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The Effect of Facial Features on Facial Anthropomorphic Trustworthiness in Social Robots

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Abstract: As the nature of human-robot relationships have become increasingly bound to shift from supervisor–machine to friend–companion, people have exhibited an increasing interest in making social judgments toward such anthropomorphic objects, such as trustworthiness. However, the facial features of social robots and their potential effect on anthropomorphic trustworthiness are seldom analyzed and discussed comprehensively. This study examined whether the trustworthiness perception toward a social robot shared similarity with baby schema features on the human face. It also explored the effects of different combinations of baby schema facial features, especially the positions and sizes of the eyes and mouth, on facial anthropomorphic trustworthiness. A 5-way mixed experiment (N = 270) was conducted accordingly. The results indicated that people would experience a high level of facial anthropomorphic trustworthiness toward robots with baby schema features (i.e., large eyes, with medium vertical and horizontal positions of the eyes and mouth). This paper contributes to the literature on facial anthropomorphic trustworthiness in human-robot interaction and provides suggestions for social robot design.

Keywords: Social robot, Facial anthropomorphic trustworthiness, Baby schema, Eyes, Mouth

1. Introduction

Suppose you are waiting in a bank to receive financial services when a social robot approaches you. “How may I help you?” the robot asks with a lovely smile, and then you begin to examine the face of this emerging creature. What would you think when you see its face? Would its facial features have an impact on your appraisal? Would you trust it and try the services it suggests? What kind of social robot would you trust more—one that looks cute or one that looks mature?

After decades of robot stories being portrayed in science movies, robots are starting to become involved in our daily lives; the abovementioned scenario has already become a reality in HSBC branches in Manhattan, which have adopted social robots to improve the financial service experience (Son, 2018). Indeed, the social robot has experienced tremendous improvements in recent years, motivating more sophisticated functionality, higher artificial intelligence, and more advanced automation (Kim et al., 2020; Körber et al., 2018; Song, 2020; Yuan et al., 2020). At the same time, improved technology influences the routine in which humans perceive and interact with such emerging creatures (Schaefer, 2016). The most significant advancement can be foreseen in the field of social robot design and evolution for human-robot interaction (HRI) in various contexts (McGinn et al., 2017). To be more specific, social robots are evolving from a passive tool-based helper to an active integrated partner (Kiesler et al., 2018). The nature of HRI is increasingly bound to shift the role of the robot from a merely unemotional machine toward being a companion, friend, or even mate, and the role of humans from attentive supervisor to mutual collaborator (Walters, 2008).

In HRI, humans also seek to evaluate robots' personality attributes as they do in interpersonal interactions (Hwang et al., 2013). One reason might lie in the evolution theory: people would have a strong instinct to set humans as a basis for inferring the characteristics of nonhuman entities and for detecting similarities and differences between humans and nonhumans (Epley et al., 2007). Accordingly, people would more likely be attracted by humans or anthropomorphic objects (Landwehr et al., 2011). Among various personality attributes, trustworthiness appraisal is considered the most fundamental in interpersonal interaction, focusing on the evaluation of people's honesty and reliability (Karpinsky et al., 2018). Similarly, trustworthiness in a social robot plays an indispensable role in HRI, even at first sight (Luo et al., 2006). Based on first impressions, people could unconsciously finish the initial trustworthiness appraisal in an incredibly short time (Phillips et al., 2018). For instance, humanoid avatars or robots are believed to be more likable, honest, and reliable (Kalegina et al., 2018).

Research on facial trustworthiness originated from and is mostly conducted within human facial features (Holtz, 2015). For example, literature has suggested the prominent role of the baby schema in different contexts: baby-faced people are generally believed to be cuter (Borgi et al., 2014), more likable (Lee, 2013), more credible (Guido and Peluso, 2009), or even less guilty (Funk and Todorov, 2013), and even accused less when they have committed a crime (Gorn et al., 2008). In the context of social robots, as computer programming advances, an increasing number of robots are shifting from physically mechanical faces to those rendered with animation, which enjoys a high level of flexibility for design representation (Westlund et al., 2016). Indeed, the latest research on HRI has begun to explore the relationship between different features of robot faces and people's perceptions (Kalegina et al., 2018; Kiesler et al., 2018; Luria et al., 2018; Pollmann et al., 2019; Reeves et al., 2020). For example, in the pioneering work of Kalegina and her colleagues (2018), they systematically summarized the prevalent facial features of social robots and further suggested how the existence of particular facial features, such as eyebrows, could shape social judgments, such as the likeableness.

However, previous research has focused more on the general effect of specific features on trustworthiness, which might potentially neglect the co-dependency or extreme displacement of features. Regarding the prominent role of the eyes and mouth in human facial processing (Ferstl et al., 2017; Masip et al., 2004), the size and positioning of the eyes and mouth on social robots might play a significant role in communicating facial trustworthiness; thus, they need to be carefully designed. The present study aimed to contribute to the literature on facial anthropomorphic trustworthiness through examining whether the features of the baby schema on the human face, both separate and combinations of eye and mouth size and positioning, could be applied to a social robot and enjoy similar effects.

1.1 Facial trustworthiness for humans and robots

The face plays a significant role in communicating social cues such as trustworthiness, even at first sight upon meeting people (Holtz, 2015). Based on people's immediate processing of facial features, this process is considered to occur impulsively, forming an initial trustworthiness evaluation and influencing the follow-up behavior (Marzi et al., 2014). Accordingly, the related facial cues, such as the eyes and mouth, might serve as basic heuristic indicators to make such decisions in everyday life (Oosterhof and Todorov, 2009; Porter et al., 2010; Stirrat and Perrett, 2010).

It is natural that people exhibit a strong inclination to look for faces; however, this instinct is not limited to detecting human faces only (McGinn, 2019; Stroessner and Benitez, 2019). Instead, people also exhibit an apparent intention to identify human-like entities, such as humanoid robots (Prakash and Rogers, 2015). In addition, state-of-the-art (SOTA) social robots, usually equipped with a screen-based head, have human-like features and expressions, which could advance design flexibility for mimicking humans to a greater extent (Kalegina et al., 2018). An eye-tracking study further suggested that no substantial differences existed in fixation patterns between human and robot face detection (Palinko et al., 2015). Considering the coherent relationship between fixation patterns and facial coding (Klin et al., 2002), humans might also identify robot faces by systematically coding relative facial features (Kanwisher et al., 1997).

Indeed, the facial anthropomorphic trustworthiness of social robots establishes the initial step in HRI, and this consideration is one of the most prominent barriers to public acceptance of social robots, regardless of their automation level (Schaefer, 2016). As Mayer and Davis (1999) suggested, trustworthiness evaluation is a potential partnership appraisal (Ormiston et al., 2017; Xu et al., 2016). Recent literature has suggested human trustworthiness and anthropomorphic trustworthiness share similarities in the HRI setting (Calhoun et al., 2019; Kim et al., 2020). Thus, facial anthropomorphic trustworthiness could be defined as impression-based trustworthiness where people rely on the facial cues of social robots to evaluate their reliability, honesty, or truthfulness (Kim et al., 2020).

1.2 Baby schema for social robots

Among the different combinations of facial features, the baby schema might play a key role in eliciting facial trustworthiness (Glocker et al., 2009a). To specify, the baby schema (also called "*Kindchenschema*") describes a phenomenon where a certain set of infantile physical characteristics, such as a relatively large head, cute facial features, short extremities, and plump body, could induce spontaneous positive evaluations and related behavioral reactions in humans, such as perceived cuteness and associated caretaking or nurturing behavior for babies (Lorenz, 1943). According to the evolution theory, such a phenomenon could provide adaptive benefits for humans, eliciting caring behavior and improving the survival rate of offspring (Glocker et al., 2009a). Thus, spontaneous reactions to baby schema might work as the basic foundations of human social cognition.

The latest neuroscientific studies have further explained this altruistic instinct by illustrating the crucial role of the brain reward system when exposed to babies or even cute faces (Venturoso et al., 2019). Specifically, based on observations using functional magnetic resonance imaging (fMRI), Glocker and his colleagues (2009b) suggested that the baby schema could trigger the essential area for reward processing, the nucleus accumbens, in nulliparous women. In addition, similar to fixation patterns when processing adult faces, people also could recognize and differentiate baby faces from adults' faces in a limited amount of time, confirming the automatic and immediate facial processing pattern in infants (Brosch et al., 2007).

Regarding the facial features in the baby schema, two basic regions, name the size and positioning of the eyes and mouth, play a significant role in attracting attention and communicating trustworthiness (Penton-Voak et al., 2001). People with facial babyishness typically tend to have large eyes, a high brow ridge, a small chin, a pug nose, short ears, and thin lips (Ma et al., 2015; Maeng and Aggarwal, 2018; Masip et al., 2004). As illustrated in Figure 1, the typical face proportion contains dimensions in three perspectives: the upper face length (forehead length), interpupillary distance (eye distance), and lower face length (chin length) (Hildebrandt and Fitzgerald, 1979).

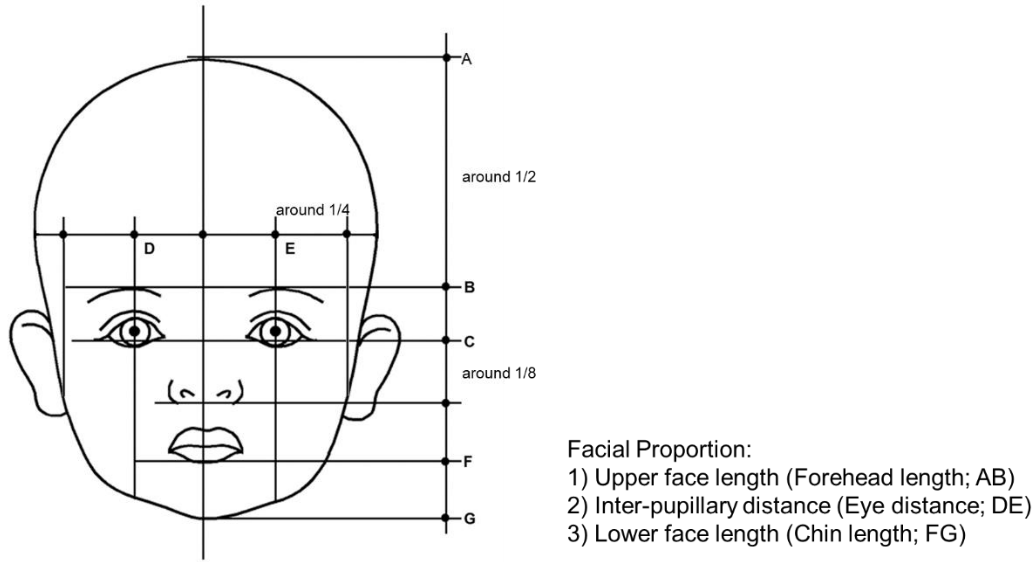

Figure 1. Illustration of the measurement parameters for an infant's facial proportions

To be more specific, as for the size of eyes and mouth, infants (normally aged under 1 year by definition) typically have large round eyes (Ferstl et al., 2017; Masip et al., 2004). Individuals with large round eyes would enjoy a high level of trustworthiness; however, people tend to have a nuanced preference toward mouth size: while a baby usually has a small mouth (Glocker et al., 2009b), people with a large mouth might also be considered more trustworthy and capable (Re and Rule, 2016). Regarding the position of the eyes and mouth, infant facial features tend to have an inward (centralized) positioning tendency (Lee, 2013; Miesler, 2011): babies normally have a higher forehead (i.e., lower vertical position of the eyes; larger AC or AB) (Gorn et al., 2008; Miesler, 2011; Miesler et al., 2011), closer pupils (i.e., closer horizontal position of the eyes; smaller DE) (Venturoso et al., 2019), and a more centralized chin (i.e., higher vertical position of the mouth; larger FG) (Zebrowitz and Montepare, 2008).

Considering the significance of the baby schema in reproductive success, such instinct-affective reactions might also arise, especially regarding artificial entities such as social robots with similar facial features to the baby schema (Miesler et al., 2011). On the one hand, the latest research has provided preliminary evidence that people might also be sensitive and have specific responses to social robots with babyish features (Borgi et al., 2014). For instance, childlike social robots might be acknowledged as more approachable, warm, and trustworthy (Reeves et al., 2020). The presence of lifelike eyes, rather than abstract or absent eyes, is believed to be more personable and suitable for the home (Luria et al., 2018), whereas the absence of a mouth, rather than presence, might aid emotional expressions (Pollmann et al., 2019). Kalegina and her colleagues (2018) systematically summarized the most common features in the current market and created a synthetic face as the benchmark. By altering only a one-dimension feature, they found that the presence of one facial element (e.g., blue eyes, extremely close eyes, ears, eyelids, hair, no mouth, no pupil, small eyes, and white face) might decrease people's perceived trustworthiness. On the other hand, the difference between a screen-based face and a human face was still distinct, which could not be neglected. Different from a general human face, a rendered screen, which is convenient and flexible, might be able to create faces with feature displacements, such as a face with "scattered" features (i.e., where the eyes and mouth are scattered on the face; the interocular eye distance, hereinafter describe as eye width for consistent presentation, is high with a low vertical position of the mouth) or a face with "huddled" features (i.e., the eyes and mouth are positioned close together; the interocular eye distance is low with a high vertical position of the mouth). Therefore, a social robot could have different combinations of feature size and displacement. Indeed, people are highly sensitive to feature displacement in both human and nonhuman faces (Yovel and Duchaine, 2006). Inappropriate or unnatural feature displacement might significantly reduce social judgments (Jones et al., 2001; Penton-Voak et al., 2001), such as perceived facial attractiveness (Friedenberg, 2001). Although the inward tendency of facial features might stimulate baby schema, its effect could be neutralized by extremely close positioning of the eyes and mouth. Accordingly, a medium vertical and horizontal positioning might enjoy a high level of trustworthiness.

Moreover, not only could the facial features of social robots influence trustworthiness evaluation but also people's prior experience of robots. For instance, as an emerging creature in our daily lives, most people might not be familiar with social robots (De Rie, 2016). To deal with uncertainties in knowledge, beliefs, and reasoning of users, Bayes inferred user states from prior theory and data, updated by observations (Kardes et al., 2004). Therefore, prior experience of social robots would act as an influential factor, which should be controlled to ensure a more precise examination.

Based on prior research on evolution psychology and HRI, this study attempted to extend the theory on facial anthropomorphic trustworthiness through systematic size and position displacement of the eyes and mouth. Accordingly, the following hypotheses were proposed:

H1: Social robots with large (vs. small) eyes are perceived as more trustworthy.

H2: Social robots with a small (vs. large) mouth are perceived as more trustworthy.

H3: Social robots with a medium (vs. high or low) vertical eye position are perceived as more trustworthy.

H4: Social robots with a medium (vs. high or low) horizontal eye position are perceived as more trustworthy.

H5: Social robots with a medium (vs. high or low) vertical mouth position are perceived as more trustworthy.

2. Materials and Methods

2.1 Stimuli

In this study, a robot designer made all the stimuli as requested. Specifically, there were five facial feature variations: eye size (3 levels: small/medium/large), mouth size (3 levels: small/

medium/large), horizontal position of eyes (far/medium/ close), vertical position of eyes (high/medium/low), and vertical position of mouth (high/medium/ low). Considering the shape of infant heads, facial characteristics, and the head characteristics of existing social robots in the current market, we carefully discussed with the designer and manipulated facial variations based on relevant literature (Ferstl et al., 2017, 2016). For example, unlike the finding in human facial trustworthiness that individuals with a high facial width–height ratio (fWHR) tend to be negatively evaluated and those with a low fWHR tend to be positively evaluated, recent behavioral research has suggested that robots with high fWHR could instead enjoy a higher level of perceived dominance and a more positive evaluation (being viewed as more rewarding) (Maeng and Aggarwal, 2018) since dominant-looking objects can lead to an individual perceiving a more empowered self, potentially resulting in a higher level of trustworthiness (Song and Luximon, 2021). Furthermore, a majority of social robots in the current market are designed with a high fWHR feature (Kalegina et al., 2018). Accordingly, we set a high fWHR (rather than a low fWHR) as the default facial shape. In addition, we used a line-shaped mouth (mouth width), instead of an area-shaped mouth, to illustrate mouth size. Since an area is a two-dimensional graph while a line is a one-dimensional graph, introducing a two-dimensional mouth might potentially confuse people into perceiving an area-shaped mouth, such as an open mouth, which would influence facial trustworthiness (Tottenham et al., 2009). To control this cofounding factor, we selected a line-shaped mouth as the mouth size by manipulating the mouth width. Figure 2 presents the detailed metrics of facial features. Furthermore, other confounding factors, such as brands, logos, or segments, were controlled to ensure their distinctness from other robots in the market. Moreover, other features, such as facial expression, body shape, posture, or background, were maintained the same. Accordingly, a total set of 243 (3*3*3*3*3) robot faces with different features was generated.

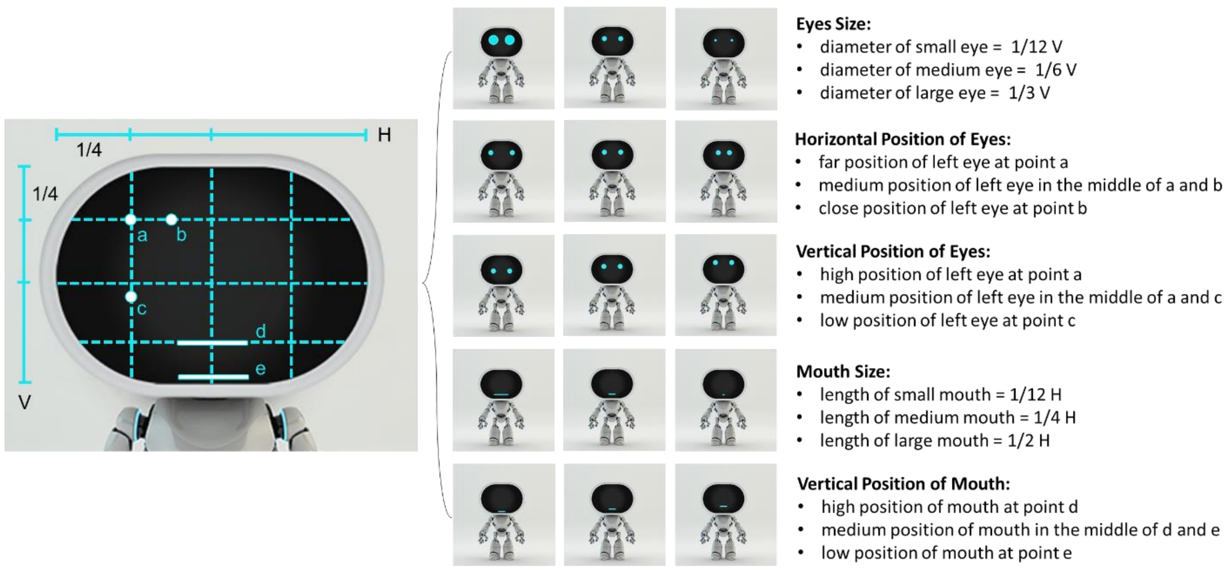

Figure 2. Detailed facial feature metrics of the social robot

2.2 Experiment design and participants

A mixed experiment was designed with the size of the eyes and mouth as between-subjects variables and vertical and horizontal positions of the eyes and mouth as within-subject variables. A total of 270 participants were enrolled to participate in this research via the Amazon Mechanical Turk platform (AMT) (Song et al., 2020). Specifically, the average age of this sample was 36.49 years (SD = 10.498). Table 1 presents the detailed demographic information.

Table 1. Demographic information of the sample in this study

Index	**Frequency**	**Percentage**	**Index**	**Frequency**	**Percentage**
Age			**Educational Level**		
17–25	24	8.9%	High school graduate or lower	22	8.1%
26–30	79	29.2%	Some college	71	26.3%
31–35	59	21.9%	College graduate or above	177	65.6%
36–40	29	10.7%	**Robot Experience**		
41+	79	29.3%	Never used before	165	61.1%
Gender			0–1 year use (exclusive for 1 year)	58	21.5%
Male	174	64.4%	1–2 years use (exclusive for 2 years)	36	13.3%
Female	96	35.6%	More than 2 years use	11	4.1%

2.3 Measurements

For the manipulation check, participants were asked about the extent to which they agreed with five statements on a nine-point Likert scale when exposed to a particular robot design: (1) I think this robot’s eyes are big; (2) This robot’s mouth is big; (3) This robot’s eyes are positioned high on its face; (4) This robot’s eyes are spaced far apart; and (5) This robot’s mouth is positioned low on its face. Regarding the measurement items on facial anthropomorphic trustworthiness, participants were asked about the extent to which they agreed with five items on a nine-point Likert scale: I think this robot looks (1) credible, (2) sincere, (3) honest, (4) believable, and (5) convincing (Gorn et al., 2008).

2.4 Experimental procedure

After consenting to participate, 270 individuals were recruited and briefly introduced to the current study. Then, they were asked to provide demographic information and randomly assigned to one of nine experimental scenarios with a different eye and mouth sizes (each scenario contained 30 individuals). In each scenario, they were exposed to 27 robot faces with various eye positions (three different vertical and three different horizontal positions) and mouth positions (three different vertical positions). Specifically, the sequence of 27 robot faces was randomized to control the learning effect in the within-subjects design (Bosmans and Baumgartner, 2005). For each stimulus, participants were asked to pay attention to the robot face and then complete the questionnaire and related manipulation checks. After finishing the questionnaire, they were told they had finished the experiment.

3. Results

To examine the hypotheses regarding the effect of the baby schema on facial anthropomorphic trustworthiness, SPSS was used to perform descriptive analysis, manipulation checks, and five-way mixed analysis of variance (ANOVA) on facial feature sizes and positions.

3.1 Descriptive analysis and manipulation checks

To examine the normality of univariate data, we performed the kurtosis and skewness test on five items. Results suggested the kurtosis and skewness of each item were within the threshold, suggesting a general normal distribution (Groeneveld and Meeden, 1984). Then, we conducted a descriptive analysis of different factors in the study (see Table 2).

Table 2. Summary of descriptive analysis of different factors

				95% Confidence Interval	
Factors	**Levels**	**Mean**	**SE**	**Lower Bound**	**Upper Bound**
Eye size	Small	5.77	0.13	5.52	6.01
	Medium	5.89	0.13	5.64	6.13
	Large	6.20	0.13	5.95	6.45
Mouth size	Small	5.84	0.13	5.60	6.09
	Medium	6.07	0.13	5.82	6.32
	Large	5.94	0.13	5.69	6.19
Eye height	Low	5.83	0.08	5.66	5.99
	Medium	6.07	0.07	5.93	6.21
	High	5.95	0.08	5.80	6.11
Eye width	Close	5.79	0.08	5.63	5.95
	Medium	6.17	0.07	6.03	6.30
	Far	5.89	0.08	5.75	6.05
Mouth height	Low	5.60	0.09	5.42	5.77
	Medium	6.13	0.07	5.98	6.28
	High	6.12	0.07	5.98	6.27

Note: for consistent usage of terms, eye width is introduced and refers to the interocular distance between eyes

In addition, manipulation checks were performed using a mixed ANOVA (between-subjects variables: eye and mouth sizes; within-subjects variable: eye and mouth positions), revealing all the five modifications to have been successful: robots with larger eyes were considered to have larger eyes (mean = 6.86 vs. 5.59 vs. 3.96; $F(2, 267) = 42.95$, $p < 0.01$); robots with a larger mouth were considered to have a larger mouth (mean = 5.32 vs. 4.62 vs. 3.17; $F(2, 267) = 16.98$, $p < 0.01$); eyes positioned high were considered to be positioned high (mean = 4.99 vs. 4.00 vs. 3.81; $F(2, 538) = 101.23$, $p < 0.01$); eyes spaced far apart were considered to be positioned far apart (mean = 5.71 vs. 4.13 vs. 3.68; $F(2, 538) = 162.74$, $p < 0.01$); and mouths positioned low were considered to be positioned low (mean = 6.68 vs. 4.97 vs. 4.12; $F(2, 538) = 180.66$, $p < 0.01$).

3.2 Effect of feature size

3.2.1 Main effect of feature size

Five items of trustworthiness were averaged and treated as a whole with a satisfactory Cronbach's alpha coefficient (0.98), suggesting high consistency of the current measurement. Then, a five-way mixed analysis of covariance (ANCOVA; between-subjects variables: eye and mouth sizes; within-subjects variable: eye and mouth positions; covariate variable: prior robot experience) was then conducted. Table 3 presents the summarized ANCOVA results. We mainly focused on the main effects of feature size and position since they were theoretically relevant to the research questions at hand.

Table 3. Summary of the main effects and significant interactions in the ANCOVA

Sources	**df**	**F-statistic**	**p-value**	**Effect size**
Experience (EXP)	1	26.60	p < 0.01	0.09
Eye size (ES)	2	3.15	p < 0.05	0.02
Mouth size (MS)	2	0.79	0.45	0.01
Eye height (EH)	2	13.89	p < 0.01	0.05
Eye width (EW)	2	41.75	p < 0.01	0.14
Mouth height (MH)	2	53.19	p < 0.01	0.17
EW * ES	4	13.61	p < 0.01	0.09
MH * ES	4	5.01	p < 0.01	0.04
EH * EW	4	3.37	p < 0.01	0.01

EH * MH	4	28.21	$p < 0.01$	0.10
EW * MH	4	6.95	$p < 0.01$	0.03
EH * EW * MH	8	3.29	$p < 0.01$	0.01
EH * MH * ES	8	2.23	$p < 0.05$	0.02
EW * MH * ES	8	3.31	$p < 0.01$	0.02
EW * ES * MS	8	2.93	$p < 0.01$	0.04

As for the main effect of feature size, we found a significant impact of eye size ($F(2, 260) = 3.15$, $p < 0.05$, $\eta^2 = 0.02$) and robot experience ($F(1, 260) = 26.60$, $p < 0.01$, $\eta^2 = 0.09$), whereas the effect of mouth size was nonsignificant ($F(2, 260) = 0.79$, $p = 0.45$, $\eta^2 = 0.01$). Specifically, (1) robots with larger eyes enjoyed a higher level of trustworthiness: a post-hoc Bonferroni-corrected comparison revealed a significant difference between large and small eye sizes ($p < 0.05$), whereas the difference in eye size between large and medium and between medium and small was nonsignificant (see Table 4). (2) A nonsignificant difference seemed to exist between different mouth sizes: people displayed no clear preference for a specific mouth size. (3) We also found a significant effect of the covariate variable, namely robot experience; specifically, people with more robot experience had an increased tendency to trust a robot.

Table 4. Summary of the comparison of different levels and hypotheses testing

			95% Confidence Interval		
	Difference	**SE**	**Lower Bound**	**Upper Bound**	**Hypotheses Tests**
Eye size					
Small − medium	−0.12	0.18	−0.55	0.31	H1 was supported
Small − big	−0.43*	0.18	−0.86	0.00	
Medium − big	−0.31	0.18	−0.74	0.11	
Mouth size					
Small − medium	−0.22	0.18	−0.66	0.21	H2 was not supported
Small − big	−0.09	0.18	−0.52	0.34	
Medium − big	0.13	0.18	−0.30	0.56	
Eye height					
Low − medium	−0.25**	0.05	−0.36	−0.13	H3 was supported
Low − high	−0.13	0.05	−0.26	0.00	

Medium − high	0.12*	0.05	0.01	0.23	
Eye width					
Close − middle	−0.38**	0.04	−0.47	−0.28	H4 was supported
Close − far	−0.11	0.05	−0.22	0.01	
Middle − far	0.27**	0.04	0.18	0.36	
Mouth height					
Low − medium	−0.53**	0.06	−0.68	−0.38	H5 was supported
Low − high	−0.52**	0.06	−0.67	−0.37	
Medium − high	0.01	0.04	−0.08	0.10	

Note: * denotes a difference significant at 0.05; ** significant at 0.01

3.2.2 Interaction effect of feature size

The significant interaction of eye size with eye width ($F(4, 520) = 13.61$, $p < 0.01$, $\eta2 = 0.10$) and of eye size with mouth height ($F(4, 520) = 5.01$, $p < 0.01$, $\eta2 = 0.04$) demonstrated that although increased eye size with an inward tendency of facial features generally enjoyed a high level of trustworthiness, this desire might have been counteracted by the extremely close displacement of facial features (e.g., large eyes with a small interocular distance or large eyes with a high vertical position of the mouth), resulting in a declining perception of trustworthiness (see Figure 3).

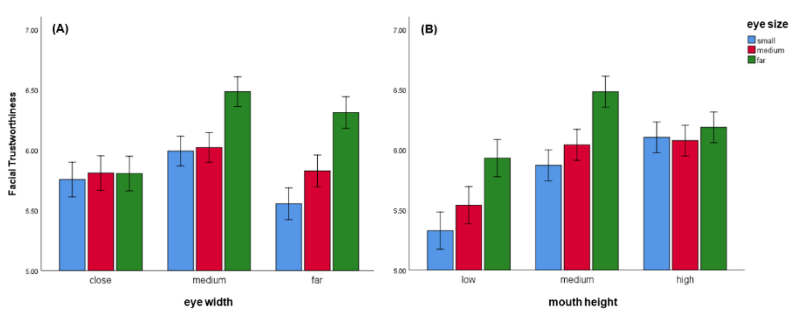

Figure 3. Bar chart representing the results of the two-way interactions in facial trustworthiness ratings. (A) eye width × eye size; (B) mouth height × eye size. Error bars represent ±1 SE.

Similar observations could also be found in three-way interactions of eye size with eye width and mouth height ($F(8, 1040) = 3.31$, $p < 0.01$, $\eta2 = 0.02$). When the mouth was moved upward (from a low to medium position), participants experience an increased perception of trustworthiness when eyes were displaced inward (horizontally positioned from far to medium), regardless of eye size. When the mouth was shifted further upward (from a medium to high position), people exhibited reluctance toward the concentrated facial features (horizontally positioned from medium to close), especially toward large eyes. Correspondingly, eye size similarly interacted with eye height and mouth height ($F(8, 1040) = 2.23$, $p < 0.05$, $\eta 2 = 0.02$), revealing that as eye size increased, people's trust toward a high mouth position continually decreased (see Figures 4 & 5).

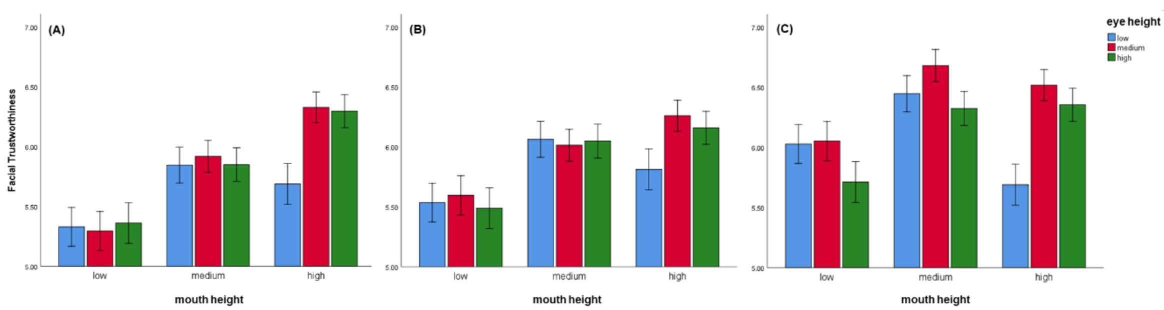

Figure 4. Bar chart representing the results of the 3-way interactions in facial trustworthiness ratings. (A) mouth height × eye height with small eyes; (B) mouth height × eye height with medium eyes; (C) mouth height × eye height with large eyes. Error bars represent ±1 SE.

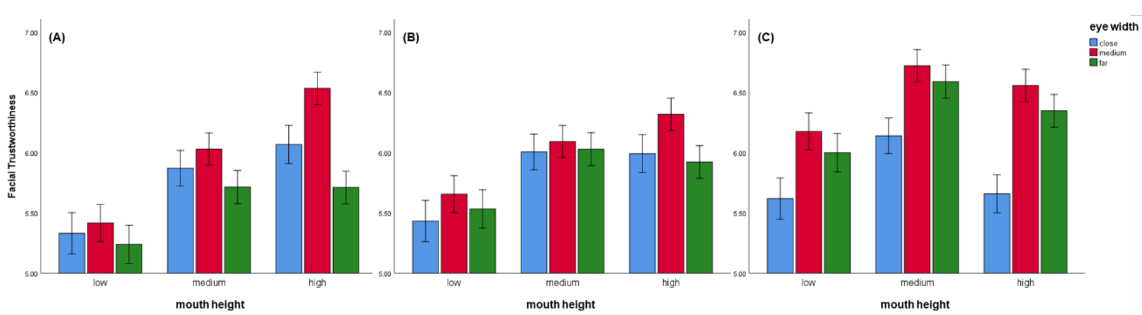

Figure 5. Bar chart representing the results of the 3-way interactions in facial trustworthiness ratings. (A) mouth height × eye width with small eyes; (B) mouth height × eye width with medium eyes; (C) mouth height × eye width with large eyes. Error bars represent ±1 SE.

3.3 Effect of feature positioning

3.3.1 Main effect of feature position

As depicted in Table 4, the ANCOVA results revealed strong main effects for eye height ($F(2, 520) = 13.89$, $p < 0.01$, $\eta^2 = 0.05$), eye width ($F(2, 520) = 41.75$, $p < 0.01$, $\eta^2 = 0.14$), and mouth height ($F(2, 520) = 53.19$, $p < 0.05$, $\eta^2 = 0.17$). A general inward tendency for feature displacement was associated with an increased level of facial trustworthiness; however, extremely concentrated feature displacement might have a counteractive effect on facial trustworthiness. In other words, although the inward tendency of feature displacement might have led to greater facial trustworthiness, people did not desire a “huddled” feature displacement (i.e., centered eye position with a high-positioned mouth).

3.3.2 Interaction effect of feature position

In addition, we made similar observations for the interaction effects among feature positions. As expected, eye height interacted with mouth height, $F(4, 1040) = 28.21$, $p < 0.01$, $\eta2 = 0.10$; eye height interacted with eye width, $F(4, 1040) = 3.37$, $p < 0.01$, $\eta2 = 0.01$; and eye width interacted with mouth height, $F(4, 1040) = 6.95$, $p < 0.01$, $\eta2 = 0.03$, revealing that participants generally exhibited an increased level of trustworthiness toward the centering direction of eye and mouth positioning (see Figure 6). However, as the distance between the eyes and mouth grew closer, participants’ facial trustworthiness perception decreased. Moreover, a reliable three-way interaction of eye height, eye width, and mouth height exemplified this conclusion, $F(8, 2080) = 3.29$, $p < 0.01$, $\eta2 = 0.01$. No other theoretically significant effects were observed.

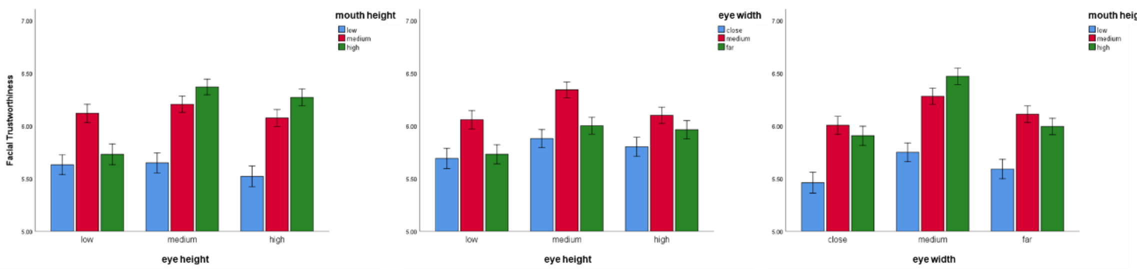

Figure 6. Bar chart representing the results of the 2-way interactions in facial trustworthiness ratings. (A) eye height × mouth height; (B) eye height × eye width; and (C) eye width × mouth height. Error bars represent ±1 SE.

3.4 Theory validation

According to the ANCOVA results, we were able to reveal the top three examples of social robots with the most and least trustworthy facial features (see Figure 7). To further validate whether the examples could indeed be perceived as more babyish, we additionally recruited 180 participants from the same resource (mean age = 37.43, SD = 12.02; 118 males and 62 females). As for educational level, 7 reported being high school graduates or lower, 39 reported some college education, and 134 reported college graduate or above education. Regarding robot use experience 74 participants had never used robots, 46 had 0–1 year of use (exclusive for 1 year), 42 participants had 1–2 years of use (exclusive for 2 years), and 18 participants had more than 2 years of use) and conducted a between-subject one-way ANCOVA. The six examples were treated as between-subject independent variables, robot experience was treated as a covariate, and perceived babyishness was treated as the dependent variable. Perceived facial babyishness was measured on a 9-point Likert scale (a single item measure: I think this robot looks baby-faced; Berry, 1991).

The results of the one-way ANCOVA revealed a significant effect of different examples, $F(5, 173) = 11.28$, $p < 0.01$, $\eta 2 = 0.25$, indicating people faced with trustworthy robots might experience a significantly higher level of facial babyishness (mean = 6.89; SD = 2.07) compared with those faced with untrustworthy robots (mean = 4.62; SD = 2.10).

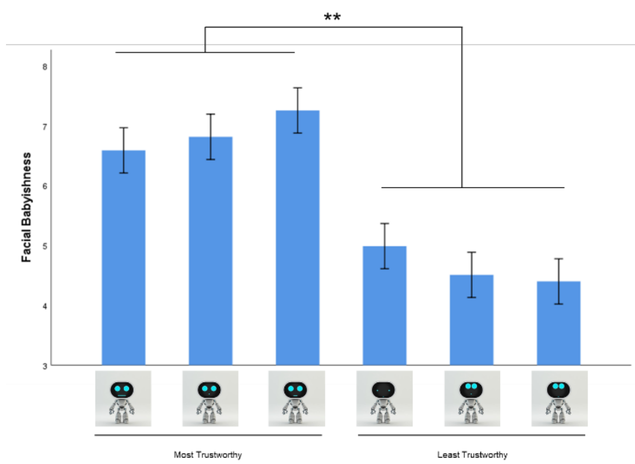

Figure 7. Bar chart representing the results of the one-way ANCOVA in facial babyishness ratings. ** significant at 0.01. Error bars represent ±1 SE.

4. Discussion

The current study attempted to examine the effect of major facial anthropomorphic features on trustworthiness in HRI. Through a full-factorial mixed experiment, this study provided the preliminary metrics of different levels of various facial features in communicating facial anthropomorphic trustworthiness. The major conclusions of each feature are discussed accordingly as follows.

With regard to feature size, the results indicated that eye size could significantly improve facial anthropomorphic trustworthiness, whereas the effect of mouth size was nonsignificant. Thus, H1 was supported and H2 was not supported. On the one hand, this finding is consistent with prior research on trustworthiness in humans and HRI: both people and robots with large eyes were considered more honest and innocent (Chen et al., 2010; Ferstl et al., 2016; Kalegina et al., 2018). Even people wearing glasses could be perceived as having larger eyes and thus as more trustworthy and intelligent

(Leder et al., 2011). On the other hand, the nuanced relationship between mouth size and perceived trustworthiness might account for this nonsignificant effect. While a small mouth is often associated with an infant face (Glocker et al., 2009b), people may exhibit a preference for a face with a large mouth since it is a signal of confidence, capability, and trustworthiness (Re and Rule, 2016). According to the theory of robot communication (TORC), people sometimes treat social robots as "hyper-persons" whose negative cues are filtered out while positive features are filtered in (Konijn and Hoorn, 2017).

As for feature positioning, the results indicated that an inward tendency of feature displacement could enhance facial anthropomorphic trustworthiness; however, extremely close feature positioning might have a counteractive effect on perceived trustworthiness. Thus, H3, H4, and H5 were supported. This is consistent with Berry and McArthur's work (1985), which discussed the adaptive covariations between baby-faced cues and appearance-based stereotypes. Although the centralized tendency of eye and mouth positioning might enjoy a higher level of trustworthiness, unnatural displacement, such as extremely concentrated positioning, might lead to undesirable reactions or responses (Chen et al., 2010; Miesler et al., 2011) and dampen facial anthropomorphic trustworthiness. Compared with the most central positions of the eyes and mouth, a medium level of centralization (medium vertical and horizontal position of the eyes, and medium/high vertical position of the mouth) was deemed to have the highest level of trustworthiness. In other words, striking a balance between ordinal positions and extreme centralized positions is suggested, where the face of a social robot could retain the evolutionary benefits of the baby schema. This finding is also consistent with a previous work that extremely close intraocular distance would reduce perceived trustworthiness (Kalegina et al., 2018).

The current research contributes to the literature on trustworthiness in HRI from three perspectives. To begin with, this study provides preliminary evidence that certain facial features of the baby schema could be applied and extended into the context of social robots to improve facial anthropomorphic trustworthiness toward a social robot. Moreover, this study further examined the effect of close displacement of facial features, which rarely appears on the human face. Considering the flexibility of rendering faces, it might be relatively convenient to have different combinations of feature size and positioning. Few works have explored extreme feature displacement in an anthropomorphic medium (e.g., a social robot), and thus, the results of this study might facilitate our understanding of peculiar features in signaling facial trustworthiness. Lastly, although prior research has discussed the relationship between facial feature displacement and perceived trustworthiness, it might have focused more on the one-dimensional effect of separate facial features and neglected to analyze the effect of co-dependency on anthropomorphic trustworthiness. Through a mixed experiment design, the current work attempted to analyze both separate and interaction effects of feature size and positioning and provides a relatively comprehensive understanding of the eyes and mouth in communicating facial trustworthiness.

5. Conclusion

While the human mindset and its adaptive behavioral pattern are increasingly affected by their surrounding ecosystem, people are still easily influenced by the appearance of an entity. For example, acting in various social roles in our daily lives, social robots' physical characteristics, such as facial features, could still shape their personality attribution, such as trustworthiness (Fortunati, 2015). Indeed, facial anthropomorphic trustworthiness plays a crucial role in HRI since it could prompt communication and accelerate further interaction, even at first sight (Luo et al., 2006). However, limited research has shed light on whether the baby schema of infant's faces can be adapted to such emerging creatures, sharing the evolutionarily positive affection. To fill this research gap, this study examined whether the baby schema could be transferred to a social robot's facial design and enjoy similar evolutionary advantages, such as trustworthiness. Specifically, this study investigated three major facial features of baby schema, namely eye size, mouth size, and facial proportion, on facial anthropomorphic trustworthiness. The results of this study indicated the following: (1) eye size has a significant impact on facial anthropomorphic trustworthiness: large eyes could enjoy a relatively high level of facial anthropomorphic trustworthiness; (2) mouth size does not have a significant impact on facial anthropomorphic trustworthiness: either a large or medium mouth could enjoy a relatively high level of facial anthropomorphic trustworthiness; (3) eye positions have a significant impact on facial anthropomorphic trustworthiness: medium vertical and horizontal positions of the eyes could enjoy a relatively high level of facial anthropomorphic trustworthiness; (4) mouth positions have a significant impact on facial anthropomorphic trustworthiness: both high and medium vertical positions of the mouth could enjoy a relatively high level of facial anthropomorphic trustworthiness; and (5) people generally trust a social robot with inward facial features; however, those features should not be huddled together.

This study had some limitations that should be acknowledged. First, although we attempted to analyze the effect of facial features on anthropomorphic trustworthiness in a relatively comprehensive manner and selected the most representative attributes, they all belong to internal facial features (Song and Luximon, 2020). Indeed, other attributes such as face color (Kalegina et al., 2018) or facial expressions (Landwehr et al., 2011) could also potentially contribute to facial anthropomorphic trustworthiness. One feature worthy of further discussion was fWHR for robots. Robots with high fWHR enjoy high popularity in the market, while humans generally have faced with a low fWHR. Although the current proportion of stimuli generally extracted relative proportions from a typical infant face, as depicted in Figure 1, the difference in fWHR might still potentially influence facial anthropomorphic trustworthiness. Accordingly, future research might be required to analyze the interaction effects between different attributes and validate the current finding in robots with a low fWHR. Furthermore, we used a one-dimensional mouth (line) to illustrate mouth size in this study; however, a line-shaped mouth may have been perceived as too long in the “large” condition due to the potential inappropriate combination. Future studies may introduce a two-dimensional mouth (area) to validate the finding. In addition, in the experiment design, there were three levels in each factor. Although it has already constituted a relatively large variation with 243 different scenarios, it would still be beneficial to have more levels in each factor, thereby reaching a more precise predictor for facial anthropomorphic trustworthiness. Therefore, in future studies, it would be ideal to have more factors and more levels to construct a more extensive model, taking into account different facial trustworthiness antecedents based on this study. Lastly, during the implementation of the experiment, we used manipulation checks to examine whether the participants were influenced by the modified area. However, current academics seem to have conflicting attitudes toward manipulation checks; while some researchers have argued that the presence of manipulation questions might potentially make participants focus on the altered area, thereby potentially influencing the effect (Hauser et al., 2018), others researchers have believed that manipulation questions can help to confirm whether participants have paid attention to the modified area, building causality where it is the modified area that makes people behave this way (Hoewe, 2017). Considering this potential cofounding effect, a future study might be required to revalidate the results without a manipulation check.

Declaration of Interest statement:

The authors declare no conflict of interest.

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