Designing an AR Facial Expression System for Human-Robots Collaboration

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***Abstract*—In recent years, Human-Robot Collaboration (HRC) has become a significant research field in industry 4.0. However, most research in robotics focuses more on technical aspects and less on the user experience (UX) including important psychological states, such as trust. Evidence suggests that robots that display facial expressions improve the trust and safety of the operator. In this paper, we introduce an augmented reality (AR) approach that uses facial expressions to convey safety-critical messages in HRC tasks, aiming to increase the operator's trust. In our experiment, we used an HRC scenario that comprises a collaborative task in which a user assembled a block-building pattern with the help of a robot. For one condition, we designed an AR display with an animated face, through which expressions varied according to the state of the HRC task. For the other condition, the face was displayed on a screen. We then measured the user's trust with self-report instruments. Despite that facial expressions were shown to convey robot state information accurately, no clear evidence was found that AR could improve trust in HRC. Possible causes of the results are discussed, including unfamiliarity with the AR technology.**

Keywords—HRC, AR, trust, facial expression

I. Introduction

With the growing demand for product customization, the organisation's necessity to meet and manage diverse customer requests, known as manufacturing flexibility, has become crucial [1]. Traditional cage robots, designed for high volume and low hybrid production, cannot always adapt to the increasing requirements of small volume and high customisation [2]. Therefore smart factories need hybrid systems where humans and robots collaborate [3]. The concept of Human-robot Collaboration (HRC) is very relevant and holds the potential for the future development of smart factories. However, most research on HRC is highly "robot-centred", primarily focusing on technological challenges and technical solutions, while lacking considerations of human aspects [4], such as user experience (UX) [3]. According to recent research [5, 6], trust is considered one of the three most critical factors, namely trust, safety, and operator experience, that affect HRC user experiences.

Facial expressions of a robot are one of the primary factors that can influence trust [7, 8]. The conventional approaches towards facial expressions in HRC usually rely on physical screens as the delivery medium, such as the animated face used in a Baxter robot [9]. The advent of augmented reality (AR), a technology characterized by the superimposing of computer images on real-world objects or settings through a head-mounted device (HMD) or handheld display [10], provides a vast opportunity for researchers and industries to explore new ways of information exchange in the context of HRC [11]. In a semi-immersive AR environment, users can observe the real world while modelling the characteristics of digital products [12]. There is no need to model the background environment entities [10]. Using facial expressions through AR in HRC can potentially provide significant research value based on these benefits.

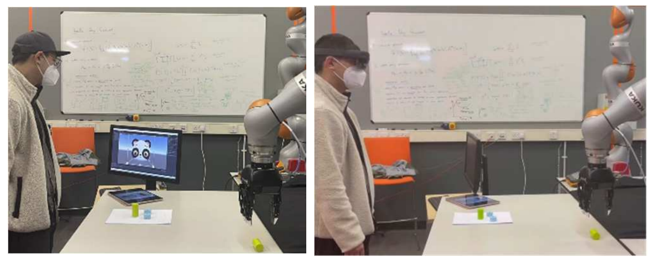

Figure 1 The image on the left shows participants completing an HRC task with the screen facial expression system, while the image on the right shows participants completing the same task using the AR facial expression system.

In this paper, we propose an AR-based approach to improve users' trust by conveying safety-critical messages through the visialization of facial expressions in an AR environment during HRC tasks. It is hypothesized that AR is more effective in facilitating trust in collaborative robots when delivering facial expressions in comparison to a screen. We conducted a controlled experiment to test this hypothesis, as shown in Figure 1. Participants experienced two conditions: one in which they completed a HRC task while wearing AR devices to observe the facial expressions of the robot, and the other in which they completed the same task while observing the facial expression on a screen. After each task, trust was measured by the administration of a questionnaire. The remaining paper is organized as the following: Firstly, we provide a brief summary of previous research on the use of AR to facilitate visualizing facial expressions in HRC. Then we introduce our proposed framework that integrates an AR facial expression system to HRC tasks, aiming at improving trust in HRC. To appraise the effectiveness of our proposed approach, the remaining section introduces how we measure user trust using self-report instruments. Finally, we present the experimental results and

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provide concluding remarks on the implications of our findings as well as future research directions.

II. Literature review

A. Trust in HRC

Researchers believe that reliable HRC requires trust of the robot partner [13]. Trust will directly affect users' willingness to interact with the robot and rely on information generated by the robot, such as data, suggestions, recommendations, instructions, etc., which users need to complete tasks or make decisions based on [14]. For a human-robot team to achieve its goals, humans must trust that their robot teammates will protect the interests and welfare of everyone else in the team [15]. However, only a few studies have focused on the development of trust in industrial HRC [16]. Trust is one of the most important factors in the evaluation of the UX goal framework in HRC [6]. Kahn et al. believe that people are willing to have a close and trustworthy relationship with robots [17]. Palmarini et al. increased human confidence and trust in robots by designing an AR interface for HRC [2]. Other researchers develop a trust repair framework through a human-to-robot attention transfer model and a user trust study [19]. In addition, a time-driven performance-aware mathematical model for trust is proposed, where the human operators and robot performances can be evaluated [20]. On the other hand, when evaluating a new automation system's trustworthiness, reliability, transparency, controllability, and communication between the user and the automation system will affect the user's trust in the system [21].

B. Role of Facial Expression

Trustworthiness evaluation is crucial for regulating behaviors towards strangers, and attractive individuals are often perceived as more trustworthy [22]. Since humans indicate and identify trustworthiness through facial expressions, there are a considerable number of related resources in the context of trust [23]. Robots gain the highest level of trust when they start with small talk and express facial expressions aligned with the expected emotions while telling stories [8]. Krumhuber et al. discovered through a two-person trust game that facial dynamics significantly influence participants' choice of with whom to play the game and decisions to cooperate [24].

Facial expressions form a universal language among various nonverbal signals by conveying emotional states and feelings [25]. Raffard et al. found results in clinical services, where negative expressions (such as anger) were recognized more quickly than positive emotions (such as happiness). These conflicting findings may stem from the nature of the research field, as users may be more sensitive to negative emotional expressions in hospital environments [26]. In virtual reality environments, users form attitudes of trust or distrust towards agents based on their appearance, behaviors, and decisions. Cartoon characters are often considered more affable and trustworthy because they are typically associated with fairy tales and pleasant memories [27]. Therefore, the authors believe that using cartoon characters as the appearance of agents in virtual reality may increase users' sense of trust and improve their user experience, thereby promoting the application and popularization of virtual reality technologies [27].

Another approach is based on how viewing cute images may influence an individual's behavior and attention. This effect may be related to the affinity and pleasure associated with those images [28]. The cuteness factor of robots can promote human trust and reliance on them. However, at the same time, we need to consider the functionality and tasks of the robots to avoid over-projecting emotions and expectations [29].

C. AR Solution in HRC

Based on the review of existing research and applications, AR solutions have three main advantages in human-robot collaboration: increased efficiency, improved safety, and enhanced UX [11]. AR technologies can help workers complete tasks more quickly and accurately, simulate dangerous environments for training purposes, and improve the immersion and interactivity of human-robot interaction [11]. However, there are challenges related to technical costs and operability that need to be addressed for the wider adoption of AR [30]. Green et al. presented an HRC system based on AR technology and evaluated its performance [30], which the proposed system significantly improved work efficiency and reduced error rates. At the same time, the system helped workers to locate and identify parts faster and to reduce assembly errors [30]. Compared to traditional human-machine collaboration methods, the AR-based system was widely accepted and positively evaluated by workers [30].

Alenljung et al. introduced the user experience evaluation results of a prototype system for assembly instructions based on the AR technology [31]. They found that AR technology has a great potential to improve user efficiency and accuracy and provide more intuitive and easy-to-understand guidance to follow assembly instructions [31]. Amtsberg et al. designed a human-robot collaboration interface based on the AR technology [32]. This system has many advantages, such as reducing communication costs, improving task execution efficiency, and reducing error rates [32]. In addition, the system can dynamically adjust the collaboration relationship between robots and personnel according to the characteristics of the task and work requirements to achieve more flexible and intelligent task sharing [32]. Therefore, an AR-based Worker Support System was designed, consisting of an AR-based teaching system, task sequence planning and re-planning system, worker monitoring system, and industrial robot control system that was used for investigation of the possibilities of AR applications in HRC [33]. However, the user experience of AR technologies is also influenced by factors such as system stability, user training, and technology acceptance [31].

Based on these articles, we can find that AR-based HRC has more advantages in terms of user experience, efficiency, and safety compared to traditional human-machine collaboration [11]. Meanwhile, there is still a lack of research on AR facial expressions in HRC. To fill this research gap, we introduce an AR approach that uses facial expressions to convey safety-critical messages in HRC tasks.

III. AR for HRC framework

This section describes the framework used for the experiments in this paper (Figure 2), which comprises three modules: Object detection, Robot control, and AR facial

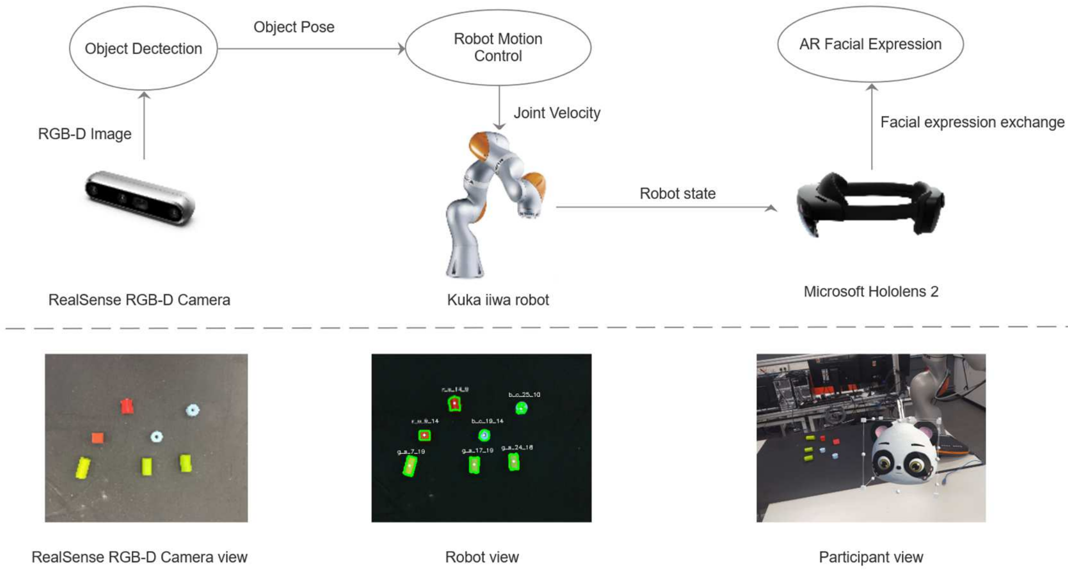

Figure 2 The AR facial expression system diagram. The ellipse software blocks were developed in this system.

expression. The Robot Operating System (ROS) is used to coordinate message communication among modules, acquire and display information, and control the robot. For our HRC scenario, we used a Kuka iiwa robot arm with 7 degrees of freedom and a Robotiq 3-finger gripper attached to the flange. Besides that, an Intel RealSense camera is mounted on the top of the table. The designated AR device is the Microsoft HoloLens 2, which provides relatively accurate spatial tracking and enables the AR facial expressions to be fixed in precise locations. The HoloLens and the robot were linked on the same local area network, and the current robot state information was transmitted via TCP for AR facial expression switching.

A. *Object detection*

This module segments the image from the camera based on the color of the blocks on the table, and the positions of the objects are obtained with the RealSense camera and OpenCV libraries. For this purpose, the contours of the objects on the table are used to extract their centroid positions in pixels. With this information, the module utilizes the RealSense cameras' depth cloud to calculate the object's position in meters with the robot's base as the reference.

Figure 3 Panda model design and shape key creation.

B. *Robot control*

This module aims to control the robot's actions while it collaborates with the user to complete a block-stacking task. During the execution of the task, the robot publishes state topics via TCP communication to the HoloLens2 or the screen, depending on the experiment. The image displayed on the device reacts according to the robot's state by switching facial expressions.

C. *AR Facial Expression*

Using cute objects as emotional triggers can prompt individuals to exhibit careful behaviors in certain situations, such as when driving or working in an office [28]. Cartoonish faces seem more trustworthy than other facial aesthetics [34]. Based on this research [28, 34], we designed a cute panda model (Figure 3). First, we created a basic panda model in Blender and add details to it. The panda model consists of 4,749 polygons. Next, we drew and applied textures and materials to the model to give it a panda-like appearance. Then, we added bones to the model to enable facial movement and adjusted the bone weights to make the movements more natural. Finally, controlling the panda's facial expressions was implemented using the function of shape keys. This method enables the panda model to make any desired facial expressions.

Figure 4 shows two expressions: angry and happy. The angry expression is mainly displayed when the robot is moving.

Figure 4 The expression on the left is angry, and the expression on the right is happy.

The happy expression indicates that the robot has completed the object-picking-and-placing task. The information about which facial expression must display is transmitted from the robot to the Hololens2 via the local area network (LAN) protocol.

IV. HYPOTHESES

We hypothesize that in HRC tasks, facial expressions are more effective in facilitating trust in the robot if they are delivered by AR than if they are delivered by a fixed screen because they offer better visual effects and reduce some of the constraints imposed by the screen, such as reflections and fixed location. Based on our hypotheses, we expect to observe a higher level of trust after deploying AR facial expressions than using a screen display, operationalised by four subjective metrics, namely reliability, predictability, propensity to trust and trust in system.

V. METHODOLOGY

In order to test the effect of AR facial expressions on increasing trust, we designed an experiment in which we measured attitudes of human users when interacting with a robotic arm in a collaborative block-building task with the assistance of animated facial expressions delivered by either an AR headset or a screen display.

A. Participants

We recruited 14 participants from Cardiff University, including 10 males and 4 females, whose ages range from 24 to 31 years old. The participants were not compensated. Among them, 4 participants had prior experience with robots, while 10 participants had never interacted with a collaborative robot before. In addition, 4 participants had prior experience with AR devices, while 10 participants only heard about AR devices through media.

B. Design

In this project, we manipulated the visualization mode as a within-subject independent variable. Participants experienced both two conditions below:

- AR: Participants will wear AR device and complete the human-robot collaborative task of block building (HRC-AR)
- Screen: Participants will observe the screen displayed changes in facial expressions and complete the human-robot collaborative task of block building. (HRC-S)

Therefore, each participant will experience two different conditions: 1) AR (HRC-AR); 2) Screen (HRC-S), the order of which was counterbalanced across participants.

C. Procedure

The experiment took place in the Robotics Lab of Cardiff University under the supervision of our 2 experimenters. Participants stood in a designated position in front of a robotic arm and started assembling the blocks. Participants first read the instructions and then signed the consent form. After reading the instructions, the experimenter provided information about the experimental process by reading from a script and collected basic demographic information, such as gender, through a short questionnaire. Then, participants received a card (both the AR group and the screen group used the same card) indicating the type of block structure they needed to build. When the participants verbally indicated they were ready, researchers manually started the robot program and the timing of the movement of the robotic arm was determined manually by a person. The AR facial expressions will appear in front of the participants, close to the position of the robotic arm, while the screen will be placed in front of the participants to their left. When the robot is in motion, the AR/screen facial expression system displays anger, indicating that interaction with the robot is not safe and may cause harm. When the robot shows a happy expression, it indicates that the robot has completed the current task, and participants can go and pick up the blocks to complete the block building. Participants will complete the block-building task under two conditions, wearing AR headset and observing the screen.

After each task, they will fill out a questionnaire as shown in Table 1. questionnaire was based on the *trust in automation* questionnaire (TiA) [21]. In order to make it easier for the participants to understand the questionnaire, we replaced the term "system" with specific references to either an AR facial expression system or a screen facial expression system. After each visualisation mode condition, participants are required to complete a questionnaire corresponding to each visualisation mode. This scale consists of 100 points, labelled as such: 0 - Strongly disagree; 25 – Disagree; 50 – Neutral; 75 – Agree; 100 - Strongly agree. The influence of technical differences, the same model and technical code were used for both the AR screen facial expression systems and screen facial expression systems. The average duration of the experiment is 20 minutes.

TABLE 1 QUESTIONNAIRE FOR FACIAL EXPRESSION SYSTEM TEST

	Subscale
	Reliability/Competence
Q1	The screen/AR facial expression system is capable of interpreting situations correctly
Q2	The screen/AR facial expression system works reliably
Q3	The screen/AR facial expression system malfunction is likely
Q4	The screen facial expression system is capable of taking over complicated tasks
Q5	The screen/AR facial expression system might make sporadic errors
Q6	I am confident about the system's capabilities
	Understanding/Predictability
Q7	The screen/AR facial expression system state was always clear to me
Q8	The screen/AR facial expression system reacts unpredictably
Q9	I can understand the reasons for things happening.
Q10	It's difficult to identify what the screen/AR facial expression system will do next
	Familiarity
Q11	I already know similar systems
Q12	I have already used similar systems
	Intention of Developers

Q13	The developers are trustworthy
Q14	The developers take my well-being seriously
	Propensity to Trust
Q15	One should be careful with unfamiliar screen/AR facial expression system
Q16	I rather trust a system than mistrust it
Q17	this system generally works well
	Trust in System
Q18	I trust the system
Q19	I can rely on the system

VI. HYPOTHESES

A. Results

We organised the ratings of the 19 questions in the questionnaire under 6 categories following the recommendations of TiA [21], calculated the mean for each category (after reverse-coding some items with a negative statement), and then performed t-test analysis on the data to explore differences between conditions. The main results are presented in Table 2 showing the comparison between the AR and screen cases.

TABLE 2 RESULTS FROM THE EXPERIMENT COMPARING AR AND SCREEN

	AR		Screen		t(26)	P(1-tailed)
	μ	σ	μ	σ		
Reliability/Competence	60.24	10.37	66.98	8.99	-1.84	0.04
Understanding/Predictability	69.61	10.89	77.09	10.79	-1.83	0.04
Familiarity	21.89	21.26	28.93	31.40	-0.70	0.25
Intention of Developers	75.86	17.32	78.32	15.54	-0.40	0.35
Propensity to Trust	56.60	11.10	68.79	14.84	-0.44	0.33
Trust in System	70.25	14.96	67.00	12.04	0.63	0.26

The reliability/competence subscale consists of Q1 to Q6. The P value for the t-test is 0.04, which is smaller than the significance level we chose (0.05), indicating that there is a significant difference between the AR group and the screen group. However, opposite to the original expectation, the mean of the AR group is lower than the mean of the screen group. But the AR group's score higher than 50 is considered positive. The understanding/predictability subscale consists of Q7 to Q10. Based on the t-test results, there is also a significant difference between the means of both groups. Again, the direction of the difference is the opposite of what we predicted. However, on the other hand, the scores (69.6% and 77.0% respectively) show that facial expressions could convey the information of robot states correctly regardless the display media. Q11 and Q12 represent the familiarity subscale. Although the mean of the AR group is 7.1 scores lower than that of the screen group, the t-test shows this difference is not significant. The subscale of intention of developers is composed of Q13 to Q14. The results show a more favourable judgment of developers in the screen condition than in the AR condition, although the difference has not achieved the level of significance. It should be noted that the means in both groups are higher than 75, indicating that participants had a high level of trust in the developer and believed that the developer had been very concerned about wellbeing. With the second-to-last subscale, propensity to trust, including Q15 to Q17, the average score of the AR group is 12.1 points lower than that of the screen group, although the difference is not significant. The last subscale is about "Trust in System", which includes Q18 to Q20. The AR group scored slightly higher than the screen group but again, this difference was not significant.

B. Discussion

Based on the description of the results, we did not find strong evidence supporting our hypothesis that AR can improve trust in collaborative robots in comparison to a fixed screen by incorporating AR facial expressions into HRC. On the contrary, the measures of perceived reliability/competence and understanding/predictability indicate that AR facial expressions could damage trust. In this experiment, prior experience with AR or robots could be a factor affecting participants' performance when using the system in an unfamiliar situation. It might be challenging for those without prior experience to operate and predict the system with the robot and AR. The familiarity and adaptation of participants to screen might explain why the mean scores of the screen group were higher than the AR group in reliability/competence and understanding/predictability subscales. Furthermore, the limitations of AR devices could also affect the reliability/competence and understanding/predictability subscales. For example, AR goggles have a limited field of view, and operator movements such as bending can cause dizziness [11].

An observation from the experiment is that AR system can accurately convey information that can be used to express the state of robot. While the AR system did not demonstrate any clear advantages over the screen in several aspects of the results, the mean score of the trust in system subscale suggests that the potential of the AR facial expression system to gain user's trust should not be dismissed. The AR approach incorporates facial expression communication into the real-world environment, providing participants with a more immersive experience during interactions. Additionally, the screen is difficult to move, while the AR model can be placed in the user's visual comfort zone according to their needs, enhancing the user experience. The AR facial expression system might have the potential to enhance trust in HRC because it allows for greater flexibility, enabling the model to generate any expression.

VII. CONCLUSION

In this paper, we proposed an AR approach to improve operator trust by using facial expressions to convey safety-critical messages in HRC tasks. The AR facial expression system can accurately convey the current status information of robot. Through experiments, we found no evidence that AR approach could improve trust in HRC compared to a screen display and the results of the questionnaire indicate that trust was lower in AR group than screen group. But this method is flexible and can create interaction models tailored to the user's specific needs. For future research, we can explore the reasons that lead to lower impact of AR group compared to the screen group. At technical level, we will explore system programming suitable for complex HRC tasks. In design level, we will develop more expression models applicable to different scenarios. At HRC level, we will try to incorporate different functionalities, such as fault detection and task planning, to further enrich our system's interactive capability with humans and adapts to more complex HRC tasks.

References

[1] C. Camison and A. V. Lopez, "An examination of the relationship between manufacturing flexibility and firm performance: The mediating role of innovation," International Journal of Operations & Production Management, 2010.

[2] R. Palmarini et al., "Designing an AR interface to improve trust in Human-Robots collaboration," Procedia CIRP, vol. 70, pp. 350-355, 2018.

[3] E. Prati, M. Peruzzini, M. Pellicciari, and R. Raffaeli, "How to include User eXperience in the design of Human-Robot Interaction," Robotics and Computer-Integrated Manufacturing, vol. 68, p. 102072, 2021.

[4] M. Nordqvist and J. Lindblom, "Operators' Experience of Trust in Manual Assembly with a Collaborative Robot," in Proceedings of the 6th international conference on human-agent interaction, 2018, pp. 341-343.

[5] I. Maurtua, A. Ibarguren, J. Kildal, L. Susperregi, and B. Sierra, "Human–robot collaboration in industrial applications: Safety, interaction and trust," International Journal of Advanced Robotic Systems, vol. 14, no. 4, p. 1729881417716010, 2017.

[6] J. Lindblom and W. Wang, "Towards an evaluation framework of safety, trust, and operator experience in different demonstrators of human-robot collaboration," in Advances in manufacturing technology XXXII: IOS Press, 2018, pp. 145-150.

[7] J. R. Dunn and M. E. Schweitzer, "Feeling and believing: the influence of emotion on trust," Journal of personality and social psychology, vol. 88, no. 5, p. 736, 2005.

[8] R. B. Paradeda, M. Hashemian, R. A. Rodrigues, and A. Paiva, "How facial expressions and small talk may influence trust in a robot," in International Conference on Social Robotics, 2016: Springer, pp. 169-178.

[9] N. T. Fitter and K. J. Kuchenbecker, "Designing and assessing expressive open-source faces for the Baxter robot," in International Conference on Social Robotics, 2016: Springer, pp. 340-350.

[10] Y. Shen, S. K. Ong, and A. Y. Nee, "Augmented reality for collaborative product design and development," Design studies, vol. 31, no. 2, pp. 118-145, 2010.

[11] M. Dianatfar, J. Latokartano, and M. Lanz, "Review on existing VR/AR solutions in human–robot collaboration," Procedia CIRP, vol. 97, pp. 407-411, 2021.

[12] H. Kaufmann and D. Schmalstieg, "Mathematics and geometry education with collaborative augmented reality," in ACM SIGGRAPH 2002 conference abstracts and applications, 2002, pp. 37-41.

[13] I. Gaudiello, E. Zibetti, S. Lefort, M. Chetouani, and S. Ivaldi, "Trust as indicator of robot functional and social acceptance. An experimental study on user conformation to iCub answers," Computers in Human Behavior, vol. 61, pp. 633-655, 2016.

[14] P. A. Hancock, T. T. Kessler, A. D. Kaplan, J. C. Brill, and J. L. Szalma, "Evolving trust in robots: specification through sequential and comparative meta-analyses," Human factors, vol. 63, no. 7, pp. 1196-1229, 2021.

[15] P. A. Hancock, D. R. Billings, K. E. Schaefer, J. Y. Chen, E. J. De Visser, and R. Parasuraman, "A meta-analysis of factors affecting trust in human-robot interaction," Human factors, vol. 53, no. 5, pp. 517-527, 2011.

[16] G. Charalambous and S. R. Fletcher, "Trust in Industrial Human–Robot Collaboration," in The 21st Century Industrial Robot: When Tools Become Collaborators: Springer, 2022, pp. 87-103.

[17] P. H. Kahn Jr et al., "Will people keep the secret of a humanoid robot? Psychological intimacy in HRI," in Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction, 2015, pp. 173-180.

[18] B. Sadrfaridpour, H. Saeidi, and Y. Wang, "An integrated framework for human-robot collaborative assembly in hybrid manufacturing cells," in 2016 IEEE international conference on automation science and engineering (CASE), 2016: IEEE, pp. 462-467.

[19] R. Luo, C. Huang, Y. Peng, B. Song, and R. Liu, "Repairing human trust by promptly correcting robot mistakes with an attention transfer model," in 2021 IEEE 17th International Conference on Automation Science and Engineering (CASE), 2021: IEEE, pp. 1928-1933.

[20] M. K. M. Rabby, M. A. Khan, A. Karimoddini, and S. X. Jiang, "Modeling of Trust Within a Human-robot Collaboration Framework," in 2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC), 2020: IEEE, pp. 4267-4272.

[21] M. Körber, "Theoretical considerations and development of a questionnaire to measure trust in automation," in Congress of the International Ergonomics Association, 2018: Springer, pp. 13-30.

[22] D. Bzdok et al., "ALE meta-analysis on facial judgments of trustworthiness and attractiveness," Brain Structure and Function, vol. 215, pp. 209-223, 2011.

[23] D. F. Galinsky, E. Erol, K. Atanasova, M. Bohus, A. Krause-Utz, and S. Lis, "Do I trust you when you smile? Effects of sex and emotional expression on facial trustworthiness appraisal," PLoS One, vol. 15, no. 12, p. e0243230, 2020.

[24] E. Krumhuber, A. S. Manstead, D. Cosker, D. Marshall, P. L. Rosin, and A. Kappas, "Facial dynamics as indicators of trustworthiness and cooperative behavior," Emotion, vol. 7, no. 4, p. 730, 2007.

[25] M. Gendron, C. Crivelli, and L. F. Barrett, "Universality reconsidered: Diversity in making meaning of facial expressions," Current directions in psychological science, vol. 27, no. 4, pp. 211-219, 2018.

[26] S. Raffard et al., "Humanoid robots versus humans: How is emotional valence of facial expressions recognized by individuals with schizophrenia? An exploratory study," Schizophrenia research, vol. 176, no. 2-3, pp. 506-513, 2016.

[27] N. Sun and J. Botev, "Intelligent autonomous agents and trust in virtual reality," Computers in Human Behavior Reports, vol. 4, p. 100146, 2021.

[28] H. Nittono, M. Fukushima, A. Yano, and H. Moriya, "The power of kawaii: Viewing cute images promotes a careful behavior and narrows attentional focus," PloS one, vol. 7, no. 9, p. e46362, 2012.

[29] C. Caudwell and C. Lacey, "What do home robots want? The ambivalent power of cuteness in robotic relationships," Convergence, vol. 26, no. 4, pp. 956-968, 2020.

[30] S. A. Green, J. G. Chase, X. Chen, and M. Billinghurst, "Evaluating the augmented reality human-robot collaboration system," International journal of intelligent systems technologies and applications, vol. 8, no. 1-4, pp. 130-143, 2010.

[31] Z. Alenljung and J. Lindblom, "User experience in augmented reality: a holistic evaluation of a prototype for assembly instructions," in Design, User Experience, and Usability: Design for Contemporary Technological Environments: 10th International Conference, DUXU 2021, Held as Part of the 23rd HCI International Conference, HCII 2021, Virtual Event, July 24–29, 2021, Proceedings, Part III, 2021: Springer, pp. 139-157.

[32] F. Amtsberg, X. Yang, L. Skoury, H. J. Wagner, and A. Menges, "iHRC: an AR-based interface for intuitive, interactive and coordinated task sharing between humans and robots in building construction," in ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, 2021, vol. 38: IAARC Publications, pp. 25-32.

[33] H. Liu and L. Wang, "An AR-based worker support system for human-robot collaboration," Procedia Manufacturing, vol. 11, pp. 22-30, 2017.

[34] J. Pinney, F. Carroll, and P. Newbury, "Human-robot interaction: the impact of robotic aesthetics on anticipated human trust," PeerJ Computer Science, vol. 8, p. e837, 2022.