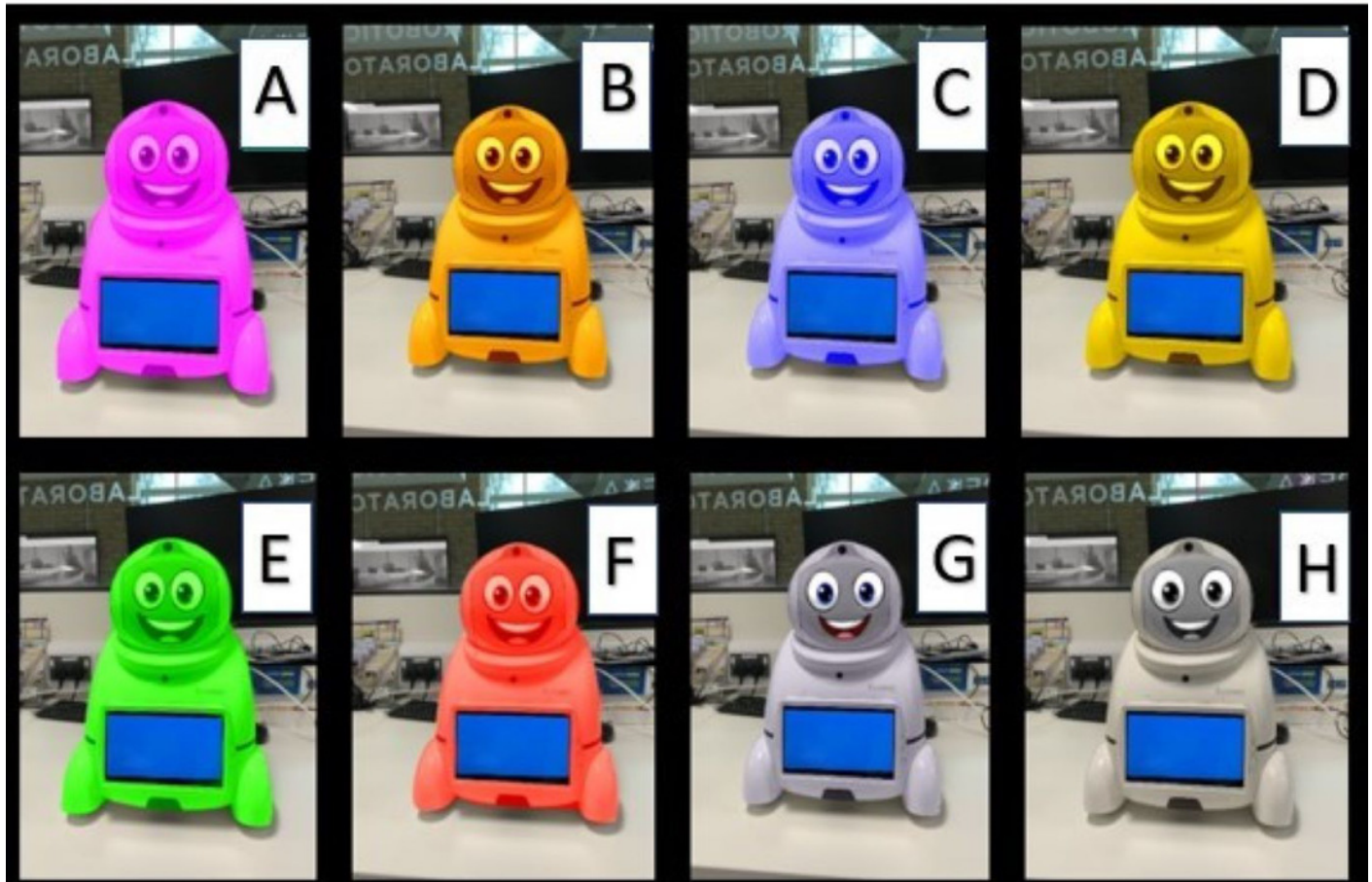
Figure 4

Question to participants: Would you trust this Canbot with the visual changes?

(A) Indicates participants responses to Canbot with no visual changes. (B) Indicates participants responses to Canbot with smiling cartoon facial expression.

Would you trust this robot?	Robot (A) with no visual changes (original robot)	Robot (B) with enhanced visual changes (Cartoon smiling facial expression)
YES	37	34
No	16	28
Don't Know	21	12

Figure 5

Canbot with Blurry facial expression and tree map diagram displaying responses from "How does this Canbot make you feel?
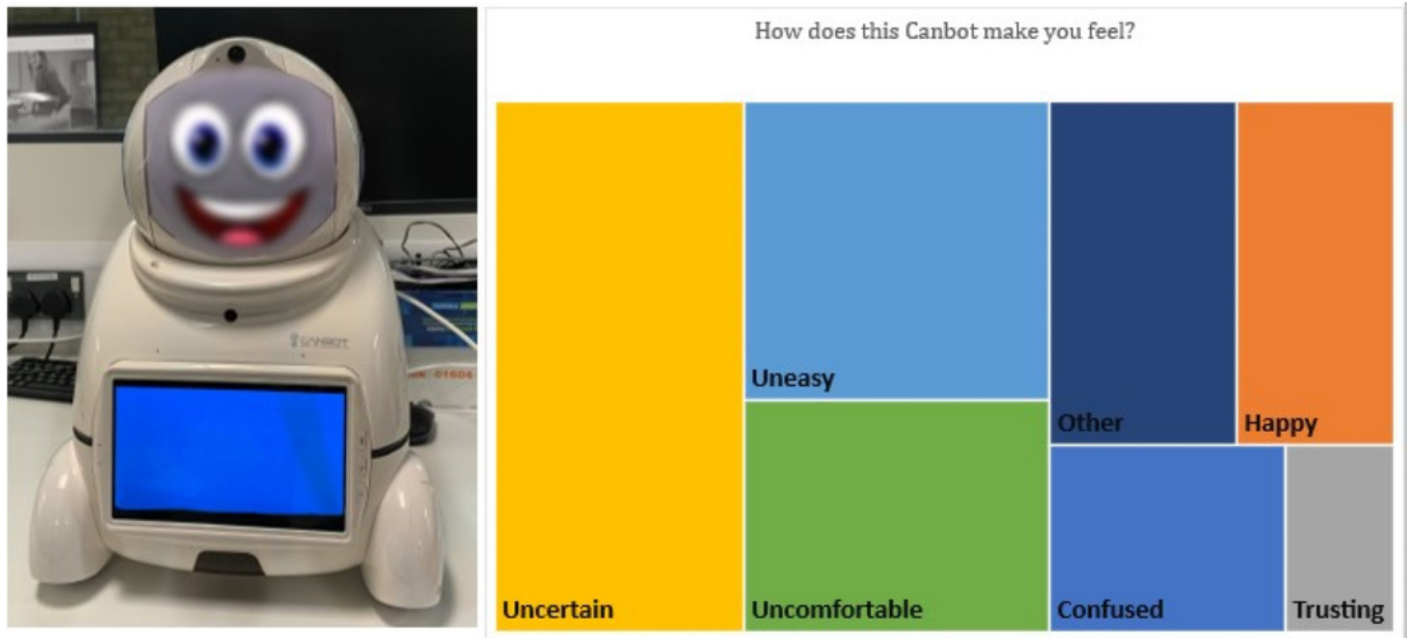
Figure 6

Heatmap displaying participants responses to: What robot would you trust is giving you the correct answer?
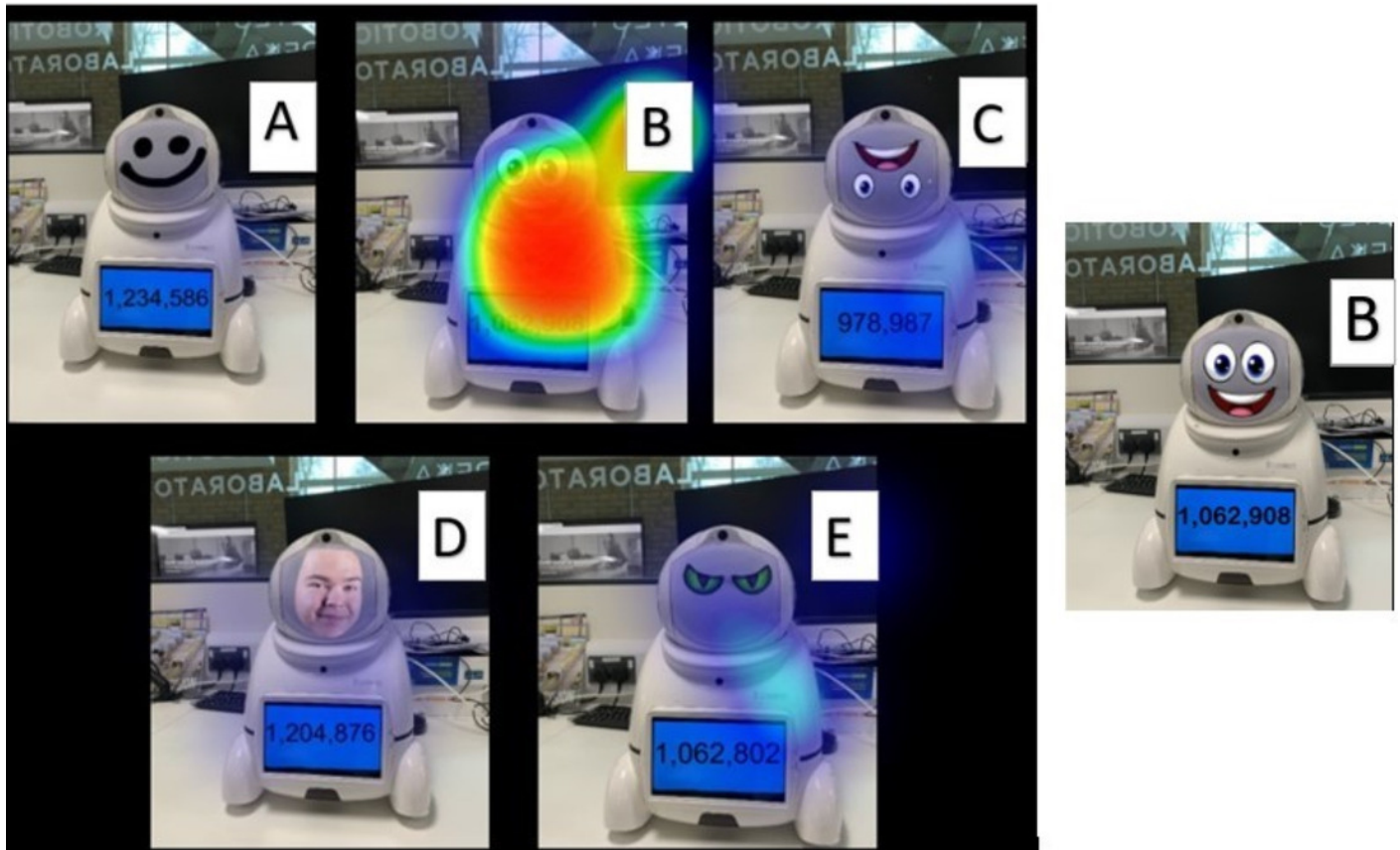
Figure 7

Heatmap displaying participants responses to: What robot would you trust is giving you the correct answer?
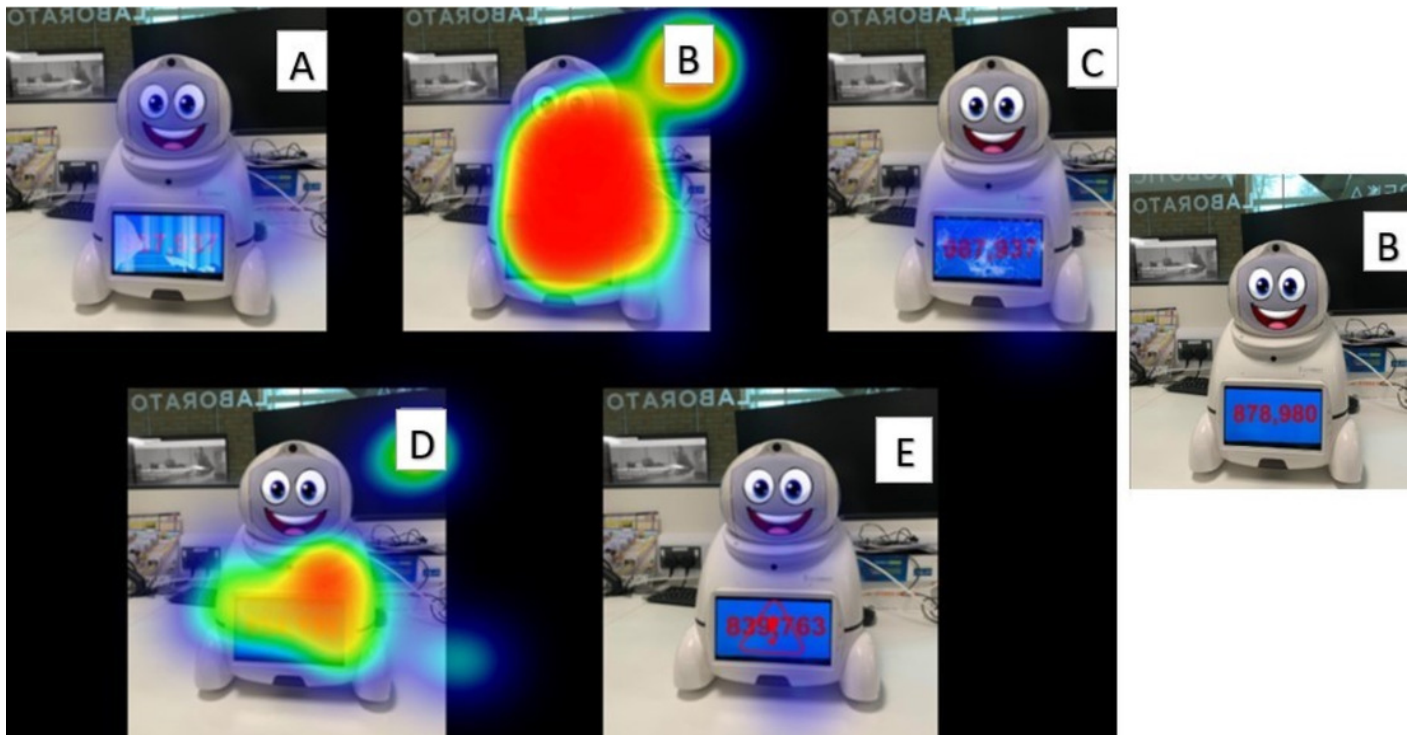
Figure 8

Robot with confused facial expression and participants responses to: Would you trust this robot is telling the truth about their age?
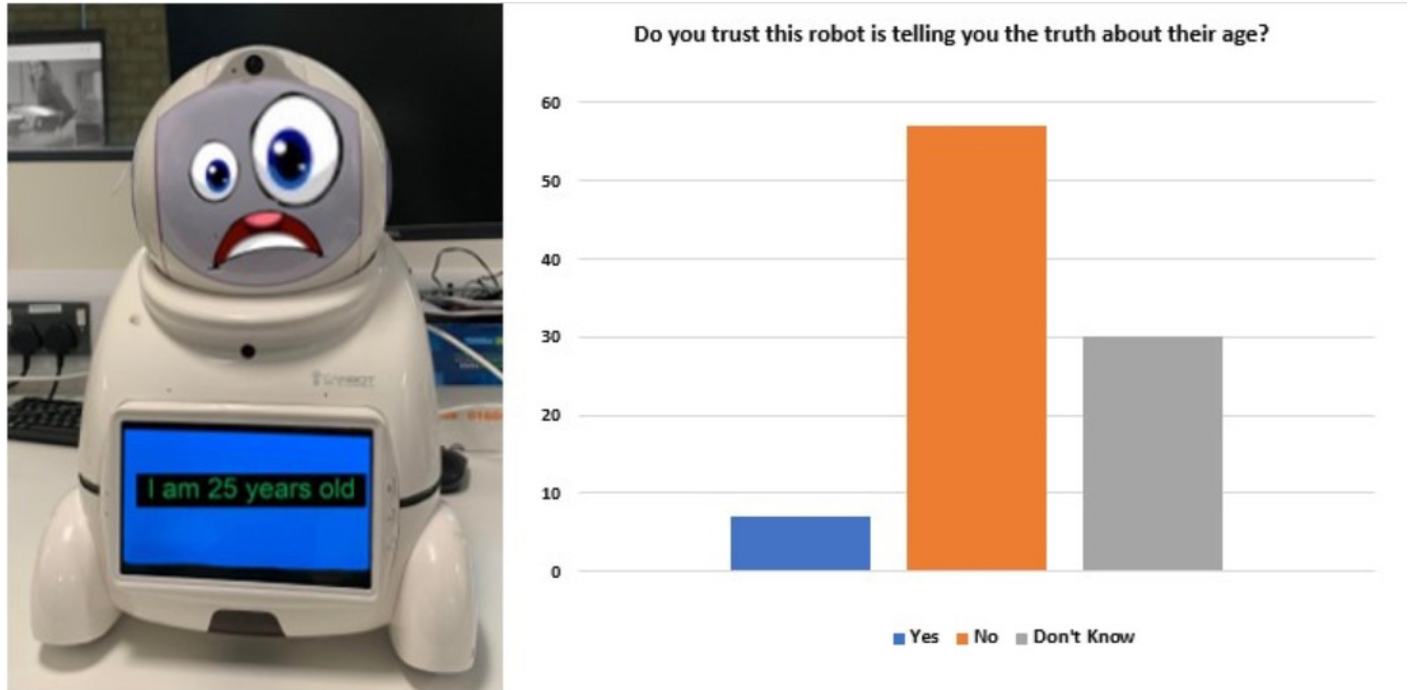
Figure 9

Sunburst visualisation displaying the visual modifications and participants associated wording.