The Key Strategies for Increasing Users' Intention of Self-disclosure in Human-robot Interaction through Robotic Appearance Design

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Abstract: Bridging the communication gap between humans and social robots constitutes a critical area of research in the field of human-robot interaction (HRI). However, inducing self-disclosure in HRI is a challenging task, primarily due to the unique characteristics of social robots. This study aims to address the following research question: Can the design expression dimensions that influence user disclosure depth in the HRI process be deconstructed? Do design strategies take precedence over appearance design? Firstly, we segmented the focus of appearance design into three dimensions: Artistic Expression, Featured Expression, and Identified Expression, hypothesizing their level of significance. Subsequently, we created a prototype with balanced degrees for experimentation and invited 52 users to participate in HRI, guiding them to self-disclose and record data. Bayesian statistics were utilized to model the data and obtain comprehensive user feedback regarding appearance design. Based on the experimental results, we reviewed the content and potential order of the three dimensions and proposed our design and research model. Currently, at the theoretical level, there is no significant emphasis on users' willingness to self-disclose in HRI. Our proposed model serves as a valuable tool for researchers in the fields of human-computer interaction, communication, and user experience design to gain quick insights into this topic. At the practical level, our model has reference significance for industrial and visual designers, enabling them to better comprehend the design goals, situations, and output design methods.

1. Introduction

Enhancing communication between humans and social robots is a crucial research area in Human-robot Interaction (HRI). Self-disclosure plays a significant role in bridging this communication gap by allowing individuals to reveal their cognitive, emotional, and attitudinal processes associated with a phenomenon. It is a fundamental component of human communication that involves sharing personal information with others [1]. However, self-disclosure in the HRI process is distinct from everyday communication since it often involves revealing hidden personal information, such as life experiences, emotions, opinions, and thoughts. This behavior is mainly expressed through verbal communication with social robots [2-3]. Engaging in self-disclosure with social robots can improve an individual's cognitive understanding of personal attributes, increase self-efficacy, strengthen social connections, reduce biases, and promote psychological recovery and relief [4].

Triggering self-disclosure in human-robot interaction (HRI) presents a unique challenge due to the distinct characteristics of social robots. Despite lacking psychological agency, robots can potentially reduce barriers and increase the willingness of interlocutors to share personal information [5]. Early theories, such as the Computers are Social Actors (CASA) and Technology Acceptance Model (TAM), have explored the process of establishing intimate relationships between humans and technology through self-disclosure. These theories have identified critical components such as perceived usefulness, technology acceptance, trust, goal achievement, enjoyment, and entertainment. However, the low perceived benefits of HRI continue to impede the development of such relationships. Moreover, individuals may be hesitant to disclose personal information to robots since they are perceived as non-judgmental and incapable of providing emotional support. Human beings disclose personal information to establish social

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connections and intimacy with others [6]. However, robots may not be considered suitable partners for such social interactions. In conclusion, eliciting human self-disclosure in HRI is a challenging task, largely due to factors such as low perceived usefulness and acceptance of social robots, lack of emotional support, and users' perceptions of the robots' appearance. Further research is needed to investigate methods for increasing users' willingness to share personal information with social robots.

When it comes to the interaction between visual and tactile senses, the design of a social robot's appearance can have a significant impact on a user's willingness to reveal personal information during the interaction. The user's willingness and the depth of self-disclosure can vary depending on the robot's appearance characteristics, particularly in short-term and initial interactions. The appearance of robots plays a crucial role in shaping user perceptions and can affect their willingness to interact and share personal information, as stated in reference [7]. Furthermore, the appearance of social robots, particularly those with human-like and appealing features, can impact users' perceptions of the robot's trustworthiness, empathy, and approachability.

Henceforth, this study posits the subsequent inquiry: Is it possible to dissect the constituent elements of design expression that could potentially influence the extent of user disclosure during the human-robot interaction process? Furthermore, do design tactics take precedence in terms of visual design? The objective of this investigation is to resolve the aforementioned inquiry via empirical structural testing.

2.The Key Dimensions in Appearance Design of Social Robots

Employing various theories to account for phenomena that may align or conflict with empirical observations can facilitate researchers in cultivating critical thinking. Thus, we have dissected and scrutinized Artistic Expression, Identified Expression, and Featured Expression across these three dimensions to assess their potential definability and their capacity to serve as research hypotheses.

2.1. Artistic Expression

Artistic expression involves the act of conveying exquisite emotions, consciousness, and personal or collective experiences to others. In HRI, social robots that incorporate artistic and cultural elements that transcend users' comprehension and daringly utilize color, composition, and materials in their expression can readily capture users' visual focus. Nevertheless, artistic strategies that cater to users' aesthetics may also result in errors and redundancies, leading to divergent opinions among researchers from various disciplines.

2.1.1. Adequate Implementation

Artistic expression ought to actively incorporate aesthetic factors and maintain an open-minded perspective. Hoorn's Theory of Robot Communication (TORC) and the I-PEFiC model, both of which are research paths aimed at advancing human-machine relationships based on media psychology, emphasize the significance of aesthetics in the development of friendships between humans and robots. The model asserts that aesthetics (beautiful versus ugly), ethics (good versus bad), and epistemic (realistic versus unrealistic) factors are equally important and, when combined with perceived affordances, influence user engagement [8]. Art serves as a means of aesthetic expression that implicitly conveys beauty through the creation of objects, environments, images, movements, or sounds. Therefore, designers must actively enhance the aesthetic appeal of their designs for users and select effective artistic expression concepts that lean towards decorative and pure aesthetics.

2.1.2. Selective Implementation

To fully account for interactive events, it is essential to apply a conservative approach to artistic expression. Semiotics, which examines the nature, rules, meanings, and interrelationships between signs and human activities, offers an alternative means of defining beauty in art. It emphasizes the achievement of harmony and unity between a product's internal and external systems, as well as the corresponding semantics conveyed to create aesthetic and authentic artistic expression [9]. According to certain scholars who draw upon Semiotics, designers must consider the relationship between the beautified product and the user, as well as that between the beautified product and the broader social environment [10]. However, the complexity of events can always compromise the feasibility of art.

2.2. Identified Expression

The concept of "Identified Expression" denotes the application of a sophisticated communication strategy by designers during the Human-Robot Interaction (HRI) process, aimed at enhancing the visual appeal while minimizing the user's cognitive load. Several theories present divergent perspectives regarding the extent of artificial optimization.

2.2.1. Adequate Implementation

Based on Hoorn's Theory of Robot Communication (TORC) and the I-PEFiC model, which draw on media psychology, artistic expression in human-robot interactions ought to actively incorporate aesthetic factors and maintain an open-ended concept. Designers should strive to elevate the aesthetic appeal of their designs and choose effective artistic expression concepts that lean towards decorative and refined aesthetics.

2.2.2. Selective Implementation

The Identified Expression possesses a suitably indistinct visual accuracy, which effectively promotes stability in the process of Human-Robot Interaction (HRI). According to the Uncanny Valley theory, which challenges the Media Equation to some extent, users may experience adverse emotions related to death, fear, and unfamiliarity as the visual realism of social robots increases. Such emotions can trigger user behaviors such as withdrawal, hostility, and avoidance. Thus, in the complex HRI process, designers should exercise restraint in employing McCloud's triangular theory, and instead, they should tactfully obscure the social robot's image, creating space for users to form a personal connection with the robot based on their imagination of its personality [12].

2.3. Featured Expression

Feature refers to attributes that are easy to comprehend and distinguish from other things, and can enhance user perception and recognition. Feature mapping method centered on [Actuality-Artifact] is also one of the methods for designers to reduce the gap between interactors, but different theories have different representations of the applicability and degree of features.

2.3.1. Adequate Implementation

The Featured Expression has the ability to assimilate real-life mappings and create context directly. Sasang's theory, which originates from the personalized medicine perspective of traditional Korean medicine, explains that this model analyzes people using a set of measurement standards and divides them into four basic categories based on their corresponding personality traits. This classification interprets the correlation between the human physical form and personality from a physiological standpoint and is useful for both personality assessment and robot research [13]. Thus, incorporating the public's perception of roles and associated cognition from real-life scenarios directly and appropriately into the HRI process can make it easier to accomplish interactive objectives.

2.3.2. Selective Implementation

A solitary mapping of real-life events incorporated into Featured Expression may be constrained by the user's perception. The concept of Experiencing Fictional Characters (PEFiC) clarifies the extent of control that Featured Expression should possess in the HRI process. PEFiC maintains that extracting features to a certain degree can enhance engagement. The Interactive Experiencing Fictional Characters (I-PEFiC) approach also posits that in order to create a robot with emotional proximity to humans, its features should strike a balance between positive and negative emotional tendencies that arise from users in the HRI process, rather than exclusively extracting overly positive elements from real-life situations [14]. Consequently, designers should avoid overemphasizing this issue.

3. Research Hypothesis

We suggest the following research query: Is there a hierarchical order of significance regarding Artistic Expression, Identified Expression, and Featured Expression in the Human-Robot Interaction (HRI) process, when it comes to addressing the communication gap between users and robots? In support of this, the following research hypotheses (H) are proposed:

H1: The level of Artistic Expression manifested in the robot's appearance is significantly critical in enhancing the users' Deepness of Self-disclosure.

H2: The level of Identified Expression exhibited in the robot's appearance is significantly crucial in augmenting the users' Deepness of Self-disclosure.

H3: The degree of Featured Expression reflected in the robot's appearance is significantly essential in boosting the users' Deepness of Self-disclosure.

4. Research Methodology

4.1. Variable Design

Based on the research hypothesis, the aim of this study is to model rules for the depth of self-disclosure and robot appearance. The dependent variable is the user's willingness to self-disclose (S), while the independent variables are Artistic Expression (A), Identified Expression (I), and Featured Expression (F).

Artistic Expression (A) is hypothesized to be correlated with the depth of self-disclosure. The literature review indicates that there is a debate between the "practical" and "aesthetic" schools of thought in Artistic Expression (A). I-PEFiC argues that during HRI, users focus more on the realism of the robot and its interactive intentions, and do not perceive much beyond the basic features in terms of aesthetics. Semiotics and Pragmatism suggest that the interaction context and appearance design should be unified to be considered true "aesthetics," and excessive artistry has no meaning for HRI. Surrealism and Dadaism believe that the appearance of the robot in the HRI process requires additional design from an artistic perspective, such as the use of points, lines, colors, and even the weakening of the link between appearance and task logic, based on composition and color expression, to arouse users' emotional disclosure. Therefore, Artistic Expression (A) will be used as an independent variable to test the research hypothesis.

Identified Expression (I) is also hypothesized to be correlated with the depth of self-disclosure. The Icons theory suggests that robot appearance can be controlled by the degree of Abstraction (abstract shapes-normal shapes) and Fidelity (realistic images-cartoon sketches) to find and generate a visually stable recognition style, namely, Icons. The Theory of Mind (ToM) on robots

suggests that the "compliance" and completeness of robot appearance can create higher user acceptance, facilitating human empathy. The Uncanny Valley has also emphasized the importance of controlling the "visual fidelity" of robot appearance. Therefore, Identified Expression (I) will be used as an independent variable to test the research hypothesis.

Featured Expression (F) is also hypothesized to be correlated with the depth of self-disclosure. Sasang has pointed out that robots with different appearance features will present different personalities, which can affect the trust between the two parties during the disclosure process, particularly in the category of Blab Droids with a stark contrast to the ordinary appearance. However, I-PEFiC believes that this type of user perception is limited. Therefore, Featured Expression (F) will be used as an independent variable to test the research hypothesis.

To evaluate the willingness to self-disclose, this study will compare the user's disclosure process (physical and verbal behavior, etc.) before and after disclosure in two dimensions. The user's self-disclosure willingness (S) will be used as the dependent variable to measure whether there is a true correlation with the independent variables. It will be divided into seven factors: Time, Frequency, Depth, Emotion, Physical Contact, Effect, and Friendship.

During the experiment, users will subjectively rate the values of An2, In2, and Fn3 to evaluate their interest in these three attributes. As for Sn, the study will employ specific variable design and measurement to evaluate self-disclosure willingness.

$$\mathbf{Sn} = \text{mean}\,(S_{Time} + S_{Frequency} + S_{Content} + S_{Emotion} + S_{Physical} + S_{Distance} + S_{Effect})$$

To conduct social robot-user disclosure testing, users who attain Sn values greater than or equal to 0.7 will be classified as deep disclosers and given a value of 1, while those with Sn values less than 0.7 will be excluded from subsequent Bayes probability statistics and weight (**W**) calculations. To calculate W for eligible deep disclosers, Bayes probability statistics will be utilized, and **Sn = WAAn, Sn = WIIn,** and **Sn = WF*Fn** will be assigned for ease of calculation. For clarity, in this paper, we will designate H1 = An, H2 = In, and H3 = Fn. We will then compare the values of WA, WI, and WF to determine the most important factor in guiding users to disclose during the HRI process and the least important factor. The most important trait will correspond to the smallest value among WA, WI, and WF, while the least important factor will correspond to the largest value.

The flowchart delineates the precise details of our experiment. The social robot (Figure.1) will endeavor to identify compatible users who share similar traits with the robot's personality (e.g., females who adore the robot's cute appearance) in order to discover suitable users. During this process, we must meticulously document the independent variables: Artistic Expression (A), Identified Expression (I), and Featured Expression (F) of the robot's appearance, to acquire a comprehensive understanding of the characteristics and symbolic connotations of the robot's appearance. Upon locating a potential user, the robot will initiate contact and evaluate the user's receptiveness to communication. If unsuccessful, the robot will continue searching for users who are willing to interact. Similarly, if a suitable user is not found, the search will persist. While interacting, the social robot will employ engaging questions to guide the user into divulging information and will record the user's willingness to self-disclose (S), without disrupting the process until the user completes the disclosure process. In conclusion, the social robot must determine if it has acquired high-quality user disclosure data. If not, it will persist in the pursuit of potential users (Figure.2).

4.2. Interactive Experimental Design

Figure.1. The Appearance of Social Robot

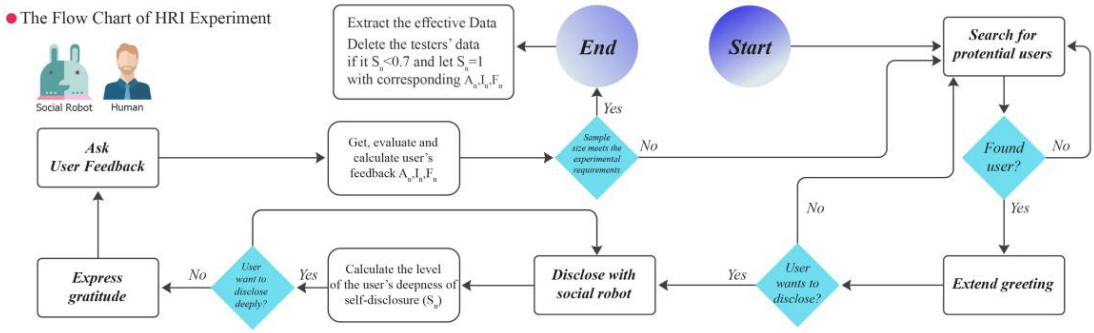

Figure.2. Experimental Flow

5. Data Modeling and Analysis

5.1. Prior Probability

Prior to commencing the design of our robot's appearance, we had already formulated some theoretical frameworks to account for this phenomenon. Drawing upon these theories, we generated our own unique ideas. Specifically, we posited that three distinct probability distributions exert equal influence on the user's willingness to engage in self-disclosure during the

self-disclosure process. These distributions corresponded to the robot's Artistic Expression, Identified Expression, and Featured Expression, with the resultant probability distribution outcomes being as follows: P(H1) = 33.33%, P(H2) = 33.33%, and P(H3) = 33.33%.

5.1.1. Prior Knowledge and Updated Prior Probability

Prior to conducting any testing or experiments, it is necessary to update the basic prior probability with prior knowledge, which is subjectively determined by the researcher. The update of the prior probability is based on the test results and feedback provided by the user. In our study, we sought to examine the importance of a social robot's Artistic Expression, Identified Expression, and Featured Expression on the user's level of self-disclosure. Our findings indicated that some users perceive Artistic Expression as a crucial factor that stimulates their aesthetic perception and enhances their interest in the disclosure process. Nevertheless, we assigned a 10% probability distribution to this factor as we do not consider it crucial to the self-disclosure process.

Identified Expression, on the other hand, is a significant factor in our study, and we assigned it a higher probability distribution of 60%. We believe that visual fidelity accuracy plays a critical role in determining how easily users can identify with the robot. The use of highly identifiable abstract and refined shapes can quickly immerse users in the disclosure process, whereas low identifiable shapes may not engender trust in users. Lastly, we assigned a 30% probability distribution to the Featured Expression factor. While Sassang's theory proposes that a robot's features can contribute to its unique personality, we believe that Identified Expression is more dominant in determining user self-disclosure. Hence, we propose P(H1) = 10%, P(H2) = 60%, P(H3) = 30%.

5.1.2. Likelihood and Category Calculation

The outcomes of our tests are contingent upon user input, and the assumed probabilities are subject to constant updates. Therefore, I can generate a fresh probability distribution based on the results that have been roughly calculated from the concept. The updated probability distribution is as follows:

P(Artistic Expression|H1) = 15%, P(Identified Expression|H1) = 55%, P(Featured Expression|H1) =30%

P(Artistic Expression|H2) = 10%, P(Identified Expression|H2) = 60%, P(Featured Expression|H2) =30%

P(Artistic Expression|H3) = 10%, P(Identified Expression|H3) = 65%, P(Featured Expression|H3) =25%

5.1.3. Updated Prior Probability

Once we have differentiated the probabilities, we can proceed with computing the Updated Prior Probability. To begin, we must extract the probability distribution we have constructed, which includes P(H1) = 10%, P(H2) = 60%, and P(H3) = 30%. Subsequently, we multiply this distribution by the subdivided probability distribution to obtain the Updated Prior Probability for each of the three categories. The calculation process and results can be found in Figure 7, which displays the Updated Prior Probability of each Hypothesis.

5.1.4. Updated Prior Knowledge

The present findings have not undergone user testing and will be taken into account in subsequent discourse. As our preceding computations account for only a portion of the score, we have opted to utilize the maximum score of the Identified Expressions as our benchmark. These expressions have been identified at rates of 5.5%, 36.0%, and 19.5%, totaling 61.0%. To standardize our results, we will rescale our percentage values to yield a total score of 100%. For the calculation procedure and results, please consult the following diagram.

5.2. Constructive Interaction

We enlisted 52 participants to take part in the testing phase of this study, during which we simulated conversations between social robots and recorded noteworthy dialogues. Utilizing a variable table, we gauged the metrics of 40 users who engaged in more in-depth interactions with the robots, including factors such as time spent, number of conversations, and language richness. Upon concluding the interactions, we asked the users which of the robot's three distinct features - artistic, identifiable, and distinctive - most appealed to them. As such, we were able to obtain conclusive results, as depicted in Table 1 below.

Table.1. Outcome of Constructive Interaction

Outcome of Constructive Interaction	
Category	**Amount of Votes**
Artistic Expression	8
Identified Expression	20
Featured Expression	12
Total	40

5.2.1. Updated Prior Probability

Currently, we proceed with the second probability distribution update, which will provide us with a more accurate probability distribution. Therefore, we first extract the rescaled probabilities from the analysis above, as follows: $P(H_1)$ = 10.6%, $P(H_2)$ = 63.1%, and $P(H_3)$ = 26.3%.

5.2.2. Updated Likelihood

In this section, we update the likelihood based on the user testing results. Among our 20 valid results, 4 (20%) people consider Artistic Expression to be important, 10 (50%) consider Identified Expression to be important, and 6 (30%) consider Featured Expression to be

important. Therefore, we assign them the following values in the calculation:

P(Artistic Expression|H_1) = 20%, P(Identified Expression|H_1) = 50%, P(Featured Expression|H_1) =30%

P(Artistic Expression|H_2) = 20%, P(Identified Expression|H_2) = 50%, P(Featured Expression|H_2) =30%

P(Artistic Expression|H_3) = 20%, P(Identified Expression|H_3) = 50%, P(Featured Expression|H_3) =30%

5.2.3. Updated Prior Knowledge

In this section, we have conducted the ultimate rescaling of our calculation outcomes. We have chosen the value for Identified Expression with the greatest proportion of votes in the user testing as the fundamental basis for our calculation. This corresponds to H1, which has a value of 5.3%, H2 has a value of 31.6%, H3 has a value of 13.2%, and the overall value is 50.1%. We have then rescaled these values to produce the following: H1 has a value of 10.6%, H2 has a value of 63.1%, H3 has a value of 26.3%, and the overall value remains at 50.1%.

5.2.4. Posterior Probability & Knowledge

We have calculated and compiled the final Posterior Probability & Knowledge, which indicates that the majority of users who engaged in in-depth self-disclosure during the experiment believe that the most crucial factor affecting their willingness to self-disclose is the Identified Expression (63.1%) of the robot's appearance, followed by Featured Expression (26.3%) and Artistic Expression (10.6%). While the sample size was limited, we can utilize the current test results as a blueprint for expanding the user testing sample size and conducting additional tests in future research. The detailed results are presented in Figure 5: Posterior Probability & Knowledge.

5.3. Result of Experiment

After the effective date, we received deep disclosures from 40 qualified sources and performed corresponding Bayesian probability calculations. The resulting probabilities were An = H1 = 0.106, In = H2 = 0.631, and Fn = H3 = 0.263. Using Sn = WAAn = 1, Sn = WIIn = 1, and Sn = WF*Fn= 1, I calculated the values of WA = 9.433, WI = 1.584, and WF = 3.802. The final outcome indicates that WI < WF < WA. By comparing and analyzing the probability distribution results of the initial content (i.e. the second and third parts), we can infer that the hypothesis probability distribution has undergone some changes. Nevertheless, the probability distribution I obtained did not vary significantly. The result of WI indicates that in the HRI process, the degree of Identified Expression of the robot's appearance remains the most critical factor for users' willingness to self-disclose, followed by Featured Expression, with Artistic Expression being the least important. It is worth mentioning that due to the limited duration of this study, obtaining more self-disclosure test data could enhance the accuracy of our research results, as this would facilitate more iterative calculations to update our findings, leading to outcomes that more closely reflect reality.

6. Discussion

After distilling all previous work into viewpoints, we present the design model generated through experiments (Figure 4). When designing social robots' appearance, content should be given priority. Our experimental results demonstrate that although hypothesis H1 is not supported, H2 and H3 are. Hence, Identified Expression and Featured Expression of social robots' appearance are strongly associated with users' self-disclosure depths in the HRI process, whereas Artistic Expression has a weaker correlation. Nevertheless, this does not imply that characteristics with a low correlation should be disregarded or abandoned in Appearance Design.

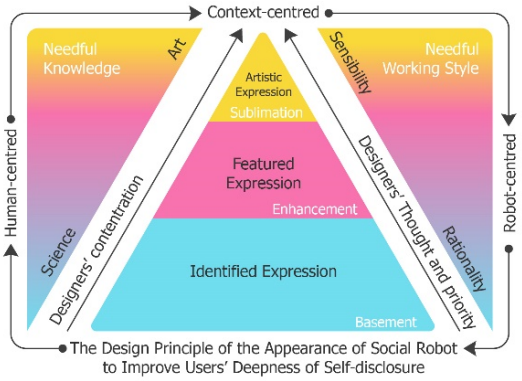

Figure.3. The Key Strategies for Increasing Users' Intention of Self-disclosure

6.1 The Consideration of Identified Expression

Designers should prioritize Identified Expression as playing a fundamental role at the base of the pyramid and which determines the potential for all disclosure behavior. According to the Theory of Mind (ToM), the cognitive understanding of things and the underlying potential for personal development are critical factors that determine whether things can successfully integrate into society [15]. Consequently, robots' appearances should aim to promote higher levels of acceptance and comfort that cater to human needs for empathy [16].

For instance, PARO, a social assistant robot designed for elderly people in nursing homes, effectively captures the vulnerability of this elderly group in HRI by meeting their demand for an easy release of a childlike mindset, kindness, and care from social robots. PARO's "pet therapy" appearance design simulates the recognizable appearance of soft fur and a movable tail of a baby seal. After conducting a three-month qualitative study, experimenters confirmed the applicability of its appearance by recording the physical, psychological, and behavioral data of nursing home residents, staff, and visitors. The results showed that PARO significantly improves the experience of touching, such as stroking

and hugging, and also provides therapeutic effects that enable users to enjoy more comfortable experiences [17]. Therefore, designers must focus on how to establish a compliant appearance visual system and architecture that can successfully integrate into the environment.

6.2 The Consideration of Featured Expression

Designers should prioritize observing Featured Expression to enhance users' perception of image depth. Anthropomorphism can foster affinity in human-robot interaction (HRI) processes across a range of scenarios [18]. In our qualitative study, users noted that our robot resembled "a little elf, a hungry and needy baby," underscoring the importance of incorporating specific human-like images. Many studies have demonstrated that the baby schema can help regulate perception and attention in visual processing and activate the brain's reward system, leading people to approach and care for it, and reveal their behavior [19].

Additionally, multimodal research has shown that distinctive symbols and rhetoric can enhance the aesthetic experience, and the visual decoding pathway of "human-like symbols" can stimulate users' higher aesthetic judgments, emotional and perceptual expressions, relative to non-human semantic content conveyance (feedback signals from visual cortical regions are delivered by parieto-premotor sensory) [20]. Our robot features childlike and anthropomorphic visual characteristics that can appeal to young women, making the image highly effective for communication and increasing the desire for disclosure among user groups.

6.3 The Consideration of Artistic Expression

Artistic expression represents the pinnacle of the appearance design hierarchy, and is employed in the refinement of both Identified Expression and Featured Expression. It serves as a reminder to designers to maintain focus on the primary objective of the design while simultaneously enhancing the overall aesthetic through the utilization of diverse artistic mediums. Research indicates that users implicitly perceive the artistic quality of design, though it is not necessarily considered the foremost attribute. Designers may incorporate various artistic styles, including Dadaism, subjective and free association style, to achieve sensory impact, novelty, surrealism, or communicate abstract concepts such as total alienation and stream of consciousness in appearance design. [21].

7. Limitations and Future Studies

One significant drawback of this study is that the HRI experiment's participants were exclusively limited to younger cohorts from China and Hong Kong due to the COVID-19 pandemic. Therefore, additional investigation and validation are necessary to determine the model's reference value.

The suggested appearance design model needs to undergo testing in design practice to showcase its worth. Design is a cognitive process that emphasizes problem-solving wisdom, utilizing adaptable, organized, and pliable thinking patterns to achieve optimal brain efficiency. The appearance design process merges divergent and convergent thinking and knowledge from various disciplines, including psychology, aesthetics, material engineering, communication studies, and sociology. The appearance design process does not yield binary outcomes of "right" or "wrong," but only whether it can effectively solve problems to the fullest extent [22].

In the Identified Expression stage, designers should approach the process with a rational and knowledgeable mindset, carefully defining, analyzing, and refining the appearance design requirements of the target users. They should extract fundamental knowledge from various fields and establish a basic human-computer interaction model. In the Featured Expression stage, designers should adopt a neutral thinking mode to integrate knowledge from diverse areas, incorporating more empathetic expressions that meet the needs of the target users, such as integrating human-like features. Finally, in the Artistic Expression stage, appearance design should be elevated by seeking inspiration from fields such as art, literature, and sociology. Designers can capture users' attention by incorporating a specific expression style.

8. Conclusion

This study examines the priority of robotic appearance design in HRI and categorizes it into three dimensions: Artistic Expression, Featured Expression, and Identified Expression. A prototype with balanced degrees was developed, and 52 users were involved in actual HRI, providing self-disclosed data. Bayesian statistics were applied to model the data and gain comprehensive user opinions regarding appearance design. Based on the experimental results, the content and potential order of the three dimensions were reviewed, and a design and research model was proposed.

Effectively organizing appearance design can improve the accessibility, desirability, and expressiveness of robot behavior in the HRI process, thus increasing the user's willingness to open up and allowing for the provision of appropriate and enjoyable user experience models, while guiding future continuous design strategies.

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