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The Face of Trust: The Effect of Robot Face Ratio on Consumer Preference

1. Introduction

A social robot is a robotic application in artificial intelligence intended to socially interact with people. Social robots can imitate human behavior and carry out tasks (Saunderson & Nejat, 2019), such as assisting autism-disorder children in learning social rules (Zhang et al., 2019) or emotionally supporting and accompanying older adults (Deutsch, Erel, Paz, Hoffman, & Zuckerman, 2019). Different from industrial or mechanical robots, which seldom have human-like traits, the latest social robots are often designed with screen-based heads, which display human-like faces, to socially communicate with people and address people's needs (Westlund et al., 2016).

Indeed, the likeness of a robot's face to a human face has been shown to play an important role in improving the interaction experience in human-robot relationships (McGinn, 2019; Stroessner & Benitez, 2019). There are two reasons for this phenomenon. The first is that, due to evolutionary psychology, people have a tendency to transfer prior experience and knowledge into emerging situations or scenarios (Prakash & Rogers, 2015). The second, more important reason, is that a robot's face is a typical point for initial contact, forming the first impression and the basis for evaluation (M. Yu, Saleem, & Gonzalez, 2014). Accordingly, the visual characteristics of a social robot, including such facial features as width, height, color, and proportions, are regarded as playing a key role in its commercial success (Goetz, Kiesler, & Powers, 2003) and in influencing consumers' purchase intentions (Homburg, Schwemmle, & Kuehnl, 2015).

As regards people's perceptions of a human being or an object, trustworthiness evaluations are considered fundamental, indicating whether or not that person or object can be relied upon (Colquitt, Scott, & LePine, 2007). Similar to interpersonal interactions, the level of trustworthiness that people feel regarding social robots is also important in human-robot interaction (HRI), potentially indicating that a given social robot can be employed as a trustworthy "friend, partner or assistant" that provides support not just physically but also emotionally (P. L. Yu, Balaji, & Khong, 2015). Considering that extant studies have suggested that the face is a significant attractive stimulus in interpersonal interactions, human-like morphological features in social robots could also influence HRI (Maeng & Aggarwal, 2018; McGinn, 2019; Stroessner & Benitez, 2019). For instance, Palinko et al. (2015) used eye-tracking experiments to demonstrate that people tend to have a similar gaze fixation towards a social robot and a real human. However, there is limited research has addressed how specific traits of a social robot's face could communicate trustworthiness.

Here we try to fill this research gap by exploring how a trustworthy image for a social robot can be constructed. Particularly, we examined whether the facial width-to-height ratio (fWHR)—that is, the bizygomatic width divided by upper-face height—of a social robot functions as a strong indicator of trustworthiness (and its sub-constructs) (Lin, Adolphs, & Alvarez, 2018; Stirrat & Perrett, 2010) and whether it could, in turn, influence people's purchase intentions, a consideration neglected in previous research. This study thus contributes to the extant literature on robot personality and social robot consumption by emphasizing the effect of robot design in general and facial appearance in particular.

1.1 Facial cues in social judgments

According to evolutionary psychology, human facial morphology is considered a significant cue in evaluating faces when making social judgments, especially upon first encounter (Stirrat & Perrett, 2010). Prior research has indicated that people might process facial information precisely and form an initial impression of social attributes from static facial traits within 100 ms (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015). Based on data-driven computerized 3D models, Todorov and his colleagues (2015; 2008) divided social judgments into two intrinsic and distinct dimensions: trustworthiness and dominance. While the assessment of dominance is a subconscious evaluation of a person's position of control or power, especially in a social hierarchy (Maeng & Aggarwal, 2018; Stirrat & Perrett, 2010), the perception of trustworthiness is a subconscious evaluation of a person's benevolence, ability, and integrity during verbal or nonverbal interaction (Colquitt et al., 2007; M. Yu et al., 2014). As our cognitive systems are continuously evolving, we focus keenly on the traits of trustworthiness we perceive in other people (Okubo, Ishikawa, & Kobayashi, 2013; Stirrat & Perrett, 2010). For example, round eyes (vs. narrow) and larger eyes (vs. smaller) are considered to be strong indicators of sincerity (Ferstl, Kokkinara, & Mcdonnell, 2017).

Recent evidence has shown that people's innate tendency to search for and identify faces is not limited to human faces; instead, people also show a strong tendency to detect human-like facial features such as might be found in the headlights of a car or the face of a social robot (McGinn, 2019; Prakash & Rogers, 2015; Stroessner & Benitez, 2019). This is because, in the process of facial recognition, the fusiform area of a face plays an important role in systematically detecting and processing facial information (Kanwisher, McDermott, & Chun, 1997). Interestingly, people are also sensitive to the fusiform area of human-like faces (Erk, Spitzer, A.P. Wunderlich, & Galley, 2002). For example, compared with machine-like robots, humanoid robots would be more likely to be perceived as real people (Dehn & Van Mulken, 2000). Mathur and Reichling (2016) further suggest that people might be more likely to attribute personality traits, such as trustworthiness, to human-like robots (compared with non-human-like robots) and that people are also more likely to evaluate human-like robots more positively. Hence, people can infer intrinsic social attributes, trustworthiness and dominance, from the facial features of a social robot (Mugge, Govers, & Schoormans, 2009; Schaefer, 2016).

1.2 Facial trustworthiness and fWHR

Research on trustworthiness has enjoyed considerable scientific attention: Scholars have try to explore the meaning of trustworthiness since it was deemed to be fine-grained in the setting of interpersonal interaction (Colquitt et al., 2007; M. Yu et al., 2014). For example, McCroskey and Young (1981) suggested two constructs for measuring source credibility (i.e., competence and character). In HRI, while prior studies have tried to explore trustworthiness and its sub-dimensions, they have focused more on the general evaluation rather than a specific understanding of the role of facial features in influencing perceived trustworthiness, a field in which there is so far a dearth of empirical research (Hancock et al., 2011). Indeed, the facial trustworthiness (an impression-based trust) of social robots constitutes the initial step in HRI, and this concern is one of the most notable obstacles to the acceptance and adoption of social robots by the general population, regardless of technological improvement (Schaefer, 2016). As Mayer and Davis (1999) suggested, trustworthiness evaluation is a potential partnership appraisal, where facial trustworthiness, in this context, could be assessed via three dimensions (ability, benevolence, and integrity) (Ormiston, Wong, & Haselhuhn, 2017; Xu, Cenfetelli, & Aquino, 2016). Recent academic work has shown these three constructs would also work as sub-dimensions of perceived trustworthiness in the HRI setting (Calhoun, Bobko, Gallimore, & Lyons, 2019; Kim, Kim, Lyons, & Nam, 2020). As Kim et al. (2020) have indicated, the ability of a social robot, referred to as the capability of the robotic system, has an impact on a specific task carried out for a given purpose in the setting of HRI; benevolence is identified as the viewpoint that a social robot is intended to do good for a human being (i.e. be caring or loyal), regardless of any conflicting motivations; and integrity is described as the human perception that the social robot would be honest and remain faithful to a set of sound principles.

Among the facial features which could help to communicate social attributes, fWHR is prominent in signaling perceived dominance and trustworthiness (Lin et al., 2018; Stirrat & Perrett, 2010). To be more specific, in human facial attribution, fWHR is negatively related to perceived trustworthiness and overall facial evaluation (liking), and positively related to perceived dominance. Thus, people with higher fWHR might be considered as more dominant, less likable, and less trustworthy (Geniole, Molnar, Carré, & McCormick, 2014; Lee, Wright, Martin, Keller, & Zietsch, 2017; Linke, Saribay, & Kleisner, 2016; Ormiston et al., 2017; Stirrat & Perrett, 2010), while people with lower fWHR might be deemed as less dominant, more likable, and more trustworthy. For example, it has been argued that in election campaigns in the USA and the UK, people with high fWHR would be more likely to achieve electoral success (Islam, Taylor, & Hayter, 2017) since they might be viewed as being more achievement-driven (Lewis & Weigert, 2012). Similar observations would also apply in predicting CEOs’ leadership and business performance (Alrajih & Ward, 2014) and athletes’ game performance (Kramer, 2015). The underlying reason for this phenomenon might be levels of testosterone: Testosterone levels for adolescents might have a significant impact on the development of their physique and nervous system, promoting the growth of the cheek, eyebrow, jaw, chin, and forehead (Carré & McCormick, 2008; Welker, Bird, & Arnocky, 2016). Regarding the prominent role of facial morphology in communicating one's apparent health (Jones et al., 2001; Rhodes, Chan, Zebrowitz, & Simmons, 2003), it is not surprising that an individual with a high fWHR could be perceived as having increased dominance and decreased trustworthiness in interpersonal interactions (Geniole et al., 2014; Kharouf, Lund, & Sekhon, 2014).

1.3 The social robot as an instrument for empowered self

Since people can also identify "faces" on social robots or in non-human products, this process would automatically evoke the same perceptions as when interacting with another human being (Sproull, Subramani, Kiesler, Walker, & Waters, 1996). Accordingly, the face of a social robot would not only be perceived in a similar manner as a human face but also might act as an instrument for self-completion (Maeng & Aggarwal, 2018). Following Ladik and Belk's comments (1988; 2015) regarding the self and how we consider our belongings as a part of ourselves, Wicklund and Gollwitzer's work (2013) further explains the role of our possessions as "another mean to self-aggrandizing, self-representation, and exerting self-influence to others" (pp. ix), a point which has been confirmed by recent neuroscientific evidence (Decety & Sommerville, 2003). By selecting and purchasing identity-consistent objects, we build and maintain an ideal self-image, not only for ourselves but also for signaling to others (Decety & Sommerville, 2003). For instance, people might be more likely to buy certain luxury items in order to demonstrate their social status in interpersonal interactions (Nelissen & Meijers, 2011).

For instance, they might choose luxury-brand clothing or conspicuous cars to maintain their public image and to communicate their socioeconomic position in society. Thus, it is not surprising that people tend to attribute a high level of perceived dominance to high fWHR objects as a representational signal for themselves (Maeng & Aggarwal, 2018).

Moreover, it is well known that people might make a more positive evaluation of an object that could satisfy their needs (Ajzen, 2001). Unlike the finding regarding human facial processing that individuals with high fWHR tend to be negatively evaluated and individuals with low fWHR tend to be positively evaluated, recent behavioral research has suggested that objects with high fWHR could instead enjoy a higher level of perceived dominance and a more positive evaluation (being viewed as more rewarding) since dominant-looking objects can lead to an individual perceiving a more empowered self (Maeng & Aggarwal, 2018). As for perceived trustworthiness, many of the latest neuroscientific studies have shown that oxytocin in the striatum, which enhances the dopaminergic reward system, is positively associated with perceived trustworthiness (Ajzen, 2001; Bellucci, Münte, & Park, 2020; Delgado, 2007; Scheele et al., 2013; Strathearn, 2011). Specifically, the reward system is a complex brain area that inclines to rewards and the avoidance of punishments when exposed to certain stimuli (Hubert, Hubert, Linzmajer, Riedl, & Kenning, 2018). For instance, Bzdok et al. (2011) stated that reward circuitry might not only adjust people’s survival behavior (e.g., food acquisition or sexual behavior) but also modulate social attributions, especially trustworthiness. Recent neurophysiological evidence has supported the view that a more aroused reward system tends to have more specific dopaminergic effects on impression-based trust, triggering facial trustworthiness and inducing more cooperative behavior (Bellucci et al., 2020; Hubert et al., 2018). Accordingly, it is likely that a social robot with high fWHR could help people to perceive a more empowered self. This process is highly rewarding, which has specific dopaminergic effects on facial trustworthiness. Thus, it is reasonable to predict that, unlike people with high fWHR, who tend to be considered less trustworthy, a social robot with high fWHR might be generally regarded as more trustworthy. Formally stated,

H1: People tend to have a higher trustworthiness perception of a robot with a high fWHR face (vs. low fWHR)

Considering the consequent consumer behavior, it is logical that, if a person trusts an object or a robot, that person is more likely to approach that object or robot and even buy one (Billeter, Zhu, & Inman, 2012). Given this, in the commercial context of social robot promotion, a trustworthy-looking robot might enjoy a higher approach intention, eventually leading to higher purchase intentions. Although people with higher fWHR are perceived as less likable, a social robot with higher fWHR would enjoy higher purchase intentions. More specifically,

H2: People tend to have higher purchase intentions towards a robot with a high fWHR face (vs. low fWHR)

H3: Robot trustworthiness mediates the effect of fWHR on purchase intentions.

Regarding the significant role of shape in product or packaging design (Hsiao & Huang, 2002), the face shape of a social robot might also influence people's trustworthiness perceptions and purchase intentions. Generally speaking, there are two shapes in product design, round and rectangular (Westerman et al., 2012). Although considerable efforts have been made to explore the relationship between product form and its evaluation, there still is much controversy about the association between robot face shape and its subjective evaluation. On the one hand, looking back into the history of robotics, the rectangular face has been a typical design element for robots (Meeden & Blank, 2006). Furthermore, product typicality could help consumers to assign a product to a certain product category (Loken & Ward, 1990) and significantly promote its evaluation (Blijlevens, Carbon, Mugge, & Schoormans, 2012). On the other hand, people have shown a general preference and higher purchase intentions for round designs (vs. rectangular designs) (Westerman et al., 2012). In this way, we propose that, despite rectangular typicality in the robot form, round robot face shape might significantly increase people's trustworthiness perceptions and purchase intentions. Namely,

H4: Round (vs. rectangular) robot face shape significantly increases trustworthiness perceptions and purchase intentions.

Based on the hypotheses mentioned above, we propose the theoretical framework specified in Figure 1.

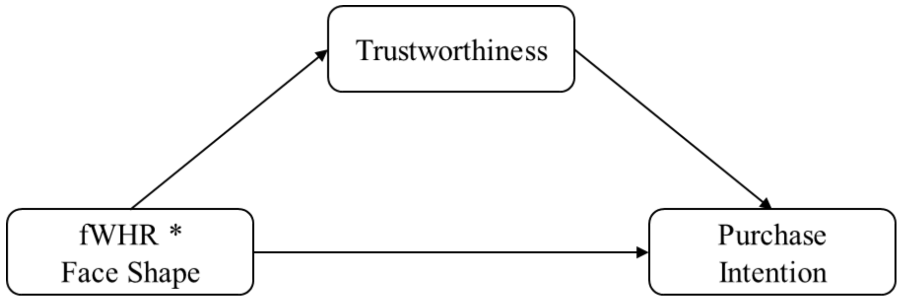


Figure 1. Theoretical model of the current study

2. Method

2.1 Experiment Design

As for the experimental design, a 2 (face shape) * 3 (fWHR) between-participants experiment was conducted. The experiment contained six different scenarios: two face shapes (round vs. rectangular) with three fWHR scenarios (high vs. medium vs. low; where high fWHR = 3:2, medium fWHR = 1:1, low fWHR = 2:3). We recruited a designer to make all of the experiment stimuli (see Figure 2). During the design process, we instructed the designer to control for potential confounding factors, such as robot facial expression, facial features, body height and width, color tone, and background. For example, in the design of robots with high fWHR, the rectangular-shaped head and the round-shaped head shared the same height, width, and proportions.

To examine the theoretical framework, we drew a sample from Amazon Mechanical Turk (AMT). AMT is a valid web-based platform that enrolls participants to complete a given task for compensation (Mortensen & Hughes, 2018). A significant amount of psychological, behavioral, and human-computer interaction research has been conducted via AMT, since it offers adequate accuracy (Khare et al., 2015) and reliability (Deal et al., 2016) compared with physical experiments (Brañas-Garza, Capraro, & Rascón-Ramírez, 2018). Accordingly, we considered it suitable and appropriate to draw a sample through this platform in order to analyze the relationship between robot design and people’s perceptions.

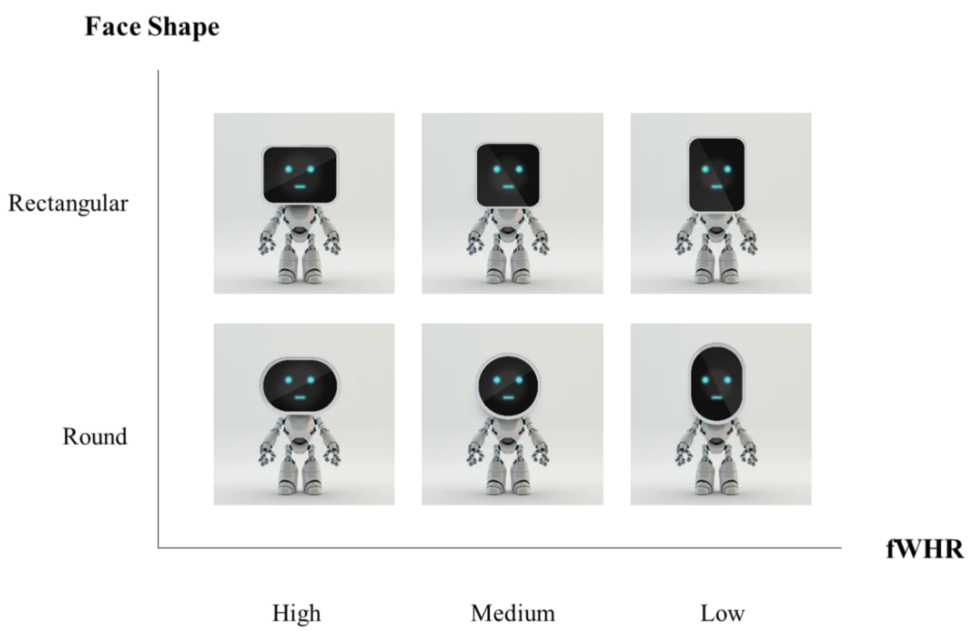


Figure 2. Robot design in the experiment

2.2 Experiment Procedure

Participants were informed of the general description of this study and consented to participate. Next, they were instructed to supply demographic information and randomly assigned to one of six scenarios (40 participants for each scenario). The participants were then exposed to the stimuli. They completed the manipulation check and the given questionnaire. Finally, they were instructed that they had completed the task.

With regard to the manipulation check, participants were asked to what extent they agreed with two statements by means of a nine-point Likert scale (“I think the face of this robot is wide”; “I think the shape of this robot’s face is round”). Regarding the dependent variables, people were similarly asked to express the extent of their agreement with the given statements by means of a nine-point Likert scale. Following the dimensions of trustworthiness (Colquitt et al., 2007), the perceived trustworthiness of a social robot was measured by three constructs (benevolence, ability, and integrity) with 17 items (Kim et al., 2020), and purchase intentions were measured by three items (Howard & Gengler, 2001). All the items used in this study are listed in the appendix.

3. Results

In total, 240 participants were enrolled in this experiment (mean age = 36.63; SD = 11.19). They were randomly and equally distributed into six scenarios (each scenario had 40 participants). Detailed demographic information regarding the participants is shown in Table 1.

Table 1. Demographic characteristics of participants

	Frequency	**Percent**		**Frequency**	**Percent**
Gender			**Education**		
Male	144	60.0%	High school graduate or lower	27	11.3%
Female	96	40.0%	Some college education	58	24.2%
			College graduate or above	155	64.5%
Age					
18–25	30	12.5%	**Robot interaction experience**		
26–30	59	24.6%	Never	169	70.4%
31–40	81	33.8%	0–1 year (1 year not included)	44	18.3%
41+	70	29.1%	1–2 years (2 years not included)	23	9.6%
			2+ years	4	1.7%

Before the main analysis, we checked the manipulation questions for fWHR and face shape. The results of the one-way ANOVA showed a significant difference between different fWHRs (mean = 6.15 vs. 7.29 vs. 7.78; SD = 2.08 vs. 1.68 vs. 1.37; $F(2, 237) = 18.35$, $p < 0.01$) and face shapes (mean = 2.81 vs. 6.45; SD = 2.57 vs. 2.31; $F(1, 238) = 132.59$, $p < 0.01$), suggesting that the manipulation of each factor was successful. As for the main analysis, we first analyzed the effect of fWHR and face shape on purchase intentions and the mediating role of perceived trustworthiness in this process. We then carried out a deeper investigation of the effect of fWHR on three dimensions of trustworthiness (benevolence, ability, and integrity).

More specifically, a two-way ANOVA was performed, with fWHR (low vs. medium vs. high) and face shape (round vs. rectangular) as the independent variables and with perceived trustworthiness and purchase intentions as the dependent variables. As for perceived trustworthiness, the internal consistency of the 17 items was evaluated by Cronbach's alpha coefficients (0.951), suggesting a satisfactory consistency and reliability (Song & Luximon, 2019; Song, Luximon, & Luo, 2020). The results of the two-way ANOVA showed that the main effect of fWHR on trustworthiness evaluation was significant ($F(2, 234) = 6.01$, $p < 0.01$), while the effect of face shape ($F(1, 234) = 0.28$, $p = 0.60$) and the interaction effect were not significant ($F(2, 234) = 0.12$, $p = 0.89$). Specifically, post hoc tests revealed that robots with high fWHR and medium fWHR showed significantly higher trustworthiness perceptions than those with low fWHR. However, the robot with the medium fWHR did not show significantly different trustworthiness perceptions compared with the high fWHR scenario. Thus, H1 is supported (see Tables 2 and 3).

Table 2. Descriptive statistics for trustworthiness and purchase intentions in different fWHR and face shape scenarios

		fWHR (Mean ± SD)			
		Low	Medium	High	Total
Trustworthiness					
Face shape	Rectangular	5.38 ± 1.41	5.92 ± 1.84	6.08 ± 1.53	5.79 ± 1.62
	Round	5.35 ± 1.79	6.05 ± 1.35	6.29 ± 1.37	5.90 ± 1.56
	Total	5.36 ± 1.60	5.99 ± 1.61	6.18 ± 1.45	5.85 ± 1.59

Purchase intentions					
Face shape	Rectangular	4.19 ± 2.24	4.88 ± 2.42	5.26 ± 2.02	4.78 ± 2.26
	Round	4.14 ± 2.39	4.67 ± 2.39	5.37 ± 2.52	4.73 ± 2.46
	Total	4.17 ± 2.30	4.77 ± 2.39	5.31 ± 2.27	4.75 ± 2.36

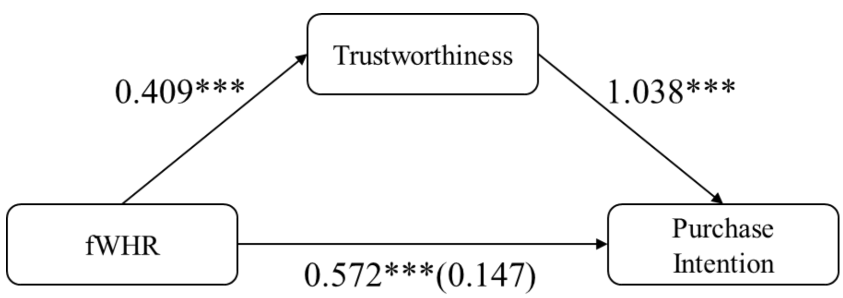
Table 3. Post hoc comparisons and effect sizes for trustworthiness and purchase intentions between different fWHR scenarios

	Mean difference	SE	*t* statistic	Cohen's d	Effect size	*p* (Tukey)	95% CI	
							Lower bound	Upper bound
Trustworthiness								
Low–Medium	−0.624	0.247	−2.526	−0.389	Medium	< 0.05	−1.206	−0.041
Low–High	−0.819	0.247	−3.318	−0.537	Large	< 0.01	−1.401	−0.237
Medium–High	−0.196	0.247	−0.792	−0.128	Small	0.708	−0.778	0.387
Purchase intentions								
Low–Medium	−0.604	0.369	−1.637	−0.257	Medium	0.232	−1.475	0.267
Low–High	−1.146	0.369	−3.104	−0.502	Large	< 0.01	−2.017	−0.275
Medium–High	−0.542	0.369	−1.467	−0.232	Medium	0.309	−1.412	0.329

Note: Effect size classification follows Cohen's work (2013)

In terms of purchase intentions (Cronbach's alpha = 0.954), we similarly found that fWHR has a significant effect on purchase intentions ($F(2, 234) = 4.82$, $p < 0.01$), though the effect of face shape ($F(1, 234) = 0.03$, $p = 0.87$) and their interaction effect were not significant ($F(2, 234) = 0.09$, $p = 0.91$). Specifically, people showed significantly higher purchase intentions towards the robot with high fWHR than the robot with low fWHR. There was no significant difference in purchase intentions between robots with medium fWHR and high fWHR and between robots with medium fWHR and low fWHR. Thus, H2 is supported (see Table 2 and 3). People tended to have similar purchase intentions when faced with a robot with a round face compared to a robot with a rectangular face. Thus, H4 is not supported.

To examine H3, the mediation role of trustworthiness in this process, we regressed the purchase intentions on fWHR through the PROCESS SPSS macro (Model 4, n = 10000 resamples (Hayes, 2015)). The results showed that fWHR (coded as 1 = low, 2 = medium, and 3 = high) had a significant and positive effect ($\beta = 0.409$, SE = 0.122, $p < 0.01$) on perceived trustworthiness, which suggests that an increase in the fWHR of a robot could elicit perceived trustworthiness. Moreover, perceived trustworthiness had a positive and significant effect on purchase intentions ($\beta = 1.038$, SE = 0.069, $p < 0.01$). Importantly, the results revealed that fWHR had a non-significant ($\beta = 0.147$, ns) direct effect on purchase intentions, but a significant and positive indirect effect on purchase intentions via perceived trustworthiness ($\beta = 0.425$, 95% confidence interval: 0.183‒0.673; see Figure 3 for a summary of results). Thus, the results indicate that fWHR has an indirect effect only on consumers' purchase intentions via perceived trustworthiness (Hayes, 2015). In full support of H3, these findings confirm that perceived trustworthiness mediates the effect of fWHR on purchase intentions.



Note: *** means $p < 0.01$

Figure 3. The effect of fWHR on purchase intentions with perceived trustworthiness as the mediator

Considering the three constructs of trustworthiness, the same two-way ANOVA was performed with ability (Cronbach's alpha = 0.945), benevolence (Cronbach's alpha = 0.885), and integrity (Cronbach's alpha = 0.914) as the respective dependent variables. This was aimed at providing a deeper understanding of the sub-dimensions for trustworthiness in HRI. Similar observations are found in the results (Tables 4 and 5). For the dimension of ability, fWHR had a significant impact on perceived ability ($F(2, 234) = 5.69$, $p < 0.01$; high fWHR was associated with a significantly higher level of perceived ability, compared with low fWHR), though face shape ($F(1, 234) = 0.85$, $p = 0.36$) and their interaction ($F(2, 234) = 0.14$, $p = 0.87$) did not have a significant effect on perceived ability. For the dimension of benevolence, fWHR had a significant impact on perceived benevolence ($F(2, 234) = 3.29$, $p < 0.05$; high fWHR was associated with a significantly higher level of perceived benevolence, compared with low fWHR), though face shape ($F(1, 234) = 0.18$, $p = 0.67$) and their interaction ($F(2, 234) = 0.25$, $p = 0.78$) did not have a significant effect on perceived benevolence. For the dimension of integrity, fWHR had a significant impact on perceived integrity ($F(2, 234) = 5.36$, $p < 0.01$; both high and medium fWHR were associated with a significantly higher level of perceived ability than low fWHR), though face shape ($F(1, 234) = 0.77$, $p = 0.38$) and their interaction ($F(2, 234) = 0.91$, $p = 0.40$) did not have a significant effect on perceived ability.

Table 4. Descriptive statistics for ability, benevolence, and integrity in different fWHR and face shape scenarios

		fWHR (Mean ± SD)			
		Low	Medium	High	Total
		Ability			
Face shape	Rectangular	5.68 ± 1.74	6.35 ± 1.62	6.61 ± 1.49	6.21 ± 1.65
	Round	6.02 ± 1.85	6.46 ± 1.32	6.72 ± 1.35	6.40 ± 1.54
	Total	5.85 ± 1.79	6.41 ± 1.47	6.67 ± 1.41	6.31 ± 1.60
		Benevolence			
Face shape	Rectangular	5.06 ± 1.86	5.70 ± 2.23	5.63 ± 1.80	5.46 ± 1.98
	Round	4.85 ± 2.16	5.44 ± 1.93	5.77 ± 1.78	5.35 ± 1.98
	Total	4.95 ± 2.01	5.57 ± 2.08	5.70 ± 1.78	5.40 ± 1.98
		Integrity			

	Rectangular	5.35 ± 1.52	5.68 ± 2.17	5.93 ± 1.85	5.65 ± 1.86
Face shape	Round	5.11 ± 2.10	6.16 ± 1.46	6.29 ± 1.48	5.85 ± 1.77
	Total	5.23 ± 1.83	5.92 ± 1.85	6.11 ± 1.67	5.75 ± 1.82

Table 5. Post hoc comparisons and effect sizes for ability, benevolence, and integrity in different fWHR scenarios

	Mean difference	SE	*t* statistic	Cohen's d	Effect size	*p* (Tukey)	95% CI	
							Lower bound	Upper bound
Ability								
Low–Medium	−0.560	0.249	−2.254	−0.342	Medium	0.065	−1.147	0.026
Low–High	−0.821	0.249	−3.301	−0.509	Large	< 0.01	−1.407	−0.234
Medium–High	−0.260	0.249	−1.047	−0.181	Small	0.548	−0.847	0.326
Benevolence								
Low–Medium	−0.615	0.311	−1.978	−0.301	Medium	0.120	−1.349	0.119
Low–High	−0.747	0.311	−2.404	−0.394	Medium	< 0.05	−1.481	−0.014
Medium–High	−0.132	0.311	−0.426	−0.069	Small	0.905	−0.866	0.601
Integrity								
Low–Medium	−0.694	0.283	−2.454	−0.377	Medium	< 0.05	−1.360	−0.027
Low–High	−0.877	0.283	−3.103	−0.501	Large	< 0.01	−1.544	−0.210
Medium–High	−0.183	0.283	−0.649	−0.104	Small	0.793	−0.850	0.483

Note: Effect size classification follows Cohen's work (2013)

4. Discussion

This study examined the effect of fWHR, face shape, and their interaction on perceived trustworthiness and purchase intentions in the context of HRI. With regard to fWHR, we found that the fWHR of a social robot played an essential role in signaling the trustworthiness of social robots. Unlike the effect of fWHR on perceived trustworthiness in interpersonal settings, it produced a counter-effect on perceived trustworthiness in HRI: Robots with high fWHR had higher levels of perceived trustworthiness while those with low fWHR had lower levels of perceived trustworthiness. This counter-intuitive phenomenon is consistent with previous findings on specific humanlike objects which act as instruments for self-completion (Maeng & Aggarwal, 2018). Individuals can experience, represent, and aggrandize an empowered self-image through their dominant-looking (high fWHR) objects (Decety & Sommerville, 2003). This process activates the dopaminergic reward system, causing people to have a more positive attitude towards the object, eventually resulting in a higher level of perceived trustworthiness (Ajzen, 2001; Bellucci et al., 2020).

Regarding face shape, previous research has shown a nuanced relationship between the robot's shape and its evaluation: People have exhibited a preference for round designs, while the typical shape (rectangular) of a robot would also be appreciated in some situations (Meeden & Blank, 2006; Westerman et al., 2012). Our results indicated that there seems to be no significant difference between these two shapes: The desire for a rounded shape might be, in turn, counteracted or neutralized by people's typicality preferences, resulting in the insignificant effect of face shape on trustworthiness evaluation.

Considering the fine-grained nature of trustworthiness in HRI (Calhoun et al., 2019), we carried out a deeper investigation into the three constructs (ability, benevolence, and integrity) of trustworthiness. The results illustrated that fWHR has a significant impact on all three dimensions (high fWHR is associated with a high level of ability, benevolence, and integrity), though there is no statistical difference for face shape and their interaction. This finding is consistent with the counter-effect of fWHR in the interpersonal context: While high fWHR in a human could decrease perceived integrity (Ormiston et al., 2017), high fWHR in a social robot might increase trust-based dimensions (ability, benevolence, and integrity), eventually leading to enhanced trustworthiness (Kim et al., 2020).

The current study makes several theoretical contributions. First of all, although previous research on facial trustworthiness has drawn great academic interest, it has mainly focused on the context of human beings. Few attempts have been made to expand this conversation to a larger field. For instance, though a recent study by McGinn (2019) suggested that a social robot with a human-like head could influence people's social evaluations, the conclusion is focused on the general discussion of robot morphology, thus ignoring the effect of specific facial features. Accordingly, it would be theoretically significant to explore whether we could utilize the results of previous work on facial trustworthiness in the facial design of social robots. By means of a behavioral experiment, our research implies that facial trustworthiness features, such as fWHR, could be adapted for purpose of social robot design and could influence people's subsequent evaluations.

In addition, the current study contributes to the literature on HRI by demonstrating how facial features, such as fWHR, could work as one of significant means to communicate trustworthiness. Previous research on HRI has explored the general relationship between robot design, "beauty premium" and "plainness penalty," and people's evaluations; however, there has been little research into the potential effect on robot trustworthiness. Based on the theory of human facial trustworthiness, our work implies that, in terms of facial cues, there might be a counter-intuitive relationship between robot facial evaluation and human facial evaluation. While people with high fWHR might be perceived as less trustworthy, a robot with high fWHR might be considered as more trustworthy and be the object of higher intentions to purchase.

The current study also has several practical implications. Compared with other industrialized products, social robot design is still an emerging market that lacks efficient, specific, and detailed guidance. From the perspective of social robot production, companies might mainly rely on competitive analysis and sales data and then focus on one or two intuition-based design elements (Vanderborght et al., 2012). However, this may be an ineffective way to communicate specific information to consumers, and in some cases it might even dampen brand equity (Ulrich, 1992). In this way, the current study could give preliminary suggestions regarding robot faces to improve their trustworthiness perceptions.

There are some limitations worth noting, which require further investigation. To begin with, this research focused only on the influence of fWHR on perceived trustworthiness; although fWHR is one of the most prominent facial features, it is merely an external feature of a face (Santos & Young, 2011). There are many other facial features, such as internal features and facial expression. For example, eyes and mouths are believed to be the most prominent internal features of a face. According to the facial trustworthiness literature, round eyes (vs. narrow eyes) are a significant facial signal for communicating trustworthiness (Ferstl et al., 2017). Similar observations are also found in the perception of mouth shape (Santos & Young, 2011). It would be theoretically interesting to examine whether these traits could also be applied in robot design, eventually influencing people's evaluations, as was found to occur in this study.

In addition, this study mainly discussed the way in which consumers' purchase intentions might be affected by different facial ratios in social robots. Although the theory of planned behavior indicates that behavioral intention can to some extent reveal people's motivations for a given behavior, it is just an indication of an individual's willingness to take real action (Cheung & To, 2017). Indeed, previous studies have suggested that people's perceptions or intentions do not necessarily lead to real-life behavior (Wee et al., 2014). Therefore, the conclusion of this study can only reflect people's intentions to carry out activities when interacting with robots at first sight. In order to examine their actual behavior towards robots with the proposed facial features, a field experiment is planned to validate the current conclusions and further explore the other aspects that affect trust in HRI.

Lastly, the current study mainly discussed the affiliation role of social robots in people's daily lives. In other words, currently, social robots mainly work as passive "responders." However, as social robots develop, they might also play dominant roles currently carried out by humans. For example, they could serve as firefighters when faced with an emergency. They might also function as pilots, not only operating planes but also leading passengers. Thus, it might also be interesting to explore whether different social roles moderate the effect of facial features on people's evaluations and reactions.

5. Conclusions

As one of the most recent applications in the field of artificial intelligence, social robots are playing an increasingly important role in people's daily lives. Since they are able to not only follow people's commands but also meet people's emotional needs (Saunderson & Nejat, 2019), it is natural that social robots should be carefully designed. In addition, trustworthiness evaluations are not exclusively applicable to other humans; indeed, we might also have a trustworthiness perception of an object or a robot. Thus far, however, few attempts have been made to explore perceived robot trustworthiness and how robot facial appearance, particularly the fWHR and face shape of a robot, influences people's evaluations, such as perceived trustworthiness and purchase intentions. In order to fill this research gap, our study employed an experimental method to explore the effect of fWHR and face shape on people's trustworthiness perceptions and the associated purchase intentions in the context of a social robot. The results showed the following: (1) fWHR is a significant factor in influencing robot trustworthiness and purchase intentions; (2) people tend to report higher levels of perceived trustworthiness and purchase intentions towards a social robot with high fWHR than a social robot with low fWHR; (3) there is no significant difference in perceived trustworthiness and purchase intentions between high-fWHR scenarios and medium-fWHR scenarios and between low-fWHR scenarios and medium-fWHR scenarios; (4) neither face shape nor its interaction effect (face shape * fWHR) has a significant effect on perceived trustworthiness and purchase intentions; and (5) the effect of fWHR on purchase intentions is mediated by perceived trustworthiness.

Appendix. Items for trustworthiness and purchase intentions in this study

Attribute	**Dimensions**	**Items**
Trustworthiness (17)	Ability (6)	The robot appears capable of performing its job
		The robot appears to succeed at the things it tries to do
		The robot appears to acknowledge the work that needs to be done
		I feel very confident about the robot's skills
		The robot appears to have specialized capabilities that can increase performance
		The robot appears well qualified
	Benevolence (5)	The robot appears concerned about other's welfare
		The needs and desires of others are important to the robot
		The robot appears it would not knowingly do anything to hurt people
		The robot looks out for what is important to others
		The robot appears it would go out of its way to help others
	Integrity (6)	The robot appears to have a strong sense of justice
		I never have to wonder whether the robot will stick to its word
		The robot appears to be unbiased towards people
		The robot's actions and behaviors are not consistent
		I like the robot's values
		Sound principles seem to guide the robot's behavior
Purchase Intentions (3)		I am willing to buy the robot
		The likelihood for me to purchase the robot is high
		The probability that I would consider buying the robot is high

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