Acute or a Cute Robot?

The Effect of Angularity on Medical Service Robot Perception

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Abstract

Despite the importance of medical care, one in three Americans avoid doctor visits (Cleveland Clinic Medical Professional, 2021). Considering our modernizing world, applying robotics to healthcare, particularly with Medical Service Robots (MSRs), yields the potential to improve patient engagement and overall care ("Medical robots," n.d.). Recognizing the impact of design on user perceptions, the purpose of this study was to manipulate the angularity and curvature of MSR designs to reduce perceived threat and increase warmth and trust among patients. Participants (N=230) were randomly assigned to one of three conditions: curved MSR design, angular design, or a no-image control group. After viewing the stimulus, participants answered Likert-type scales that measured their perception of them. ANOVA tests revealed that perceived trust was unaffected by angularity, while perceived warmth approached significance ($p = .06$). Significant effects were found for preference ($p = .02$) and perceived threat ($p = .04$), with the curved MSR design being most preferred and the angular version perceived as most threatening. Additionally, gender was found to have a significant main effect for preference ($p < .01$), warmth ($p = .04$), and trust ($p = .04$) as males rated the robots higher than females. These findings can be used to create MSR designs that are most positively perceived, thus optimizing their ability to improve patient care.

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Despite the importance of medical care, one in three Americans report that they avoid medical visits (Cleveland Clinic Medical Professional, 2021). Considering our rapidly modernizing world, applying robotics to this field may have the potential to improve patient engagement and overall care. Particularly, Medical Service Robots (MSRs), robots that interact with patients, can serve as a tool in medicine as they possess the potential to create efficiencies. More specifically, MSRs can alleviate the workload of healthcare staff by performing monotonous tasks and routine tests (ex. drawing blood), enabling staff to focus on providing more direct care to patients ("Medical robots," n.d.). Additionally, MSRs are immune to illness, thus possessing the ability to protect doctors in the face of contagious disease (ex. Covid 19) while still providing care and treatment to patients ("Medical robots," n.d.). The diverse benefits and applications of MSRs reinforce their potential to improve patient care by serving as a tool for doctors and staff alike.

The design of MSRs plays a crucial role in shaping the impressions and opinions of users (Hegel et al., 2009). By manipulating elements in design and appearance, one can change the way an image is perceived. This technique is commonly used in character design, where specific shapes are associated with evoking particular emotions. For instance, designs that incorporate curved shapes are typically associated with warmth and friendliness while designs that incorporate triangles and sharp angles typically evoke feelings of fear (Naghdi, 2021). This concept can be applied to MSRs in order to create a design that projects positive emotions. The purpose of this study was to manipulate the angularity and curvature of MSR designs to

decrease perceived threat and increase perceived warmth and trust to patients.

Previous research has found that curved stimuli are preferred to their angular counterparts. For instance, one study which manipulated the contour of smartphones found that the curved version was preferred to the angular (Lu & Ho, 2013). Similarly, Silvia and Barona (2008) conducted a study utilizing angular and round polygons as stimuli, and found that participants preferred the round, circular polygons significantly more than the angular, hexagonal ones. Additionally, another study observed the perceptions of two green (environmentally conscious) brand logo designs that varied in their application curvature and angularity. The findings show that participants preferred the round logo brand design (Meiting & Hua, 2021). Despite the diversity in stimuli across these studies, the findings consistently reveal that curvature is favored over angularity. Oros et al. (2014) expanded on this insight by exploring preference in children regarding therapy service robot designs. Their stimuli involved five robot designs that varied in aspects including human-likeness/animal-likeness, gender, and round/sharp edges. The results revealed that children most preferred the designs that were characterized by curvature. The robotic stimuli of this study are closely related to the stimuli of the current, indicating that preference for curvature likely extends to MSR designs.

Previous research has found that curved shapes are associated with warmth. For instance, in a study which manipulated angularity and curvature of green brand logos, participants perceived the rounded logo as significantly warmer compared to its angular counterpart (Meiting & Hua, 2021). Other studies did not directly observe the effects of curvature on perceived warmth; however, they portrayed that curved shapes are perceived as more pleasant. In a study

that tested implicit associations between downwards pointing “V” shapes versus curved “U”

shapes, it was found that the “U” shapes were implicitly regarded as more pleasant than the angled shapes (Larson et al., 2012). This was assessed using the Implicit Association Test, revealing that individuals have a warm and pleasant “gut” reaction toward curved shapes. Additionally, Bar and Neta (2006) adopted curved and angular versions of emotionally neutral objects (eg. sofa, wristwatch) as their stimuli. Emotionally neutral objects were deliberately used in this study to ensure that previous associations of the image did not override the influence of curvature, a concept known as the familiarity effect. Their results showed that participants perceived the curved versions as most positive. Based on these findings, one may associate that the pleasant perceptions evoked by the stimuli stem from positive emotions and associations such as warmth and comfort. Therefore, one can predict that curvature contributes to warmth individuals experience.

In contrast, angular shapes have been found to evoke feelings of threat. In a study that tested implicit associations between downwards pointing “V” shapes versus curved “U” shapes, it was found that the “V” shape was associated with threat and unpleasantness (Larson et al., 2012). Friedenberg et al. (2023) expanded on this by measuring the effect of angularity degree on perception. Their study incorporated angles ranging from 0 to 180 degrees, revealing that the sharper (more acute) the angle, the more it was perceived as threatening. Additionally, among Bar and Neta’s (2006) stimuli consisting of emotionally neutral objects (eg. wristwatch, sofa), the angular versions of the image conveyed a sense of threat, eliciting a negative bias in

comparison to the rounded counterparts. To expand upon their initial study, Bar and Neta (2007) attempted to explain the origin of the angularity phenomenon. To achieve this, they observed brain region activation in participants when viewing the angular version of emotionally neutral

objects. Their findings revealed an increased activation of the amygdala, the region of the brain responsible for processing threatening and fear-evoking stimuli, indicating an implicit connection between threat and angularity. This relationship has been shown to stem from an evolutionary mechanism that allowed early humans to rapidly recognize dangers. Previous research has observed this response activate in the presence of sharp angles, especially when viewing unique and novel stimuli.

Little research has been conducted on the effects of curvature and angularity on perceived trust. However, existing studies suggest that curved shapes elicit trust. For instance, Bernotat et al. (2019) conducted a study on the impact of robot waist-to-hip ratio (WHR) and shoulder width (SW) on perceived gender and trust. The findings revealed that the female (more curved) featured robot (large WHR and small SW ratio) was attributed more trust than its counterpart (Bernotat et al., 2019). This concept is crucial to investigate in the context of MSRs because it can reveal people's trust towards the robot's performance. Based on the increased sense of threat evoked by angular figures (Bar & Neta, 2006, Friedenberg et al., 2023, Larson et al., 2012, Silvia & Barona, 2008), one could predict that angularity will not contribute to an increase in trust. Rather, round figures, which research has associated with warmth and higher preference (Silvia & Barona, 2008, Meiting & Hua, 2021), will be considered less threatening and hence more trustworthy.

To understand the effects of angular and curved MSR designs on people's perception of them, this study seeks to explore preference, perceived warmth, threat, and trust. Although research has been conducted on the perceptions of round and angular shapes, this concept has not been applied to MSR designs, rendering it a novel aspect of this study. This

application is important to investigate because it can facilitate the development of MSR designs that patients find warm and comforting. This would enhance positive interactions between the robot and patient, thus optimizing their impact on society. Furthermore, limited research has been conducted regarding the perceived trust of MSR designs. However, this topic is crucial to investigate in order to identify people's perceptions of MSRs and the impact of their designs. In light of the limited research conducted on this topic, perceived trust is considered to be another novel aspect of this study.

Based on previous research, it was hypothesized that compared to both the angular MSR and no image shown conditions, a curved MSR…

- Will be preferred
- Will be perceived as more warm
- Will be perceived as less threatening
- Will be perceived as more trustworthy

Methodology

Participants

Participants were recruited on the website Prolific. Screeners were applied to source a population of American young adults. These conditions include residing in the United States of America, being fluent in English (for survey comprehension purposes), and being between 18-25 years of age. This particular age restriction was applied as young adults are most likely to be the generation to witness the implementation of MSRs. Therefore, it is particularly important to

gauge their perceptions of these robots. In total, 230 responses were collected. One hundred twenty-five of the participants were male and 105 were female.

Variables

The independent variable of this study was the angularity and curvature of MSR designs. This variable had three levels: an angular MSR condition, a curved MSR condition, and a no image condition. The no image condition served as a control group as it was used as a base of comparison for the other two conditions.

The dependent variables were preference, perceived warmth, threat, and trust. These variables were measured using scales adapted from previous studies that demonstrated their validity and reliability. Preference was evaluated using a single-item measure which asked participants to indicate the extent to which they agree with the statement, "I like the visual appearance of the robot." Additionally, warmth was measured using a four-item scale adapted from Cuddy et al. (2009) which had a Cronbach's alpha value of .892. This involved rating the extent to which the MSR exhibits certain adjectives, such as "friendly" and "warm," among others. Perceived threat was assessed using a one item measure developed by Friedenberg et al.

(2023). For this, participants were provided with a basic definition of threat, a threat is something that appears dangerous and can inflict pain or cause potential harm, and then were asked to evaluate the level of threat posed by the MSR based on this definition. Lastly, perceived trust was measured using a six-item trust scale adapted from Bernotat et al. (2019). This scale had a Cronbach's alpha of .882. All survey items were adapted as six-point Likert scales.

Stimuli/Materials

The stimuli were created using the digital art program Procreate. All aspects of the designs were kept constant except contour (See Figure 1). The robots were colored blue as research by Oros et al. (2014) demonstrated that blue is the most suitable color for healthcare settings. Additionally, the robots were designed with features including a caduceus symbol to indicate their medicinal purposes and a compartment on their "stomach." The compartment drawer, a common feature of MSRs, enables them to transport goods around the setting. Other features include wheels for mobility and arms for interacting with the environment.

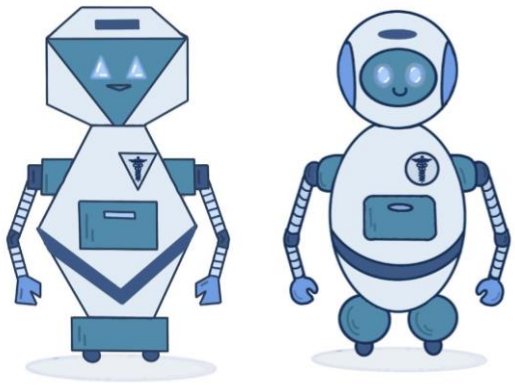

Figure 1: Curved and Angular Versions of the MSR designs

The survey was designed on the website, Qualtrics. Participants were given a consent form and only those who agreed to participate were included in the study. After giving consent, participants were randomly assigned their condition and a description of the MSR. The description was identical across all conditions as it explained the functions of MSRs. The general purpose of the design features (ex. Compartment drawer) was also defined. After viewing the stimulus, participants were asked to answer the scales for each variable, demographic questions, and a manipulation check.

Results

Preference Results (Hypothesis 1)

A one-way ANOVA revealed a statistically significant difference between the rating of preference among the conditions, $F(2,230) = 3.80$, $p = .02$. Figure 2 portrays the mean ratings across all three conditions, the curved MSR having the highest rating of 4.81, the no image condition having a mean rating of 4.41, and the angular MSR having the lowest rating of 4.38. In other words, of the three conditions, the curved MSR was most preferred.

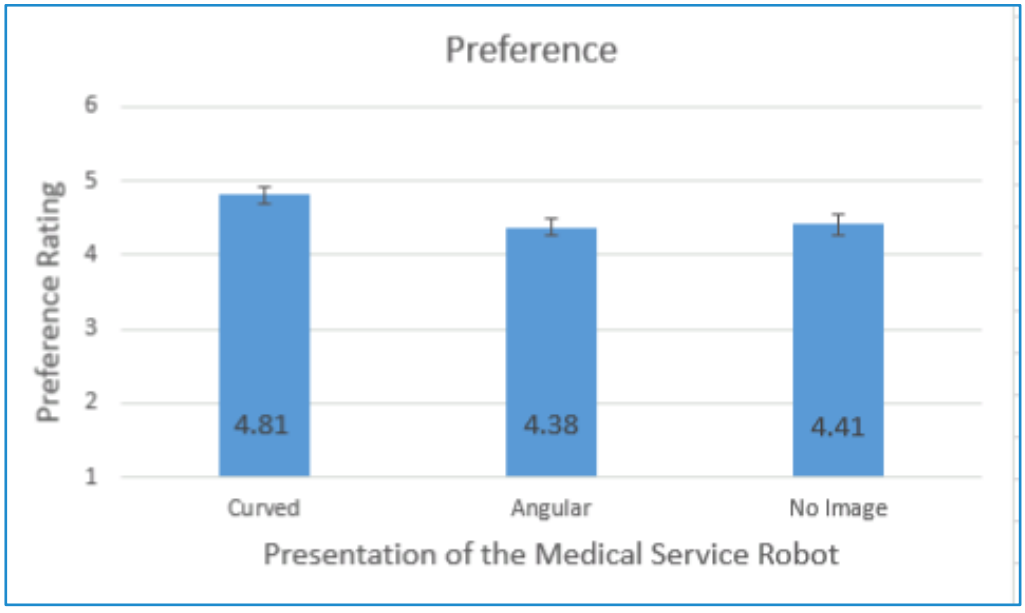

Figure 2: The Effect of Angularity on Preference

Warmth Results (Hypothesis 2)

A one-way ANOVA analyzing the effect of angularity on perceived warmth did not demonstrate statistical significance, $F(2,230) = 2.94$, $p = .06$. Consequently, the hypothesis was refuted. Figure 3 depicts the mean rankings of perceived warmth; namely, the curved version with mean rank of 2.97, angular mean rank of 2.79, and no image mean rank of 2.69. Although the main effect was not significant, the Post Hoc test reveals that the curved MSR was significantly more preferred to the no image condition ($p < .01$).

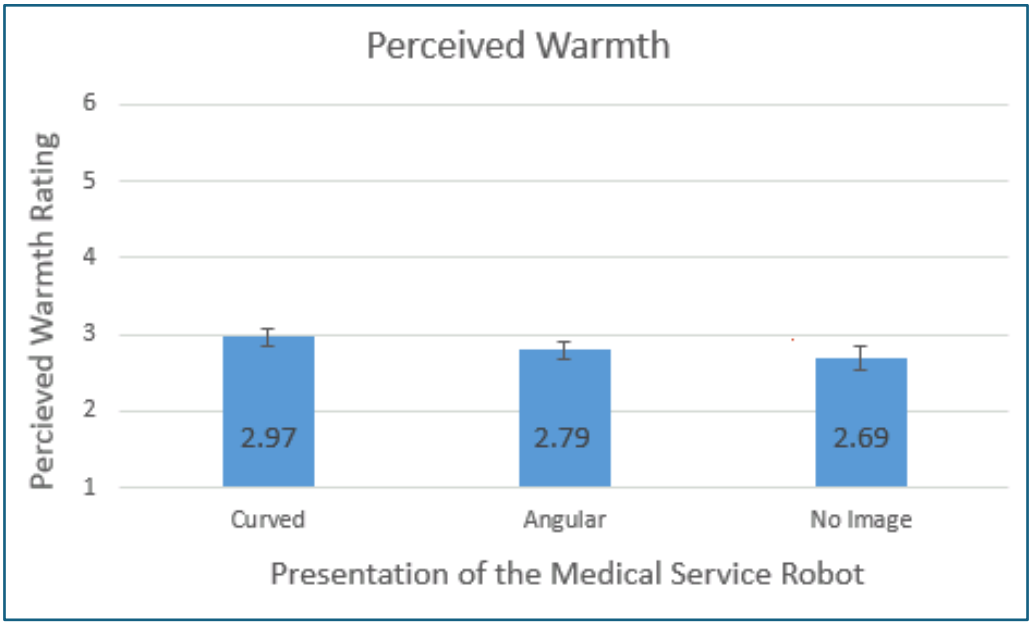

Figure 3: The Effect of Angularity on Perceived Warmth

Threat Results (Hypothesis 3)

. The results of a one-way ANOVA analyzing perceived threat revealed a statistically significant difference, $F(2,230)= 3.18$, $p=.04$. Figure 4 portrays the mean ranks across the conditions; the curved MSR with a mean rank of 2.3, angular MSR with a mean rank of 2.82, and the no image condition with a rank of 2.66. The results are consistent with the direction of the hypothesis as the angular MSR was perceived to be most threatening.

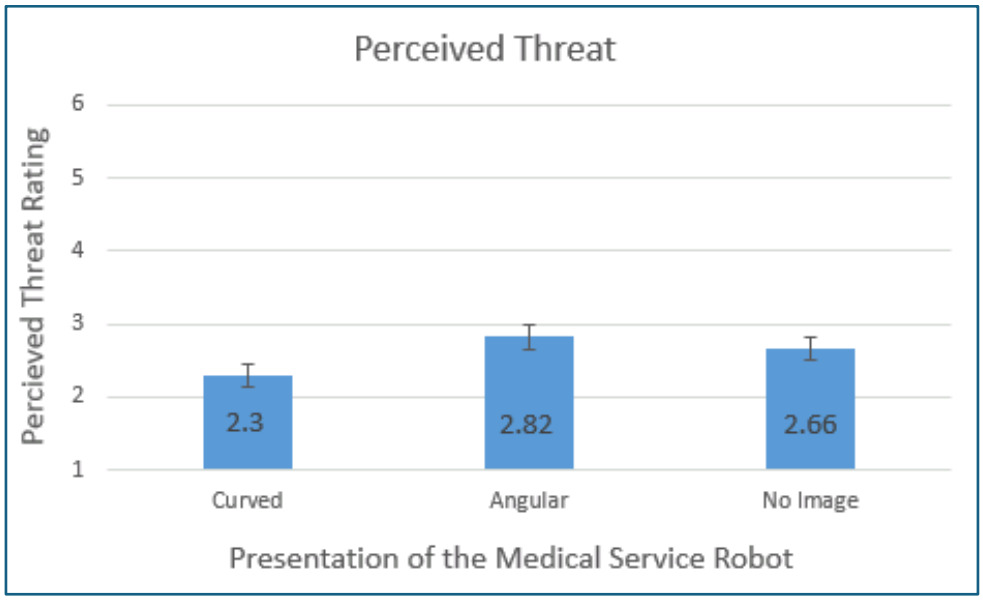

Figure 4: The Effect of Angularity on Perceived Threat

Perceived Trust (Hypothesis 4)

The one-way ANOVA analyzing the effect of angularity on perceived trust did not portray statistically significant results, $F(2,230)= .69$, $p=.50$. As a result, the hypothesis was refuted. Figure 5 depicts the relationship between angularity and perceived trust. The values represent the mean ratings for each condition (curved MSR: 4.35; angular MSR: 4.16; and no image condition: 4.23). As portrayed by the graph, there was minimal variation across the three conditions.

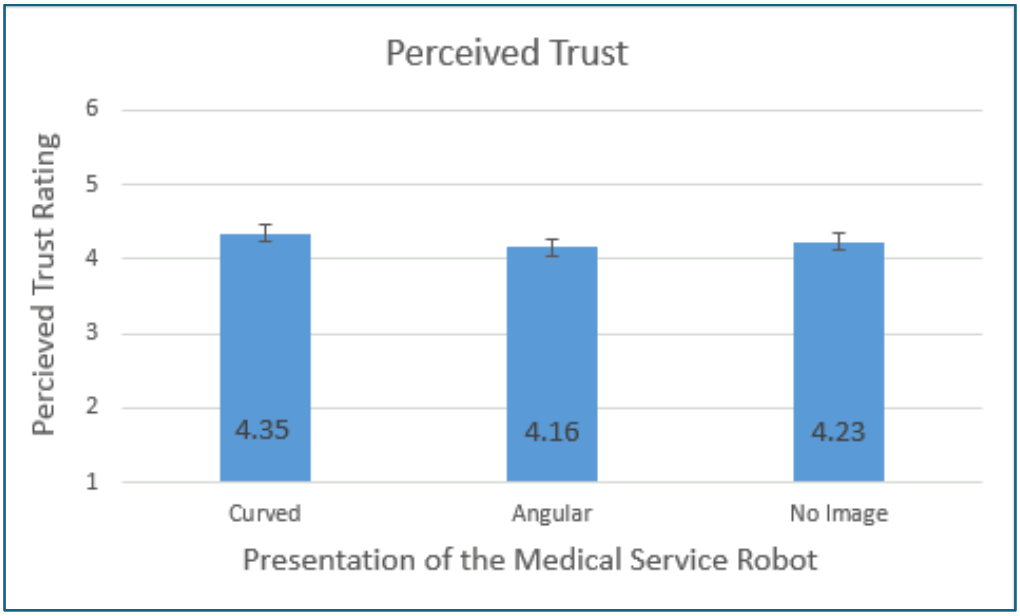

Figure 6: The Effect of Angularity on Perceived Trust

Gender Results

ANOVAs were also run to analyze the effect of gender on perception. None of the interactions were significant, however, there were notable main effects. More specifically, perceived threat did not exhibit a statistically significant relationship, however, preference ($F(1,230) = 7.10$, $p < .01$), warmth ($F(1,230) = 4.10$ $p = .05$), and trust ($F(1,230) = 4.50$ $p = .04$) did. Figure 7 portrays gender main effects for all the variables. Across preference, perceived warmth, and perceived trust, males rated the MSRs higher than women.

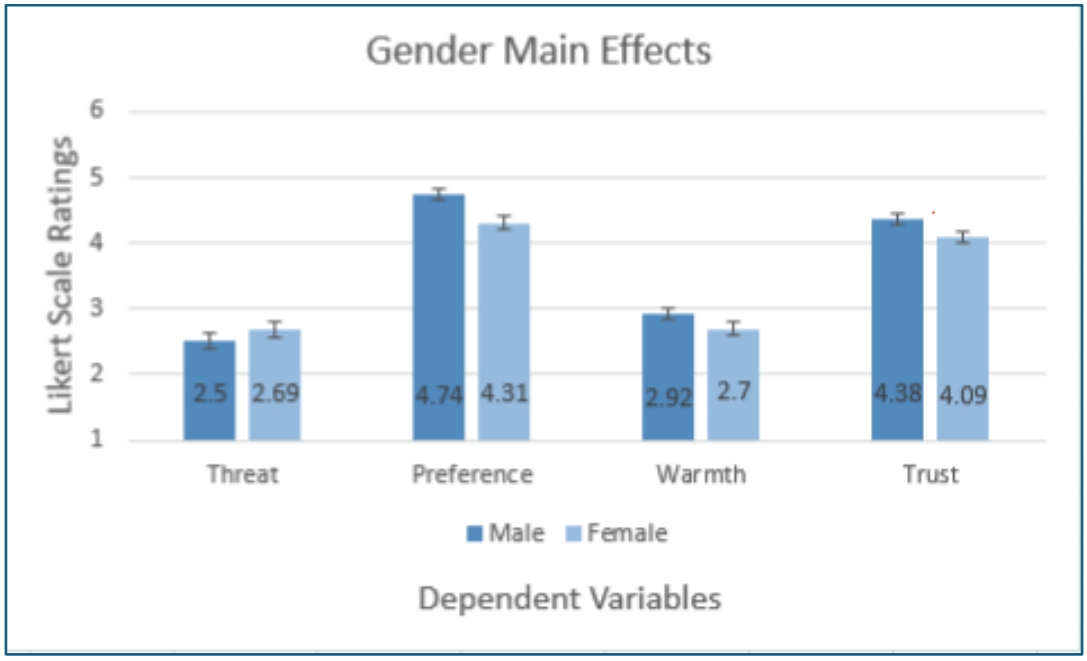

Figure 7: The Effect of Gender on MSR Perception

Discussion

Preference

The results demonstrated that the curved MSR was the most preferred version. These results are not generally considered surprising given the previous studies that demonstrate a higher preference for curved stimuli (Lu & Ho, 2013; Meiting & Hua, 2021; Oros et al. 2014; Silvia & Barona, 2008). In other words, in terms of MSR perceptions, designs that incorporate curvature will be more preferred in comparison to angular ones.

Perceived Warmth

This study did not find a statistically significant relationship between angularity and perceived warmth. Although the p value did not meet the threshold of $< .05$, the relationship approached significance as the p value was .06. This finding was considered surprising since Meiting and Hua's study (2021) found that participants rated the round version of a logo design as more warm than its angular counterpart. When performing multiple comparisons between the variables, no significant difference was found between curvature and angularity. However, participants rated the curved MSR as significantly more warm than the no image condition ($p<.01$). This relationship most likely accounts for the approaching significance of the main effect. A potential explanation for this finding involves that perhaps with no image at all, participants found it difficult to attribute warmth. This reveals that the appearance of a subject, in

this case MSRs, is a vital aspect in perceiving warmth, as it allows the viewer to connect with the subject and potentially experience reassurance.

Perceived Threat

The results portrayed a significant relationship between angularity and perceived threat. Namely, angularity contributes to an increased sense of perceived threat. This finding is not particularly surprising as it is consistent with the numerous studies demonstrating that angularity elicits fear and threat (Bar & Neta, 2006, 2007; Friedenberg et al., 2023; Larson et al., 2012). Consequently, the hypothesis was supported, as the angularity of the MSR triggered a negative bias.

As highlighted by Bar and Neta (2007), angularity evokes a sense of fear by activating

the amygdala, a response rooted in evolutionary adaptation. This activation proved beneficial for early humans as it enabled them to protect themselves against potential threats. However, its activation in the presence of angular MSRs is negative as it would lead to ineffective interactions, given that patients would fear them.

Perceived Trust

The results of this study did not demonstrate a statistically significant relationship between angularity and perceived trust. Although limited research exists conducted on this topic, these findings were still surprising given the study by Bernotat et al. (2019) found that the female (more curved) robot was attributed more trust. A potential explanation for this discrepancy could be related to the adapted scale measuring trust, since the wording of certain items may have been

somewhat vague. The trust scale used in the study was adapted from Bernotat et al. (2019), with certain items altered or removed to better suit the study's objectives. While the scale demonstrates high internal reliability, some items may have been ambiguous due to adjustments made to align with the context of MSRs.

For instance, the item "This Medical Service Robot would be independent" might have been unclear, as the question did not specify the context in which or how the MSR would demonstrate independence. Such ambiguous items may have compromised the validity of the scale, potentially leading to an inaccurate measurement of trust.

Gender

While the interactions between gender and perception did not yield significant results, main effects were observed for preference, warmth, and trust. Across all relationships, males rated the robots higher than females. This observation suggests males are potentially more receptive to technology, indicating a greater willingness to incorporate MSRs into healthcare settings. On the contrary, women appeared to be more skeptical, demonstrating the likelihood to require more persuasion or reassurance before embracing the idea of utilizing MSRs in healthcare. This gender-based difference in perception emphasizes the importance of understanding and addressing gender-specific attitudes in the implementation of healthcare technologies.

Limitations and Further Study

The primary limitation of this study pertains to the inability of participants to interact and experience the MSR prototypes in-person. Research by Hwang et al. (2013) emphasizes participant perceptions are more nuanced and impactful when they can engage with the prototypes in real-life settings. This is particularly significant for variables such as trust, where interaction significantly contributes to the formation of opinions. Given this limitation, there are many opportunities for future research to build upon these findings.

Future research can investigate similar topics to contribute to the development of a more rounded understanding of MSRs. For instance, considering the observed impact of participant gender on perception, further studies could delve deeper by manipulating the gender of the robot itself. This exploration might reveal interesting insights, such as whether a female MSR is

perceived as warmer than a male counterpart, drawing from existing stereotypes associating females with caregiving roles. Additionally, measuring the perceptions of medical staff is imperative for gaining a more developed perspective. While MSRs are intended as tools to assist healthcare professionals, doctors and nurses might feel their roles are being threatened. Investigating the perceptions of medical staff would shed light on the dynamic of staff-robot interactions, a facet equally crucial for successful integration of MSRs into healthcare settings. Despite these limitations, this study serves as a foundation for further exploration, offering insights into potential directions for future research.

Implications

This study identified that the appearance and contour or MSRs influences their perception as curved designs elicited more positive responses. The impressions an individual forms from

appearance plays a major role in their acceptance of the subject, emphasizing the versatility and importance of this phenomenon. More specifically, the incorporation of design elements that convey warmth and reassurance to patients holds substantial potential for enhancing the positive perception of MSRs. This would not only contribute to the functionality of MSRs, but also improve interactions between the robot and user. Through the suggestive nature of appearance, one can manipulate the designs of MSRs in a way that facilitates positive perceptions, ultimately reinforcing the societal value of MSRs as a beneficial tool in the healthcare setting.

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