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RESEARCH ARTICLE

Investigation of Factors That Influence Human Presence and Robot Anthropomorphism in Telepresence Robot

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This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by the Ethics Committee of the National Institute of Informatics.

ABSTRACT These days, we see different types of telepresence robots, and there has been a tremendous amount of research and development on these robots. Some telepresence robots have monitors to show the faces of remote operators and mobility to move around, but some do not have a monitor and instead have a robot face, and also they have robotic arms to do motions and perform functions. Many people feel that artificial intelligence (AI) in robots depends on their appearance, which is anthropomorphism, and telepresence robots without arm or body motions can also have a human presence. It is important to identify and configure how these robots give people a sense of presence and anthropomorphism by including human-like and robot-like faces and arm motions. We carried out web-based experiments and used videos of a telepresence robot (2×2 between-participant study; face factor: human face, robot face; motion factor: moving, static) to investigate which factors significantly give users the sense of human presence and anthropomorphism in a robot. Our results show that participants felt that the robot had more anthropomorphism when its face was replaced with a human's face and it did not make any motion. In addition, the robot's motion invoked a feeling of human presence regardless of whether the face was human-like or robot-like. Our novel findings provide a guide for designing telepresence robots, revealing that motion enhances presence, and displaying the operator's face increases anthropomorphism. These innovative insights offer a new approach to optimizing the design of telepresence robots depending on the desired user experience. When designing these robots, focusing on the sense of presence involves considering both stationary and moving robots to evoke a feeling of human presence. Conversely, to emphasize anthropomorphism, it is crucial to display the remote operator's face.

INDEX TERMS Anthropomorphism, human–robot interaction, robot motion, robot mediated communication, telepresence, social robots.

I. INTRODUCTION

There is a wide variety of choices when it comes to digital communication these days, with the telephone, email, SNS (Social Network Service), and video conferencing being the most common. In recent years, communication via telepresence robots has been attracting attention. In general, telepresence robots that enable robot-mediated interaction, also called "mobile robotic presence systems," are physical robotic platforms with a video-conferencing system mounted on a robotic mobile platform [1], [2], [3]. Since remote operators can control this physical embodiment from a remote location, these systems increase opportunities for video-conference and audio-communication [1], [4].

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Furthermore, they imbue communicators with a strong sense of presence, including feelings of "being there" [5], [6] and feelings of "being together" [7], [8]. Other researchers have mentioned that telepresence robots provide a new communication platform in various areas such as business, education, and medical fields [9], [10], [11], [12], [13], [14]. These robots have also shown promise for people with disabilities in terms of helping them join in society more actively and perform labor [15].

With telepresence robots, the appearance of the face is an important factor that has one of the biggest effects on whether people feel the presence of a person [3], [5], [13]. Meanwhile, previous research on movement with telepresence robots has shown that robots that can express themselves socially through movement are more immersive and desirable than those that do not move [16]. In some cases, a robot that does not have a human face can make people feel the presence of a person through its movements.[1] In general, however, the effect of the face depends on whether the face is human-like or robot-like, and people may feel that one type gives a greater sense of anthropomorphism or presence. This also raises a related question: which makes people feel more anthropomorphism or presence in a robot, a robot that is moving or static or that has a face that is human-like or robot-like? Hence, in this paper, we try to give a solution to this research question in an experiment.

Despite the growing interest in telepresence robots, there is limited research on how the combination of facial appearance and motion affects user perceptions of anthropomorphism and social presence. While previous studies have investigated these factors individually, there is a lack of understanding regarding their interaction effects and how they can be optimized for different user outcomes. This gap in the literature limits our understanding of how to design telepresence robots that effectively support remote communication and collaboration across various applications.

Our study aims to address this gap through experiments on the combined impact of facial appearance and motion on user perceptions using a novel experimental design. By providing insights into how these design factors work together to shape user experiences, we seek to contribute to the development of more effective telepresence robots that can better support remote communication and collaboration. The findings of this study have the potential to guide the design of telepresence robots in various applications, ultimately benefiting industries such as healthcare, education, and customer service.

In this paper, we conduct a web-based experiment featuring videos of a telepresence robot using the Rapiro platform shown in Figure 1 (2×2 between-participant study; face factor: human face, robot face; motion: moving, static) to investigate which factors have the biggest effect on the sense of human presence and robot anthropomorphism.

[1] https://orylab.com/en/#product

FIGURE 1. Humanoid robot Rapiro.[2]

Prior works have explored facial displays or motion capabilities for telepresence robots but largely in isolation. Table 1 summarizes and compares how our proposed work is a novel combination of both motion and face factors and relates to prior works that examined these design elements more individually for their impacts on perceived anthropomorphism and sense of presence in telepresence robots.

A key novel contribution of our research is the investigation combining both the robot's facial appearance (human vs. robot face) and motion (moving vs. static) as factors influencing user perceptions. Our 2×2 experimental design uniquely identifies that a static robot displaying a human face enhances anthropomorphic perceptions more than one that moves with a human face. Notably, we found that the robot's ability to move and make physical motions was the most important factor in creating a sense of human presence for local users, rather than the appearance of the robot's facial display. This novel finding contrasts potential assumptions that human-like facial representations would be most important for perceived presence. By quantifying the effects of combining these two design factors through experimentation, our work provides new insights overlooked by studies examining facial displays and motion in isolation.

Another of our approaches involves considering the implications when designing a telepresence robot in order to optimize their design for industrial applications. For example, when a telepresence robot needs to convey more humanness, the remote operator needs to show their face. Furthermore, when a telepresence robot only requires human presence, it should utilize non-verbal communication based on arm motion.

Therefore, the rest of this paper is organized as follows. Section II discusses related work on facial expression cues, non-verbal motion cues, and anthropomorphism in human-robot interaction. Section III describes the robot system used

[2] http://www.rapiro.com

in our experiments, including the platform and user interface. Section IV details the experimental design, hypotheses, participants, task, procedure, measurements, and results. Section V discusses the findings, generality, and limitations of the study. Finally, Section VI concludes the paper and outlines potential future work.

II. RELATED WORK

In general, telepresence robots are being applied in a wide variety of fields such as business, education, and medical fields [9], [10], [11], [12], [13], [14]. In particular, telepresence robots are commonly being used for higher education [17], [18], [19]. For telepresence robots used in schools, Ahumada-Newhart and Olson provide specific recommendations for improving telepresence robot design to better suit educational environments and the needs of young users [20]. In collaborative team settings, remote participants using telepresence robots spoke less, perceived the task difficulty to be greater, and were viewed as less trustworthy than collocated members, highlighting potential challenges for integrating remote students via robots in educational group activities [21].

Medical fields are now commonly using telepresence robots for general healthcare [22], elderly healthcare [14], healthcare for COVID-19 [23] and people with special needs [24]. Beyond institutional settings, there are use cases involving long distance relationships and families for facilitating and helping with communication [25], [26].

Among these applications, a particularly promising direction has emerged in employment accessibility. Through telepresence robots like OriHime-D [15], people with disabilities have been able to engage in employment opportunities in café settings [27], [28], [29], [30]. Recent research has demonstrated how both robotic [29] and virtual avatars [30] can enable disabled workers to provide customer service and participate meaningfully in the workforce. These technologies have created new pathways for remote work and social inclusion in hospitality environments that were previously inaccessible [15], [27], [28], [29], [30].

Despite these diverse applications, there remain important questions about how to optimize telepresence robot design for effective interaction. As shown in Table 1, prior works have explored facial cues or motion capabilities as non-verbal cues for telepresence robots. In this section, we review the existing literature on telepresence robots, focusing on two key aspects that may influence user perceptions and experiences: the display of the operator's face and the robot's ability to perform non-verbal motions. We first discuss the different types of telepresence robots based on their facial display and how this may impact user interactions. Next, we examine the role of non-verbal motion capabilities in telepresence robot design and their potential effects on user outcomes. Finally, we highlight the gaps in current research regarding the specific impact of these factors on presence and anthropomorphism, motivating the need for the current study.

A. FACIAL EXPRESSION CUES IN HRI

In human-robot interaction (HRI), one of various key points is facial cues in this study. McGinn conducted various studies on service robots in which the heads and facial cues were changed to determine the effect on social interaction between humans and robots [36]. To facilitate communication, it is significant for robots to have some kind of face for social feedback. Although not a real human's face and expressions, research has shown that relations between humans and robots can be enhanced when robots are equipped with human-like "robotic" faces that can express and show emotion like humans do [36]. OriHime [29], [37], created by Ory Laboratory Inc,[1] is an avatar and telepresence robot that provides a bidirectional sense of presence even with its non-human facial appearance.

In addition, interactions with a robot get even better when the robot exhibits social behaviors with anthropomorphic characteristics [36], [38]. The projected face telepresence robot performs synchronous actions, and the facial expressions of the remote user increase agreement during conversation [31]. Regarding the effect of human facial cues on robots, it was found that eye gaze and certain facial expressions from a human can be used to further improve relations between humans and robots by physically displaying a human's face on a 2D screen using either telepresence or a virtual agent [39]. For example, Beam is a telepresence robotic system that utilizes this method by replacing the robot's head with an LED screen to display a human's face via video-conferencing. Several studies have indicated that people can really feel the presence of a human in such robots [5], [11].

B. NON-VERBAL MOTION CUES IN HRI

Non-verbal cues are important factors in the HRI research area. A telepresence robot that has the ability to display expressions used in social interaction by means of motion can make the user feel more engaged and the robot more likeable [16]. The spatial configuration and body orientation of telepresence robots affects the way people orient themselves toward the robots, and these robots tend to copy human-like actions and detect surrounding motion [32]. This greatly increases the quality of the interaction between humans and robots. In one study using a robot tele-operated by the "Wizard of Oz" method, the enjoyment of the participants was not affected by the knowledge of whether the robot was being controlled by a program or a human [40]. Yamada et al. proposed motion-based artificial subtle expressions (ASE) in which a robot slowly hesitates by turning to a human before giving advice with low confidence. They found that long- or short-wait expressions might be useful for expressing a robot's confidence, and that fast- or slow-motion ASE is more suitable for such expressions [41].

Another study demonstrated that synchronized on-screen and in-space gestures significantly improve viewers' (participants') interpretation of an action compared with on-screen or

TABLE 1. Comparative analysis of motion, face, anthropomorphism, and presence in telepresence robot literature and list of work. Overview of key aspects of factors mentioned in work (✓means mentioned or dealt with factor, blank means did not mention or did not deal with factor).

Work	Moving (arm motion)	Static motion	Human face	Robot face	Anthropo -morphism	Presence	Experiment
[11]		✓	✓			✓	In-person experiment
[31]				✓ (projected robot face)	✓	✓	In-person experiment
[15]	✓			✓		✓	In-person experiment
[32]	✓			✓			In-person experiment
[16]	✓		✓			✓	In-person experiment
[13]		✓	✓			✓	In-person experiment
[2]	✓ (one arm motion)		✓			✓	In-person experiment
[33]	✓			✓ (projected robot face)	✓	✓	In-person experiment
[34]	✓ (virtual environment)		✓ (virtual human agent)	✓ (virtual robot agent)	✓		In-online virtual environment experiment
[35]	✓	✓	✓		✓	✓	Online experiment
Ours	✓	✓	✓	✓	✓	✓	Online experiment

in-space gestures alone, and that the addition of proxy motion also improves the measure of perceived collaboration [42]. It was also found that in-space gestures positively influence perceptions of both local and remote participants [42]. Neustaedter et al. discussed using a telepresence robot called Beam to attend a conference, and as a result, they showed that the robot was able to attend the conference [11]. Fitter et al. did a comparison experiment between expressive arm motion, non-expressive arm motion, and light expression [2]. As a result, participants felt an advantage toward light expression, and the use of motion increased the perception of the robot being human-like [2].

Although OriHime [37], [43] and OriHime-D [15] do not have expressive facial cues, they have social expression embodiment and the ability to operate in a variety of social situations, which can help disabled people participate more actively in society and social events [15], [27], [28], [29], [30].

C. ANTHROPOMORPHISM IN HRI

An important key point in HRI is anthropomorphism, whose effects have been researched using telepresence robots. One researcher reviewed and explained anthropomorphism and its role in the design of interactive social robots and HRI [44]. Telepresence robots need anthropomorphism for social expression. There is one anthropomorphic telepresence robot that has expression display and gesturing for social expression [33]. The concept of robomorphism, which was introduced by Schouten et al., is based on anthropomorphism, and using this concept in telepresence robots for cooperation showed that it is an important concept to consider when studying the effect of human-mediated robot interaction [3]. When comparing telepresence robots (both with motion and without motion) with smartphones as two distinct types of video teleconference systems in terms of anthropomorphism, the results yielded an ironic outcome. Surprisingly, the anthropomorphism perception was higher for smartphones used as video teleconference systems than for telepresence robots, regardless of whether they had motion capabilities or not [35].

In HRI, researchers have discussed how anthropomorphism affects interaction. One team of researchers thought anthropomorphism might reduce psychological stress related to HRI and tested participant anticipation vs. no anticipation in interactions with human-like and machine-like robots [45]. As a result, anticipation increased psychological stress independent of the robot type [45]. Other researchers have discussed the development of social interaction between robots and people through anthropomorphism in terms of the robot's physical embodiment design and behavior [46]. The factor of anthropomorphism in social robot development, looking forward to considered to using mechanism that should be adopted in social robot research [46]. Furthermore, other researchers discussed the benefits of anthropomorphic robots from a philosophical point of view in HRI, and they believe that this human-like factor can help in implementing these robots in the real world [47]. In addition, anthropomorphism was researched with two dimensions, competence and warmth, as determinants of trust development, and the result showed that they are important for trust development and that anthropomorphism may increase user's trust in HRI [48]. Mandl et al. provide a nuanced view of anthropomorphism in HRI. While more human-like robots were generally perceived as more anthropomorphic, results were not always consistent.

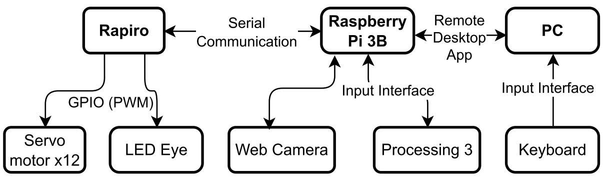

FIGURE 2. Specifications of robot system.

The authors emphasize that anthropomorphism is multiply determined, not just by physical design. Importantly, they found no clear relationship between anthropomorphic design and perceived competence or trustworthiness of robots [49]. A service robot with a high level of anthropomorphism positively influences the willingness of users to follow recommendations [34].

III. ROBOT SYSTEM

In this section, we describe the platform and system used in our experiment. We first introduce the Rapiro robot platform, including its technical specifications and the modifications made for our study. Then, we present the user interface developed to control the robot's motions and gestures.

From the comparative analysis in Table 1, our proposed work for two type of telepresence robots makes it possible to enable abilities such as arm motion in both hands and static motion, in addition to being able to show the operator's face or instead show a robot face.

A. PLATFORM

In our experiment, we used a humanoid robot called Rapiro, which has been widely utilized for various applications related to education and hobbies [50], [51], among others. The Arduino and Raspberry Pi boards in the robot enable users (developers) to communicate with it simply by sending command signals from a PC, and they also allow for the system to be extended easily. These are the reasons we used this robot as the telepresence robot for our experiment. For the experiment, we fixed Rapiro's eye color to blue due to avoid color bias and modified the head so that it could show a remote user's face similar to a video teleconference system.

Rapiro has 12 degrees of freedom (DoF), a USB camera, a microphone in its forehead, and a speaker in its head. Figures 3 to 6 show an overview of Rapiro with and without our modifications, respectively. We modified the head of another Rapiro with a 5-inch portable monitor to show the face of a remote user; the head was made of PLA using a 3D printer. This Rapiro also had 12 DoF, a USB camera, a microphone, and a speaker. Hardware specifications are shown in Table 2

B. USER INTERFACE AND ROBOT MOTION

To control Rapiro, we made a keyboard input interface in Processing 3. When the operator (from a geographically separate location) presses the number "2" on the keyboard, a local PC receives the signal from the operator's location via Wi-Fi, and the robot makes that specific motion. The specifications of the system are shows in Figure 2

We generate robot motions according to the following principles. For both robots, we used preset motions and original motions that we developed for the experiment, such as "hands up" and "wave both hands." In total, we used six motions in the video task, as listed in Table 3. The preset motions included actions like going forward or backward, but we did not use these at this time.

IV. METHOD

This section outlines the methodology employed to investigate the impact of facial appearance and motion on user perceptions of anthropomorphism and social presence in telepresence robots. We first describe the study design and experimental conditions, followed by details on the participants and recruitment process. Next, we present the materials and apparatus used, including the telepresence robot platform, video stimuli, and questionnaires. Finally, we explain the procedure followed by participants and the data analysis approach.

A. EXPERIMENTAL DESIGN

We conducted the experiment using a 2×2 (robot face: human face, robot face; arm motion: moving, static) between-participant design. To explore the different ways people could interact with our design, we used G*Power [52] sample size calculation (with effect size $= 0.5$) and ran our experiment using online questionnaire surveys after showing a video. Participants were recruited from Yahoo! Japan Crowdsourcing, and we used Google Forms for the survey. Most methods examined through online experiments use crowdsourcing services like Amazon Mechanical Turk and Yahoo! Japan Crowdsourcing, and we prepared video clips and questionnaires in Google form for a survey, referring to Sirkin and Ju [42]. We wanted the remote operator's speech and gestures to have precise timings and the same interaction content. While online responses may differ from in-person experiments, Powers et al. demonstrated that remote robots could be used in experiments and be more sociable and engaging than co-located robots [53]. Furthermore, live and video-based HRI trials are known to be broadly equivalent in most cases [54]. However, in some cases, people may empathize less with video-based HRI trials compared with in-person experiments [55], [56]. Therefore, we chose to run the experiment online. Our dependent variables were presence and anthropomorphism. We designed the online experiment so that we could compare which condition affected the dependent values and perceptions of the remote operator who communicated with the participants via the telepresence robot across the following four robot conditions.

1) **Human face and moving** (Figure 3): The face of the robot is a video-conference style screen on which the remote operator is shown, and the robot's arm makes motions.

TABLE 2. Hardware specifications of robot.

Robot name	Rapiro	Modified Rapiro
Height	250 mm[H] × 200 mm[W] × 155 mm[L]	300 mm[H] × 200 mm[W] × 155 mm[L]
Weight	1 kg	1.5 kg
Degrees of freedom	12	
Input voltage	DC 6-12V 4A upper	
Computing unit	Rapiro mainboard (Atmega328P) Raspberry Pi 3B	
Electronics	Rapiro mainboard (ATmega328P) 5-inch monitor (for modified Rapiro only) Full color LED for eyes	
Material	PLA: modified Rapiro head	

TABLE 3. List of robot motions.

	Motion
1	Both hands up
2	Wave both hands
3	Stretch right hand out
4	Grip both hands
5	Left hand up
6	Flutter both hands

FIGURE 3. Human face and moving.

2) **Human face and static** (Figure 4): The face of the robot is a video-conference style screen on which the remote operator is shown, and the robot's arm is static.
3) **Robot face and moving** (Figure 5): The face of the robot is robot-like, and the robot's arm makes motions.
4) **Robot face and static** (Figure 6): The face of the robot is robot-like, and the robot's arm is static.

B. HYPOTHESES

As mentioned above, we conducted the experiment using a between-participant design (face: human face vs. robot face; motion: moving vs. static) to investigate which factors significantly affect presence and anthropomorphism. We wanted to independently see the effects of the motion and face factors, so we formulated four hypotheses for our experiment.

- **H1** The face factor positively affects anthropomorphism.
- **H2** The motion factor positively affects anthropomorphism.
- **H3** The face factor positively affects presence.

FIGURE 4. Human face and static.

FIGURE 5. Robot face and moving.

FIGURE 6. Robot face and static.

- **H4** The motion factor positively affects presence.

Recent telepresence robots can be broadly categorized into two types: monitor-type, similar to traditional telepresence robots [1], [11], and robot face-type, exemplified by robots like Orihime-D [15].

In **H1** and **H2**, in terms of motion factors, typical telepresence robots usually lack arm or manipulation functions, making it difficult to engage in non-verbal communication through gestures despite having mobility [1]. In contrast, Orihime-D [15] possesses arm or manipulation capabilities, allowing for the possibility of non-verbal communication through gestures. Furthermore, telepresence robots with arm-motion expression have been shown to increase the perception of being closer to local participants [2]. Therefore, we aim to investigate how motion factors affect presence and anthropomorphism as dependent variables in telepresence robots, whether they have motion capabilities or not.

In **H3** and **H4**, most telepresence robots show the remote user's face, but some, like Orihime-D [15], [27], [28], do not show faces and still evoke a sense of human presence. Usual telepresence robots have a monitor that shows the tele-operator's face [1], but Orihime-D [15] does not have a monitor and only displays the robot's face. Therefore, we aim to explore how the face factor affects presence and anthropomorphism as dependent variables in telepresence robots, whether they have a human face or a robot face.

C. PARTICIPANTS

A total of 216 participants took part in the experiment online (male: 147, female: 69). Their ages ranged from 18 to 76 (MEAN = 46.04, standard deviation (SD) = 10.61). We recruited the participants from Yahoo! Crowdsourcing, which is a service provided by Yahoo! Japan. All our experiments were approved by the ethics committee of the National Institute of Informatics.

D. TASK

The participants watched one video from among the four different conditions shown in Figures 2–5. These videos showed a remote operator communicating via a telepresence robot and discussing moon survival and item ranking. We created this Moon Survival scenario from the Desert Survival Problem [57] and also a NASA exercise,[3] as the Desert Survival Problem is used by many social scientists and robotics researchers [4], [13], [16], [31], [58].

The video was about an astronaut who had crash-landed on the moon and was discussing how to select 5 items that he needed from the 15 items left to return to his distant home planet. Due to the video length, we discussed ranking up to only 5 items because if we had gone up to 15, the video would have been too long. The ranking of the five items is shown in Table 4.

E. PROCEDURE

The procedure of the whole experiment is shown in Figure 7. First, participants viewed the instructions and watched one video from the four conditions. The instructions stated, "In the experiment, you will watch a video of a human talking to a robot controlled by a human via remote control" and "Watch as if you were talking to the robot." Afterward, we also told them that the task of the video was to have a discussion on moon survival. When participants finished watching the video, they were asked to rate their agreement on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree) in two questionnaire surveys. When they finished the experiment, there was an additional comment or question space. We paid 100 yen (about $1US), and the average time to complete the procedure was about 15 to 30 minutes.

[3]https://www.psychologicalscience.org/observer/nasa-exercise

TABLE 4. Ranking of items.

	Experimenter	Remote operator
1	Oxygen cylinder	Oxygen cylinder
2	Stellar map	Water
3	Nylon rope	Food concentrate
4	Parachute	First aid kit
5	Life raft	Stellar map

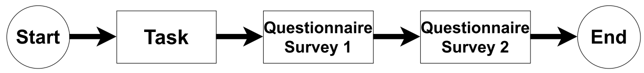

FIGURE 7. Flowchart of experiment.

TABLE 5. Godspeed questionnaire.

	Anthropomorphism	
1	Fake	Natural
2	Machine-like	Human-like
3	Unconscious	Conscious
4	Artificial	Lifelike
5	Moving rigidly	Moving elegantly

In our experiment, we used two different questionnaires: the Godspeed series and one for social presence. Godspeed is a standardized measurement tool for HRI [59] that examines five key concepts: anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety. We used only the anthropomorphism section for our study. For the second questionnaire, we used Networked Minds Measure of Social Presence, which is a measure of presence [58]. We modified it a little due to some of the statements not fitting into our experiment, and the questionnaires are listed in Tables 5 and 6.

F. MEASUREMENTS AND RESULT

To test our hypotheses, we used a two-way analysis of variance (ANOVA). This statistical method makes it possible to investigate the main effects of each independent variable, as well as their interaction effect. By using a two-way ANOVA, we can determine whether face and motion independently influence anthropomorphism and presence, and whether the effect of one factor depends on the level of the other factor. Before the data collection, we determined the sample size on the basis of power analysis. G*Power's parameters [52] had effect sizes of $f = 0.25$, α err

TABLE 6. Networked minds measure of social presence questionnaire.

	Social Presence
1	I often felt as if I was all alone.
2	I think the other individual often felt alone.
3	I was often aware of others in the environment.
4	Others were often aware of me in the room.
5	The other individual paid close attention to me.
6	I paid close attention to the other individual.
7	The other individual tended to ignore me.
8	My behavior was in direct response to the other's behavior.
9	The behavior of the other was in direct response to my behavior.
10	My partner did not help me very much.
11	The other's mood did NOT affect my mood/emotional state
12	My mood did NOT affect the other's mood/emotional state.
13	The other understood what I meant.
14	I understood what the other meant.
15	My actions were dependent on the other's actions.
16	The other's actions were dependent on my actions.

prob = 0.05, and power = 0.8. The G*Power (version: 3.1.9.7) [52] analysis suggested that the sampling size was 128. For each condition, 32 participants were used for analysis. In total, 216 participants participated in this experiment. To ensure that the sample size matched the desired number, we randomly selected 32 participants using Excel.

Before participants watched a video, they were asked to rate their agreement on a seven-point Likert scale (1 = not very familiar, 7 = very familiar) for two statements: "Are you familiar with video conferences?" and "Are you familiar with robots?" Most participants were not familiar with robots (mean = 2.46, SD = 1.57), but they were familiar with video conferences (mean = 3.39, SD = 1.84). We used anthropomorphism from the Godspeed questionnaire series to measure anthropomorphism [59]. To measure presence, we used the Networked Minds Measure of Social Presence questionnaire [58].

The ANOVA results are shown in Tables 8(b) and 9(b), and the results of the simple main effect for anthropomorphism are shown in Table 9(c). The means and standard deviations (SD) for all dependent variables are shown in Tables 9(a) and 8(a). Furthermore, interaction plots are shown in Figures 8 and 9, and the conditions are explained again in Table 7.

For anthropomorphism, we found that the interaction was significant ($p < 0.01$, $\eta_p^2 = 0.0518$). In the static group, the simple main effect of face was significant ($p < 0.0001$, $\eta_p^2 = 0.1110$). It was higher in the group with face. For presence, there was a significant interaction between the two factors. We found that the main effect was significant only for the motion factor ($p < 0.01$, $\eta_p^2 = 0.0616$). Furthermore, the motion with moving was the highest.

V. DISCUSSION

In this section, we discuss the findings of our study investigating the impact of facial appearance and motion on users' perceptions of anthropomorphism and social presence in interactions with a telepresence robot. We begin by summarizing the main results and their significance in relation to our research questions and hypotheses. Next, we situate our findings within the broader context of human-robot interaction literature, comparing them with those of prior studies. We then consider the implications of our work for the design and development of telepresence robots, offering practical recommendations for optimizing user experiences based on our findings. Finally, we address the limitations of our study and propose directions for future research to further advance our understanding of the factors that shape user perceptions and experiences in human-robot interaction.

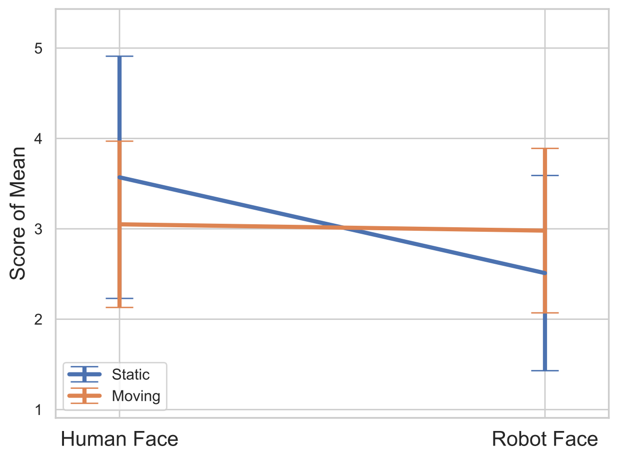

FIGURE 8. Average scores for motion perceived for each condition in experiment. Anthropomorphism is dependent value.

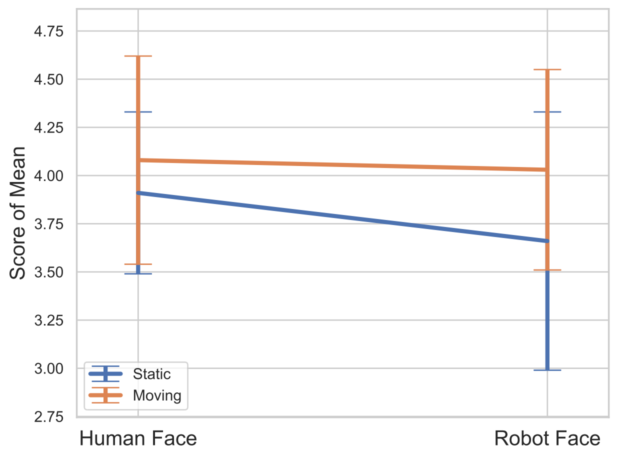

FIGURE 9. Average scores for motion perceived for each condition in experiment. Presence is dependent value.

TABLE 7. Experiment conditions.

Condition	Face	Motion
Condition 1	Human face	Moving
Condition 2	Human face	Static
Condition 3	Robot face	Moving
Condition 4	Robot face	Static

TABLE 8. **Result of two-way ANOVA table for presence.**

(a) Mean and SD of presence.

Condition	Mean	SD
Condition 1	4.08	0.54
Condition 2	3.91	0.42
Condition 3	4.03	0.52
Condition 4	3.66	0.67

(b) Results of two-way ANOVA for presence.

Source	F(1,124)	p	
Face	2.457	0.119	n.s.
Motion	8.144	0.005	**
Interaction	1.00	0.316	n.s.

$^*p < .05$, $^{**}p < 0.01$

TABLE 9. **Results of two-way ANOVA table for anthropomorphism.**

(a) Mean and SD of anthropomorphism.

Condition	Mean	SD
Condition 1	3.05	0.92
Condition 2	3.57	1.34
Condition 3	2.98	0.91
Condition 4	2.51	1.08

(b) Results of two-way ANOVA

Source	F(1,124)	p	
Face	8.776	0.003	**
Motion	0.021	0.883	n.s.
Interaction	6.772	0.010	*

$^*p < .05$, $^{**}p < 0.01$

(c) Results of simple main effect test for anthropomorphism.

Simple main effect	F(1,124)	p	
Face (Moving)	0.0648	0.7994	n.s.
Face (Static)	15.4846	0.0001	***
Motion (Human face)	3.7806	0.0541	n.s.
Motion (Robot face)	3.0139	0.0850	n.s.

$^*p < .05$, $^{**}p < 0.01$, $^{***}p < 0.001$

The present study investigated the impact of facial type and motion on users' perceptions of anthropomorphism and social presence in a telepresence robot. Our findings revealed a significant interaction effect between face type and motion on anthropomorphism, with a human-like face leading to higher ratings only when the robot was static. Additionally, motion was found to be a key driver of social presence, regardless of the robot's face type. These results make several novel contributions to the field of human-robot interaction (HRI). First, our study systematically investigates the interaction effects of a telepresence robot's face type and motion on users' perceptions of anthropomorphism and social presence, providing new insights into how these design factors work together to shape user experiences. Second, our findings reveal that the impact of face type on anthropomorphism is more pronounced when the robot is static, highlighting the importance of considering the robot's intended use and mobility when designing its facial features. Third, our results demonstrate the crucial role of motion in conveying social presence, regardless of the robot's face type, underscoring the need for telepresence robots to have expressive movement capabilities to foster user engagement. These contributions advance our understanding of the factors influencing human-robot interactions and provide valuable guidance for designing effective telepresence robots that can support remote communication and collaboration.

A. HYPOTHESES SUMMARY

The first section in the Experiment section set four hypotheses for what we expected to be the outcome of the experiment. The results are as follows.

- **H1** Face affects anthropomorphism: In the static group, a simple main effect was found for the face factor ($p < 0.0001$), which was partially supported.
- **H2** Motion affects anthropomorphism: This hypothesis did not hold since no simple main effect was found for the motion factor.
- **H3** Face affects presence: This hypothesis did not hold since there was no main effect of the face factor on presence.
- **H4** Motion affects presence: This hypothesis held since a main effect on presence was found for the motion factor ($p < 0.01$).

When the telepresence robot had a human face and no arm motion, which is the static condition, the participants felt the robot to be human-like. Since a real human's face could be seen, they felt this robot to be the most human-like. Even when the human's face appeared with motion, the participants did not feel the robot to be not human-like. Regarding the presence factor, participants felt presence when the robot was performing motions since there was a main effect on the presence factor ($p < 0.01$). In other words, it did not matter whether there was a human face or a robot-like face because there was no main effect on the face factor. For further information on this experiment, several participants pointed out that it was difficult to watch the video and answer questions because the motors of the robot were too loud. However, there was no problem with the motions.

B. ANTHROPOMORPHISM IN TELEPRESENCE ROBOTS

Regarding anthropomorphism, our findings demonstrate that a static telepresence robot with a human face was perceived as more anthropomorphic compared to other conditions. This suggests that the presence of a human face, even without motion, can significantly impact perceptions of a telepresence robot's human-likeness. These results align with previous work on telepresence robots that display either a remote operator's face or a robot face. Our previous study [35] found lower anthropomorphism in motion conditions, which is consistent with our current results, possibly because the embodiment as a moving robot while showing a human face may have felt uncanny [60].

Interestingly, robots like OriHime [37], [43] and OriHime-D [15] can evoke a sense of presence in both directions even with a robot face. While Fitter et al. [2] found mixed preferences among local participants between basic and arm conditions for telepresence robots, they did not directly measure anthropomorphism.

Similarly, while mobile telepresence robots like Beam [1], [11] potentially provide human-likeness, anthropomorphism was not directly measured in these studies. Our results suggest that using a robot face, as seen in OriHime-D [15], might not provide high levels of human-likeness to local participants.

C. PRESENCE IN TELEPRESENCE ROBOTS

Our study found that motion was a key factor influencing presence in telepresence robots, regardless of face type. However, measuring presence in human-robot interaction is challenging, and prior work found both similar and different results.

Several studies, including ours, have found consistent results regarding presence in telepresence interactions. Adalgeirsson and Breazeal [16] found no significant differences in co-presence between static and expressive conditions in their MeBot [16] experiment, although they did find differences in other measures. Our previous work [35] found no differences in presence between smartphone conditions and telepresence robot conditions with and without motion. Similarly, Fitter et al. [2] did not find significant differences in presence measures across their experimental conditions, although they noted some trends favoring the expressive arm condition. These studies suggest two important implications: First, the effect of expressiveness or motion on presence might not be as strong or significant as generally expected in the field of telepresence robotics. Second, there may be other factors that have a greater influence on how present someone feels during a telepresence interaction.

Previous studies [1], [4], [11], [61] suggest that using mobile telepresence robots like Beam [1], [11] may influence presence without necessarily requiring motion or expressive arms. This indicates that the relationship between expressiveness, motion, and presence is not as straightforward as initially expected, suggesting the need to consider a wider range of factors when trying to understand what creates a feeling of presence in telepresence systems.

However, some studies have found positive effects of embodiment and motion on presence. Schouten et al. [3] found that the use of a telepresence robot increased social presence compared to videoconferencing, highlighting the importance of physical embodiment. Furthermore, studies by Kristoffersson et al. [1] on spatial formations in telepresence interactions hint at the importance of positioning and orientation in creating a sense of presence. A prior study [13] found that mobility significantly increased the remote user's feelings of presence, especially in tasks requiring more movement. Rae et al. [5] found that movement conditions (both mimicry and random) led to more positive outcomes compared to the static condition. Supporting these findings, the Orihime-D [15], [27], [28], [29], [30] telepresence robot, which features a robot face without showing the operator's face but can express arm motions, demonstrates how motion capabilities can effectively convey presence even without facial displays.

While our results align with studies showing the positive effect of motion on presence, the broader complexity of presence was not our main research focus. Rather, our contribution comes from the systematic comparison across our four experimental conditions, which revealed that motion consistently influences presence regardless of facial type (human or robot face). This novel finding advances our understanding of how different design elements impact presence in telepresence robots. Based on these research outcomes, we can provide concrete recommendations for the field: incorporating motion capabilities should be prioritized when developing telepresence robots aimed at enhancing presence. These insights offer valuable practical guidance for designers developing telepresence robots, researchers studying human-robot interaction, and users selecting or implementing telepresence systems in various applications.

D. GENERALITY AND LIMITATIONS

There are certain generalities among our results, and the study presented here has limitations that may affect these generalities. First, our use of Rapiro as the robot platform might affect generality since we only experimented with two particular robots. Naturally, each type of robot had its own limitations due to the number of actuators. However, the findings for our robot embodiment might not necessarily be generalizable to other types of robotic embodiments [39]. Second, there was a lack of support for our hypotheses on motion because we chose robot motion from the general movements in our human life. In addition, the delay between the remote operator's speaking and the motion playback speed might also have affected the perceptions of presence and anthropomorphism. Third, the robot face may have affected the generality. We mentioned above that the findings for robot embodiment might not necessarily be generalizable to other types of robotic embodiments [39], and we believe the same to be true for facial cues. In addition, Japanese people often imagine humanoid robots as friendly [40], and since we only used Japanese participants, it is uncertain whether our results would apply to people of other cultures.

Regarding online experiments in general, Crump et al. [62] showed that data collected online using a web browser seemed mostly in line with laboratory results, so long as the experimental methods were solid.

There were a few problems with the human-likeness and machine-likeness in the video task. When the face was robot-like, the robot appeared human-like even for those participants not used to robots, and the way the robot talked sounded human-like. When the face was that of a human, the participants felt the robot to be uncanny because it had a human face but a robot body. This may relate to the uncanny valley. Furthermore, most participants felt as if they were having a video chat in the condition using a human face without arm motion (static condition). /colorred In future work, we will conduct in-person experiments with the same conditions and method used in this study. We will also compare video chat and this condition of using a human face and no motion. Furthermore, we need to consider a wider range of factors when trying to understand what creates a feeling of presence in telepresence systems. /colorblack

Finally, we found that no matter which robot we used, even simple motions could invoke a feeling of presence. Regarding human-face conditions, there was no significant effect of gender in the study by Sirkin and Ju [42]. The design of future telepresence robots will change depending on whether the emphasis is on human likeness or presence.

VI. CONCLUSION

In this work, we conducted a 2 × 2 between-participant experiment (face: human face, robot face; motion: moving, static) and found that people felt a presence with the motion factor regardless of whether the face was human-like or robot-like. Furthermore, what we also found in the condition where the face was a human face and motion was static was that anthropomorphism was highest, which means that people felt the human face to be more human-like than in the other conditions.

Our findings on presence in telepresence robots reveal a more complex picture than some previous studies have suggested. While we found motion to be a key factor influencing presence regardless of face type, this relationship is not straightforward. Our results, along with those from prior work, indicate that presence in telepresence interactions is a complex phenomenon influenced by multiple factors beyond just motion and facial appearance.

Enhancing telepresence robot design for presence and anthropomorphism, based on these insights, can improve the effectiveness of such robots in various fields, such as healthcare, education, and customer service. As telepresence robots see increasing adoption in industry, understanding the impact of core design attributes such as facial appearance and expressive motion is crucial for aligning design choices with the desired user experience. Our experimental approach using online video-based studies also offers an efficient way for companies to test different telepresence robot designs with target users before investing in physical prototypes, potentially accelerating development cycles.

This study contributes to human-robot interaction research by combining the investigation of a telepresence robots' facial appearance (human face vs. robot face) and motion capabilities (moving vs. static). Our novel approach explores how these factors together affect user perceptions of anthropomorphism and presence. Unlike previous studies that looked at these elements separately as shown in Table 1, our research shows that expressive motion can enhance presence, while a human face increases anthropomorphism. These innovative findings provide a new way to optimize telepresence robot design for different user experiences and applications across various industries.

Our findings on facial and motion cues should help support social interaction using a telepresence robot. By contributing insights that guide the design of telepresence robots optimized for their intended application, our work supports the effective deployment of this technology across industries.

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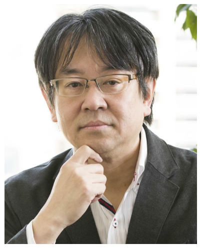

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