IN/ACTive: A Distance-Technology-Mediated Stage for Performer-Audience Telepresence and Environmental Control

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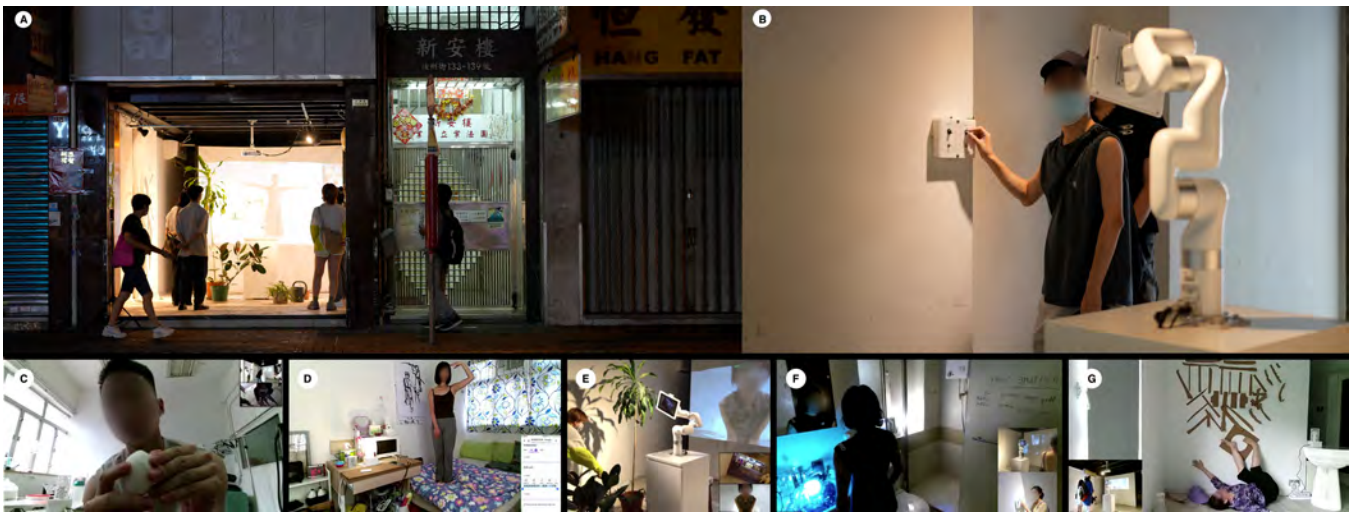

Concept and venues for IN/ACTive: a distanced performance exhibition. a) Exhibition venue for robot and audience engagements embedded in a local ethnic neighbourhood. b) In the exhibition site, the audience controlled the light and music at the performer's location via the control panel. c) P01 was eating with the audience during the performance. d) P02 used her body to imitate a letter for the audience to guess. e) P03 instructed the audience to water the plants. f) P04 was observing when the audience changed the light. g) P05 was doing contemporary dance.

Abstract

The increasing virtualization of the performance process has resulted in passive interactions between performer and audience based on the observing paradigm, but without the presence of in-person staging. We designed a more interactive paradigm of remote performance using a multimedia exhibition strategy where visitors can alter the environment of the performer's location by changing its music and lighting, whereas the performer can create engagement in the exhibition space by affecting a remote robotic arm. We conducted a case study with five participating performers, investigating their expectations, workflows, and perceptions before and after the performance-exhibition, and examining the video footage of their interactions with visitors to understand how they adapt and respond to this remote performance paradigm. We found that the robot arm was perceived as a mediating character with its own distinct identity, that musical changes have implicit behavioral effects on the performance, that lighting manipulations actively changed performer actions during improvisation, and that audiences appear to identify themselves and the robot as integral co-performers in this setup. This work provides insights into how performers learn to engage with audiences in novel distanced spaces and diverse interactive media, generating insights for future virtualized performative interactions beyond the classical stage metaphor.

CCS Concepts

• **Human-centered computing** → **Empirical studies in interaction design**; • **Applied computing** → **Performing arts**.

Keywords

multimedia performance, remote performance, remote robotics, performance technology, environmental control

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1 INTRODUCTION

Due to public health concerns, recent virtualization of performances has resulted in a transformation of the public performance space into interactions with diverse media at a distance [7]. Motion capture for exhibitions [45], augmented projection spaces [11], shadow play for merging multiple artists in different locations, and remote robotics for expressive movements [15] have all been used in these remote strategies. While these multimedia technologies allow for the functional connection of performance locations, they also raise fundamental issues about how performers connect with audiences.

Using mediated-telepresence systems to convey emotional gestures is one way performers and audiences can connect despite their distance [43]. While remote robotics has been used in both rehearsal and performance processes [16], the devices tend to be mechanical, rigid, and subservient instruments [9], failing to reflect the way humans interact with others in person. Instead, recent research suggests that we can interpret machines as playing their own characters, using their own gestural language [6, 12, 22], similar to how we use gestures to communicate in video chat [30]. This relationship between humans and machines makes them co-actors, so the robot is not a clone, but rather plays a role of its own.

The classical stage has audiences who watch attentively as performers perform, with little participation but applause [40]. Recent work in live-streaming captures spectators giving gifts and commenting on virtual performances while occupying the perimeter of a center-surround digital realm [25]. Streaming and Zoom-based performances suggest a new type of interaction in which audiences can contribute by changing environmental properties or backgrounds for affecting performative presence [29]. The new interactive performance forms a mixed reality where space and movement are linked to virtual and physical worlds [3].

We created a distanced interactive setup to see how performers engage with remote controlled interactions and are affected by environment control in a hybrid multimedia performance. Performers in their own studios can engage with exhibition visitors via a remote robotic arm while reacting to audience control of the studio lighting and music. We investigated the following:

RQ 1: How do telepresence robotics affect the perception and use of performers' own bodies in distanced interaction?

RQ 2: How are the performance artists' specific workflows affected the way they perform in remote interaction formats?

RQ 3: What are performer-audience engagements when audiences can control properties of the performer's stage at a distance?

To answer these questions, we conducted pre- and post-exhibition interviews with five participating performers and evaluated video footage of their performances. This distanced performance-exhibition intervention sheds light on how performers and audiences interact with one another in novel digitized spaces, generating design implications for future interaction strategies that serve as a blueprint for contextualized performances beyond the classical stage.

2 BACKGROUND

2.1 Robotic Performance

Robots have been used in performance paradigms as part of artistic investigations for engaging the audience, since they have social performative features that can be interpreted as human [31]. A Humanoid robotic machine could be anthropomorphized and show emotional expressions of curiosity and shyness [22]. These emotional expressions of machines had been used previously to show personality of robotic arms engaged in an interactive chess game as performative installation [24]. The robot Lola (ActivMedia) was employed to dance to music for entertainment purpose [27], while Chico McMurtrie's "The Ancestral Path Through the Amorphic Landscape" uses 60 human-like robots that can behave in human-like ways, such as sketching and singing music [10]. Sun Yuan and Peng Yu's "Can't Help Myself" created an industrial robot arm to do its specific endless duty of shoveling and containing the red fluid, which critically invokes human sympathy [44]. "Petit Mal" by Simon Penny is an autonomous mobile device that attempts to explore the behavior of a machine in the real world [33].

These robotic works demonstrate the growing understanding of robots as performers with human characteristics. However, there is a relative lack of HCI work on human-robot collaborative performance and how it affects performer workflows. With the recent virtualization of performance practice, there has been an increasing focus on how remote interactions can be studied in HCI communities [39]. New interventions have been designed to serve as a bridge between the audience and the performance to reduce the detrimental impact of distancing [35]. These participatory processes have included new audience engagements using mobile technology to participate in the performance process [1]. These fresh perspectives invite a need for further research on robotic performance art, exploring performer reactions, strategies of interactions, and influences on both collaboration and audience engagement.

2.2 Technology Applied to Remote Performance

Digitized performance has been actively explored recently [5], for more accessible remote performance and to maintain the connection with the audience [14]. Recent work in HCI has explored combining remote interactive technologies with dance and performative movements for presenting embodied interaction during the performance in technical frameworks from the artistic performer's perspective [13], as well as designing hardware and software supporting tools for these engagements [19].

Remote dance performances distance the performer and the audience, thus creating a need for technology-enhanced interactions that affects audience perception. Online streaming and video performance are more accessible to the audience and can encourage their virtual engagement and activity [14]. The lack of shared experiences with other audiences has led to the use of immersive methods like VR [38]. Novel telepresence VR systems allow the users to control a robot arm remotely, while being immersed in the holographic virtual scene [20]. Interactivity in performance alters both the audience's and the performer's perception of the movements and affects the audience's and performer's roles [4] [28]. The AI-based technology and virtual interaction via mobile devices have allowed the audience to communicate with the performer at a distance with accuracy in movement information exchange [42], while also questioning social constraints [1]. Robotic dance as a nonverbal expression of the robot during collaboration with human dancers can attract the audience's attention [32], with potential usage in remote performances.

2.3 Body and Emotional Influence by Robotic Performance

Body, as a performing language, is a tool for artists to learn and grow [41]. Body movement-based performance is a core part of the performing arts [18], while body perception in such paradigms is a multifaceted concept related to one's self-awareness [8]. Body perception could be influenced by movement [21], either to strengthen or undermine the performance [35]. Previous research shows that embodied interactions enhance the understanding of the body in its movements and dimensions [19]. Happy Feet, a remote dance project, showed that the embodiment of limbs in performance offers participants useful information regarding awareness, such as their exact position and movements [2].

While the human body could convey emotions in performance, it is also a way to connect with the audience [26]. However, movement performance using robotic systems may influence the emotional expression of the audience also [43]. Research on virtual avatars shows that changing the expressed emotion of the dancing character influences the audience emotionally, even if it does not depend on whether the depicted emotion is correct [34]. Interactions with different non-human avatars in choreography can also lead to emotional changes [46]. Despite these findings, more needs to be known about the effect of human-machine collaboration on performance processes and the differences between Eastern and Western performance artists.

3 RESEARCH METHODOLOGY

To understand how performers can work in a medium of remote communication and interact with audiences, we produced a multimedia installation and performance that linked an exhibition space with a remote performance space. Before the start of these performance exhibitions, interviews were conducted with five participating performers via Zoom. The performers were of Chinese ethnicity, but interviews were conducted in English. We used open coding to analyze the videos of each of the five performances and thematically analyze the outcomes. We conducted a survey with 58 audience members right after the performance.

3.1 Design and Implementation

We created the setup to allow audience to participate in the performance process, while allowing performers to take actions at a distance. We used a robot arm because it is ambiguous enough to represent humanoid actions but not human enough to become an avatar for the performer, i.e. it can have its own agency in the work. The robot serves as a surrogate for the performer while still providing its own identiy.

The performance-exhibition consisted of two venues, one at the studio of the performer and one exhibit for visitors. The artists performed on a Kinect connected to a computer on Zoom from their homes or studios. Visitors to the show could watch the performance on projection and use panels to adjust the lighting and music at the artists' houses (Fig. 1). The lighting and music controllers use NodeRed and the Mosquitto MQTT broker to access the Arduinos that change the lighting level on two lamps and play songs on a Spotify playlist specified by the performer, respectively. The latency is 400 ms due to separate performance and exhibition locations.

Previous work suggests that robots with their own language of gestures can be used to affect audience engagement [23]. Thus, we built nonverbal rules for the human-machine interaction to allow for co-performance in the distanced stage. The robot arm at the exhibition was a bridge between digital and physical space, producing movements triggered by human gestures at the performers' site in its own language of machine gestures, converting human body movements to robotic gestures (Fig. 2).

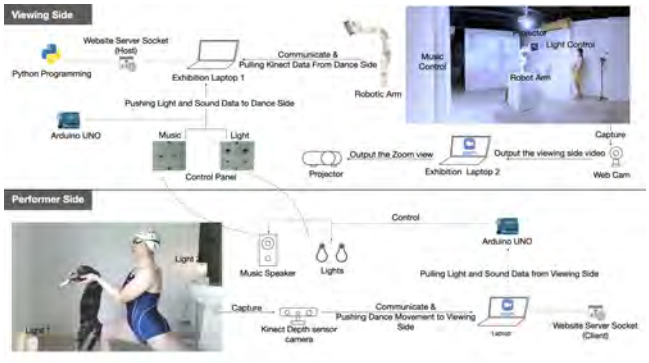

Figure 1: Performance-exhibition setup. In the performance locations, a Kinect camera captured the movements of performers and triggered robotic gestures; a laptop connected performers to Zoom and allowed them to see the audience; speakers and lamps were controlled by the audience in the exhibition. In the viewing location, the robot arm was controlled by the performer; two panels allowed modification of performer studio lighting and music via IOT; robot's head held a webcam-tablet displaying the audience to performers.

Figure 2: Interactive robot movements. When performers lifted their left hands above the waist, the robot turned to the left side and stared at the lighting-control panel. When performers lifted their right hands above the waist, the robot turned to the right and faced the music-control panel. When the performers sat down and made a crossing motion, signaled thumbs up, or lifted both arms, the robot would sit, stay steady while turning away, nod, and turn around, respectively.

ID	Gender	Area of Practice	Theme of Performance	Duration
P01	M	Contemp Dancer, Choreographer	Daily Eating Performance	1h38m
P02	F	Performance Artist	Searching Audience's Texts	4h30m
P03	F	Performance Artist	Watering Plants	1h22m
P04	F	Dancer, Performer	Bath time Story	2h24m
P05	F	Dance Artist, Choreographer	Human Aging Exploration	2h28m

Table 1: Information of Interviewees

3.2 Interviews

We conducted interviews with five participating performers before and after the performance-exhibition in English. All five of the selected performers are Asian (Chinese) and due to Eastern performers' better acceptance of pandemic restrictions than western performers, it may be simpler for them to adapt the novel performance platforms. Their performance styles and themes are also different from each other but complement each other, allowing us to gather information as an ethnographic qualitative study. The semi-structured interviews consisted of questions based on our three core research questions, including their perception of body movements, adaptations for the performance, the process of rehearsing and performing with the robot, audience engagement with lighting and music, etc. Each interview was performed by at least two researchers: one who asked questions and another who took notes. To arrive at the themes, we used open coding on the interview transcripts as part of a grounded theory study [37].

3.3 Video Observation

To explore how performers interact with the robot and the audience in the exhibition outcome, we applied open coding to each Zoom performance video [37]. Two researchers determined the possible codes across all performances, such as interaction with the robot, music, lights, and audience by body movements, facial impressions, as well as other behaviors. Then the researchers independently coded the actions of one performer and calculated a measure of inter-rater reliability (Cohen's kappa = 0.73). Due to high reliability, each remaining performance was coded by one researcher.

3.4 Survey for Audience

We surveyed 58 audience members after the performance to compare the intended effect of the performers with the actual outcome using a 7-point Likert scale (Fig. 8). The survey asked questions about the interpretation of creative performances, specifically regarding the interactions among performers, the robot, music, light, and the audience.

4 Results

4.1 Telepresence robot affected performance workflow

4.1.1 Performer expectations

Pre-performance interviews showed that none of the five performers were quite sure how their interaction with the robot would turn out. Performers thought that robots should "have a character," with P02 noting that "the robot could be my mom" as the character in the show. P05 considered the robot as an "innocent being," thinking that it should have human characteristics since it imitates human movements. This would enable a connection between robot and human that is "more powerful than only a human performing."

Performers expected to see the movement of the robot arm and its impact. P01 was curious about seeing the consequences of his movements and whether they could successfully trigger the robot or not. P03 specifically designed rules for the robot to "do special movements that I want, like pouring water into the plants." P04 expected that "the robot can finish the movements that I designed." Besides the performance part, performers hoped the robot could have other functions, such as "help attract the audience" (P02, P03) or "learn from each other" (P05). None of the five performers had previous experience performing with robots; instead, pre-visualized their interactions with the robot.

4.1.2 Telepresence robot affects performer bodily interactions

The performance causes the performers' bodies to self-reflect in order to activate the telepresence robot. Performers used body movements and interactions with other objects to trigger the robot. P01 designed part of his performance as daily stretching, which involved body movements that could trigger the robot arm (Fig.3A). He also tried to trigger the robot with facial expressions. P02 exaggerated body movements, including waving limbs in the air and moving around to make the robot arm move for communicating with the audience (Fig. 3B). P03 had specially designed body movements to trigger the robot arm for interaction with the audience. She moved closer to the camera and opened her mouth when the audience showed the plants close to the camera (Fig. 3C). These interactions demonstrated that she used the robot to complete physical tasks that she was unable to complete due to her lack of presence in space. P04 performed movements slowly to let the robot react more clearly. When designing movements for the telepresence performance, performers had to consider the effectiveness of communication with the robot arm.

However, its presence did not distract the performers. P01 thought he was overly focused on how he adjusted the robot's movements, but he really wanted to focus on the gesture he devised. P05 believed that in order to avoid body changes before movements, she needed to be extremely sensitive.

4.2 Performer adaptations to distanced performance

4.2.1 Adaptation to the telepresence robot

Based on the post-performance interview, performers found that the movements of robots were different from their imaginations. For most performers, the interaction with the robot was "much

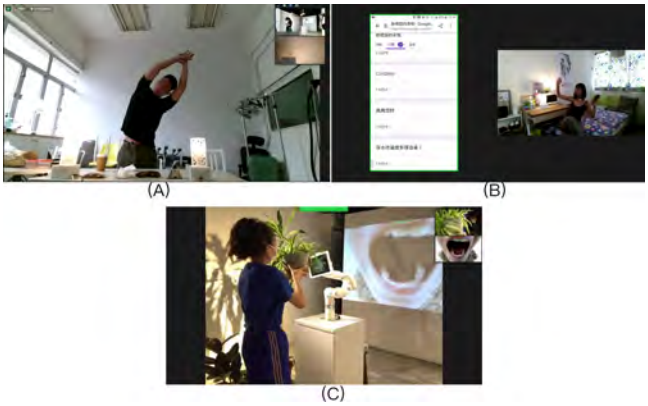

Figure 3: Performers' interaction during the performance. A) P01 was stretching his body to invoke the robot arm by these movements. B) P02 exaggerated her movements to invoke the robot arm as a way of communication with the audience. C) P03 was approaching the camera with mouth opening as an interaction with the audience.

smoother, more sensitive, and easier to trigger or lead" (P01, P02, P03). Performers tried to adjust their body movements or facial movements to lead the robot (P01, P02, P03, P04, and P05) (Fig. 4).

P05 tried to focus attention on her own performance instead of on the robot. She also felt challenged when "not recalling the rule of the robot", but it did not constrain or affect her movement. Instead, P03 adapted to controlling the robot arm at the beginning. The movement used to trigger the robot arm was made clear in her performance. P01 focused more attention on interacting with the robot arm through movements. He used different movements, including facial expressions, to trigger the robot arm (Fig. 4A). It did not always "happen as expected", but he explored the possibilities.

When deciding whether or not to interact with the robot arm, performers can adjust to the telepresence situation early on and develop their own approach to better deliver the show to the audience.

Figure 4: Performers' interaction with the robot arm. A) P01 tried to stretch his body and do facial expressions to invoke the robot. B) P03 held up both arms and thumbed up to invoke the robot . C) P05 danced to the music to invoke the robot arm. D) P04 stood on the toilet and did postures to invoke the robot arm. E) P02 waved her feet in the air to invoke the robot arm.

4.2.2 *Adaptation to the music*

Certain performers particularly reacted to music using body movements or interactions with other objects. P01 and P02 moved or danced to Cantonese music (P01) and English pop music (P02). The nature sounds and music alternately played, but they had no strong relationship with the movements of P03. Songs changed several times during the performance, but P04 only focused on her "shower show", the music was the background for the performance. According to the post-performance interview, performers did not feel affected by music control (P02, P03, and P05). Although two of the performers adjusted their movements along with the music, they still did not think the control of the music affected their performance; they used music as a part of their performance.

P04 mentioned before the performance that music can help connect with the audience emotionally during a performance. However, when performing, she paid less attention to the change in music and did not react to it. Even though P01 and P02 did react to music, it was more intuitive than intended. They also did not consider music to be a vital factor in communicating with the listener. More visual interaction between the audience and the performer occurred as a result of body movement. The engagement in music had no effect on the performance.

4.2.3 *Adaptation to the light*

Some performers used the lighting system to interact with the audience. They reacted by moving their bodies, making facial expressions, and interacting with other items (see Fig. 6). Two performers performed at night, and the light effect had a more obvious influence (P03, P04). P02 was not heavily affected by the lighting interactions

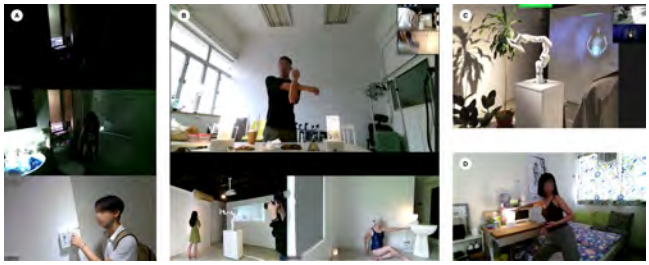

Figure 5: Lighting system and the influence on performers. A) P04 performed in the evening. The light had a more obvious influence on the performing site. The figures show the scenes of both lamps off and one lamp off, as well as one audience controlling the light through the panel at the exhibition venue. B) P01 and P05 performed during the daytime with partly opened windows. The influence of lamps was not obvious to the environment. C) P03 performed with the lamps as the only light source at the performing site. D) P02 discovered the sudden change of the light and touched the lamp as a response to the audience.

but had surprised facial expressions and touched the lamp when it suddenly lit up (Fig. 5 D). She felt the changing of light "made the scene more exaggerated and dramatic". P03 considered the lighting part of her performance by moving and holding the lamp (Fig. 5 C).

P04 said that she was sometimes interrupted by the suddenly lit-up light. When the light turned off, she had the feeling of "sharing a secret" with the audience. For P01 and P05, the performance took place in the daytime with partly opened windows, so the lighting interaction was not as clear (Fig. 5 A).

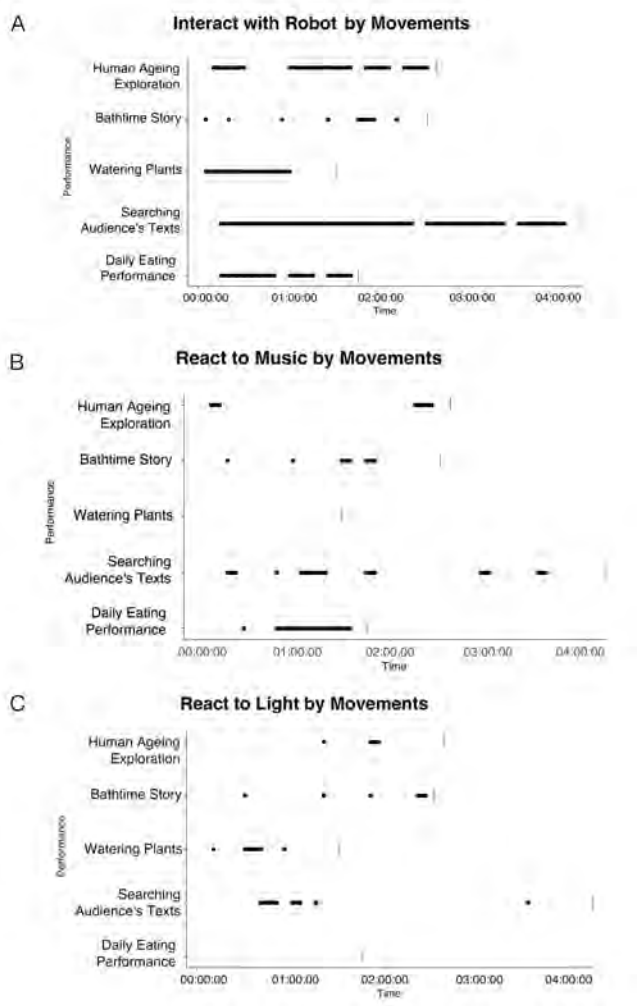

Figure 6: Performers' movement in performance A) All five performers have interacted with the robot through body movements. P01 and P02 have non-stop interaction with the robot. P03 had continuous movement to invoke the robot except the last half hour. P04 had relatively fewer movements during the shower show. P05 made some continuous movements but not the whole performance. B) All other performers had reactions to the music by movements except for P03. C) Apart for P01, all other performers had reacted to the light by movements. P02 reacted to the light mostly at the beginning of the performance. P03 reacted to the light mostly during the middle of the performance. P04's reaction to the light were discontinuous but from beginning to the end. P05 rarely reacted to the light.

These reactions could sometimes invoke the robot arm and reach the audience as a way of getting feedback. When the lighting system could change the visibility of the performer, the audience had more control over the performance and influenced the performer's reaction.

4.3 Connection with the audience

4.3.1 Performers' expectation for engaging the audience
Performers wanted to build connections with the audience (P02, P03, P04, and P05) and hoped they could understand their intention (P01, P03, and P04).

The telepresence performance for P01 is a new and challenging form. Despite his telepresence performance, he expected to see "the audience interacting with the venue". According to P01, telepresence performance is a form that combines daily activities and gallery art. P02 expected to use the audience's faces and reactions as material for her performance. P03 felt that due to the lack of direct communication, the interaction with the audience might be less controllable for her in the telepresence performance. Because the audience's ability to control the lighting and music is unknown, P04 decided not to plan her reaction ahead of time and instead concentrate on her movement. According to her previous experience, the visual scene is important for communicating with audiences since distance might affect the emotional connection. P05 felt that the telepresence performance using screen media could not effectively show the emotion of the performer. Therefore, she designed more "visual cues for the audience to understand performance and emotion". She wanted the audience to see "how the robot arm's movement echoed with the human's".

Figure 7: Audience and interaction with the audience during the performance. A) During the performance of P01, one audience tried to control the robot arm with his movement. B) During the performance of P04, she suddenly turned to the camera and was watching the camera interaction with the audience. C) The exhibition venue was located by the street. People passing by would occasionally stop to see the show.

4.3.2 Performers' perception of the audience during the performance
All the performers perceived communication with the audience during the performance (P01, P02, P03, P04, and P05). Some performers felt surprised by the behavior of the audience (P02 and P03). P01 mentioned the "audience tried to do movements to trigger the robot arm" and "negotiating with the machine" as unanticipated interactions (Fig. 7A). As P02 mentioned, "I felt less lonely during the performance" when seeing people talking on the street and

people who were not intended to come but joined for interaction (Fig. 7C). P04 compared the experience of the telepresence performance for the audience to "watch a film". By "suddenly turning to the camera and watching it" as an interaction (Fig. 7B), P04 tried to evoke the reaction of the audience and create the experience of "people in the film watching you". P03 and P05 maintained control of the performance as the performers and kept the traditional performer-audience relationship when both of them stated that they "were not affected by the audience". P05 "tries to ignore the audience" especially when she "has a chance to interact with the audience but does not do it".

The telepresence performance provided multiple interactions between the audience and the performers due to the enhancement of the robot arm and cameras. Performers perceived the audience differently through the screen than they did on stage, and the interaction emphasized the audience's presence. However, if the performer does not want to interact with the audience, the distance may help them do so.

4.3.3 *Audience's perception of performers*

Most audiences stated in the survey that they made reactive movements to the performance. The most commonly mentioned reaction was moving closer to the robot arm to observe. The movement of the robot arm evoked the reactions "move with the robot by tapping the feet along with the BGM" (A20), "Using body movement to imitate the movement of the robot arm" (A28), and "move with the robot arm even though I cannot control it" (A43). Some audience members sweated during the performance (A12, A16, A18, and A24) after moving with the performer and the robot arm. The performer P01 noticed that the audience "tried to react to the robot... and then found it was controlled by performers but not them". During the performance of P02, due to the lack of vision of the performer, the audience was not aware that the robot was controlled by the performer and thought that the robot was the "performer".

Some audience members believed that "the audience is the performer" while others considered that "the audience and the performer shared the identity of the performer". There is also an interesting statement about recognizing the performing site as the audience (A38). A16 and A18 said that "I am the performer while the others are the audience", which separated them from the performing activities. A13 gave the identity of the audience to the robot arm, while A44 believed that "the identity of audience and performer is fluid". When the interaction of the audience is considered part of the performance, the audience absorbs itself in the performance and is fully engaged with the performer. The identities of the performer and the audience were blurred due to the constant interaction and mutual influences.

The quantitative analysis data suggests that the performer has a clear idea of what they want to achieve in the show piece, whereas the audience is making exploratory attempts to engage with the performer. Although the audience did not fully comprehend every aspect of the interactions, they did understand the emotion that the performers were attempting to express. The telepresence performer and the replica of the robot arm helped the audience to understand the performance's purpose in the majority of cases. Throughout the performance, the relationship between the robot and the performer can also be well interpreted. The audience's perception of the performer was unaffected by the telepresence performance.

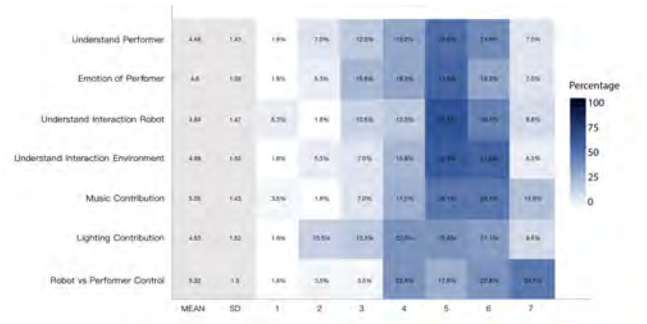

Figure 8: Quantitative results of the audience survey (n=58). Questions: Understand Performer "How well can you understand what the performer was trying to do?", Emotion of Performer"How well can you feel the emotion that the performer was trying to convey?", Understand Interaction Robot"How well can you understand the interaction between the performer and the robotic arm?", Understand Interaction Environment"How well can you understand the interaction with the environment in the performer's location?", Music Contribution"How well do you think the music in the performer's location helps you interact or connect with the performers?", Lighting Contribution"How well do you think the music in the performer's location helps you interact or connect with the performers?", Robot vs Performer Control"Do you think the robotic arm is controlling the performer or the performer is guiding the robotic arm?".

5 DISCUSSION

To investigate the research questions, we created a novel multimedia interactive performance with a robot translating a performer's movements in its own way and audience manipulation of the lighting and music systems of the performer's space, in contrast to traditional strategies of visual media enhanced remote performance [14, 38]. With the robot arm, the performer could choose to interact directly with the audience as a telepresence of themselves. The robot serves as a conduit for communication between the performance and the audience, but it is not one of the performers. In particular, it cannot move around, does not have arms and legs, and can be interpreted either as a body with a head or an arm with a hand. It has its own agenda and has had distinct encounters with both performers and audience members. The remote music and lighting control of the audience, in turn, changed the performer's actions both implicitly (music) and explicitly (lighting). These changes enhanced engagement for the audience in distance performance and made them feel like performers in the exhibition space, which in turn stimulated the improvisation of the performers as reactions.

5.1 Limitations of Distanced Remote Performance Engagements

We used interview and video observation studies to learn that the five performers built their performances on their unique practices, which the remote format affected differently in each case, in order to answer RQ 1 and RQ 2. P02, for example, texted the audience, whereas P03 used specially designed gestures to command the robot arm to act. As a result, the findings regarding engagement may not apply to all types of performances. The differences between the performers and their interventions, in particular, provided inspiration for future interactions, but they may not apply to all performance types. The variety, on the other hand, provided insights into various strategies for improving this remote control format.

Since all the performers were of Asian ethnicity, they may use the robot and remote control in ways that are different from what Western performers would do [36]. Eastern-trained performers may prefer to create more peaceful environments for interaction, and due to their greater acceptance of pandemic restrictions, it may be simpler for them to adapt the novel performance platforms [17]. Western artists may design various shows even in the same remote interactive format because of the difference in cultural background and performance methods, which leads to different improvisations. In future studies, we would engage artists from various cultural backgrounds to see how they would adapt to the remote format.

5.2 Performer-Audience Relationships

The hybrid exhibition format created a new understanding of the performer-audience relationship and identities in order to investigate RQ 3. Because of the robot arm's physical presence and direct interaction, some audiences identified it as the "performer." When the audience noticed that the robot arm was following the performer, the robot arm and the performer shared the identity of the "performer." The audience, on the other hand, felt they shared the performer's identity because they were actively interacting with the performer and had some control over the performance environment.

We were also interested in what behaviors and perceptions people have when given the option to remotely alter the performance environment, as opposed to the classical stage, and to allow actions to remotely trigger a robot gesture as a distanced performance. According to the audience survey, the majority of the parts were understandable. Even though the communication methods with the performer were limited and may have caused some confusion in comprehension, we discovered that engaged performers and audiences, who may not understand exactly how things work, gave all of these interactions a try in their attempt to perceive. Our work has provided an experimental engagement for allowing audience physical engagement with performers through changes to the performance context. Future research should look into ways to improve the audience's understanding of the robot's behavior and the overall structure of the extensive performance in order to make the interaction more engaging and responsive.

5.3 Limitation of Music And Lighting Interaction

The music and lighting interaction system did not have a clear influence on every performance. Some performances occurred during the daytime, when the lighting did not have obvious changes. Music appeared to affect the performers' actions in the video, but they did not self-report their effect to the audience. This was possible because, unlike on a traditional stage, visitors were not immediately visible to the artists but instead relied on a moving camera on a robot and cameras of varying resolutions at different locations. Compared to live-streaming interactions [25], audiences were forced to be behaviorally rather than verbally active and encouraged to try manipulations that affected the stage rather than comment on or reward performers, creating a more curiosity-driven environment for the performer.

6 CONCLUSIONS

Our work created a multimedia, interactive environment for performers to improvise and engage audiences who were not physically present at the exhibition. We created audience engagements that have an impact on the performance environment while using robotic telepresence to establish a technologically mediated character in the exhibition space that allows for new identity roles between performer and audience.

We would like to investigate how the distanced interaction between the audience and the performer via telepresence technology influences the performer's identity and future performer-audience relationships. Other technologies, such as augmented reality (AR) or biosensors, can be used to increase the level of interaction between performer and audience data. The current work includes audience participation in the form of music and lighting system control, but it can be expanded to include other environmental variables such as space, background visuals and color, and temperature. Finally, while we focused primarily on performer perceptions and workflows, the performer's mutual perceptions with audience members can be studied in future work where the expectations of each group of the distanced interaction process can be analyzed.

Our work created a technology-mediated way of promoting performer-audience interactions that extends the participatory interaction process beyond classical stage-like performances by allowing performers to have a gestural-based presence on the remote stage and allowing audiences to interactively modify the performer's environment.

References

[1] Sarah Fdili Alaoui and Jean-Marc Matos. 2021. RCO : Investigating Social and Technological Constraints through Interactive Dance. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–13. https://doi.org/10.1145/3411764.3445513

[2] Hesam Alizadeh Talarposhti. 2016. *HappyFeet: Embodiments for Joint Remote Dancing*. Master's thesis. Graduate Studies. https://doi.org/10.11575/PRISM/26337 Accepted: 2016-09-06T21:41:05Z.

[3] João Beira, Rodrigo Carvalho, and Sebastian Kox. 2013. Mixed reality immersive design: a study in interactive dance. In *Proceedings of the 2013 ACM international workshop on Immersive media experiences (ImmersiveMe '13)*. Association for Computing Machinery, New York, NY, USA, 45–50. https://doi.org/10.1145/2512142.2512147

[4] Johannes Birringer. 2004. Interactive dance, the body and the Internet. *Journal of Visual Art Practice* 3, 3 (Jan. 2004), 165–178. https://doi.org/10.1386/jvap.3.3.165/0

[5] Laura Bissell and Lucy Weir (Eds.). 2021. *Performance in a Pandemic*. Routledge, London. https://doi.org/10.4324/9781003165644

[6] John-John Cabibihan, Wing-Chee So, and Soumo Pramanik. 2012. Human-Recognizable Robotic Gestures. *IEEE Transactions on Autonomous Mental Development* 4, 4 (2012), 305–314. https://doi.org/10.1109/TAMD.2012.2208962

[7] Randy Cohan. 2022. *COVID-19's Pandemic's Impact on The Arts: Research Update May 12, 2022*. Technical Report. https://www.americansforthearts.org/node/103614

[8] Ajau Danis, Ain Nadiah Jamaludin, Hayati Adilin Mohd. Abdul Majid, and Khairil Anuar Md Isa. 2016. Body Image Perceptions among Dancers in Urban Environmental Settings. *Procedia - Social and Behavioral Sciences* 222 (June 2016), 855–862. https://doi.org/10.1016/j.sbspro.2016.05.196

[9] Donna Z Davis and Shelby Stanovsek. 2021. The machine as an extension of the body: When identity, immersion, and interactive design serve as both resource and limitation for the disabled. *Human-Machine Communication* 2 (2021), 121–135.

[10] Steve Dixon. 2007. *Digital Performance: A History of New Media in Theater, Dance, Performance Art, and Installation*. https://doi.org/10.7551/mitpress/2429.001.0001

[11] Hannah J Ellis. 2021. *Intersection Between Digital and Dance: The Digital Environment's Impact on the Arts, The*. Ph. D. Dissertation. University of Wyoming. Libraries.

[12] Hadas Erel, Tzachi Tov, Yoav Kessler, and Oren Zuckerman. 2019. Robots are Always Social: Robotic Movements are Automatically Interpreted as Social Cues. 1–6. https://doi.org/10.1145/3290607.3312758

[13] Sarah Fdili Alaoui. 2019. Making an Interactive Dance Piece: Tensions in Integrating Technology in Art. In *Proceedings of the 2019 on Designing Interactive Systems Conference (DIS '19)*. Association for Computing Machinery, New York, NY, USA, 1195–1208. https://doi.org/10.1145/3322276.3322289

[14] Marie Fol. 2021. Virtualised dance ? Digital shifts in artistic practices. https://www.ednetwork.eu/uploads/documents/63/EDN_Virtualized%20Dance%20Full%20Publication.pdf

[15] Oliver Gingrich, Alain Renaud, and Eugenia Emets. 2013. Kima-a holographic telepresence environment based on cymatic principles. *Leonardo* 46, 4 (2013), 332–343.

[16] Tom Gorman, Tiina Syrjä, and Mikko Kanninen. 2019. There is a world elsewhere: rehearsing and training through immersive telepresence. *Theatre, Dance and Performance Training* 10, 2 (2019), 208–226.

[17] Tuomeiciren Heyang and Rose Martin. 2022. Teaching through TikTok: a duoethnographic exploration of pedagogical approaches using TikTok in higher dance education in China and Norway during a global pandemic. *Research in Dance Education* (Oct. 2022), 1–16. https://doi.org/10.1080/14647893.2022.2114446 Publisher: Routledge.

[18] Jodi James, Todd Ingalls, Gang Qian, Loren Olsen, Daniel Whiteley, Siew Wong, and Thanassis Rikakis. 2006. Movement-based interactive dance performance. In *Proceedings of the 14th ACM international conference on Multimedia*. ACM, Santa Barbara CA USA, 470–480. https://doi.org/10.1145/1180639.1180733

[19] Stephan Jürgens, Nuno N. Correia, and Raul Masu. 2021. The Body Beyond Movement: (Missed) Opportunities to Engage with Contemporary Dance in HCI. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '21)*. Association for Computing Machinery, New York, NY, USA, 1–9. https://doi.org/10.1145/3430524.3440624

[20] Gauthier Lafruit, Laurie Van Bogaert, Jaime Sancho Aragon, Michael Panzirsch, Gregoire Hirt, Klaus H. Strobl, and Eduardo Juarez Martinez. 2022. Tele-Robotics VR with Holographic Vision in Immersive Video. In *Proceedings of the 1st Workshop on Interactive eXtended Reality (IXR '22)*. Association for Computing Machinery, New York, NY, USA, 61–68. https://doi.org/10.1145/3552483.3556461

[21] Susan W. Langdon and Gina Petracca. 2010. Tiny dancer: Body image and dancer identity in female modern dancers. *Body Image* 7, 4 (Sept. 2010), 360–363. https://doi.org/10.1016/j.bodyim.2010.06.005

[22] RAY LC. 2021. NOW YOU SEE ME, NOW YOU DON'T: revealing personality and narratives from playful interactions with machines being watched. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '21)*. Association for Computing Machinery, New York, NY, USA, 1–7. https://doi.org/10.1145/3430524.3442448

[23] RAY LC, Aaliyah Alcibar, Alejandro Baez, and Stefanie Torossian. 2020. Machine Gaze: Self-Identification Through Play With a computer Vision-Based Projection and Robotics System. *Frontiers in Robotics and AI* 7 (Dec. 2020), 580835. https://doi.org/10.3389/frobt.2020.580835

[24] RAY LC, Maurice Benayoun, Permagnus Lindborg, Hongshen Xu, Hin Chung Chan, Ka Man Yip, and Tianyi Zhang. 2021. Power Chess: Robot-to-Robot Nonverbal Emotional Expression Applied to Competitive Play. In *10th International Conference on Digital and Interactive Arts*. ACM, Aveiro, Portugal Portugal, 1–11. https://doi.org/10.1145/3483529.3483844

[25] Jie Li, Xinning Gui, Yubo Kou, and Yukun Li. 2019. Live Streaming as Co-Performance: Dynamics between Center and Periphery in Theatrical Engagement. *Proceedings of the ACM on Human-Computer Interaction* 3 (Nov. 2019), 1–22. https://doi.org/10.1145/3359166

[26] Vivien Lin, Hui-Chin Yeh, and Nian-Shing Chen. 2022. A Systematic Review on Oral Interactions in Robot-Assisted Language Learning. *Electronics* 11, 2 (Jan. 2022), 290. https://doi.org/10.3390/electronics11020290 Number: 2 Publisher: Multidisciplinary Digital Publishing Institute.

[27] Andreas H. Marpaung, Sarah M. Brown, and Christine L. Lisetti. 2002. A technical demonstration of Lola, the robot entertainer. In *Proceedings of the tenth ACM international conference on Multimedia (MULTIMEDIA '02)*. Association for Computing Machinery, New York, NY, USA, 91–93. https://doi.org/10.1145/641007.641027

[28] Eric Mullis. 2013. Dance, Interactive Technology, and the Device Paradigm. *Dance Research Journal* 45, 3 (Dec. 2013), 111–123. https://doi.org/10.1017/S0149767712000290

[29] Eric B. Nash, Gregory W. Edwards, Jennifer A. Thompson, and Woodrow Barfield. 2000. A Review of Presence and Performance in Virtual Environments. *International Journal of Humanâ€"Computer Interaction* 12, 1 (May 2000), 1–41. https://doi.org/10.1207/S15327590IJHC1201_1 Publisher: Taylor & Francis _eprint: https://doi.org/10.1207/S15327590IJHC1201_1.

[30] Jiazhi Ou, Susan R. Fussell, Xilin Chen, Leslie D. Setlock, and Jie Yang. 2003. Gestural communication over video stream: supporting multimodal interaction for remote collaborative physical tasks. In *Proceedings of the 5th international conference on Multimodal interfaces (ICMI '03)*. Association for Computing Machinery, New York, NY, USA, 242–249. https://doi.org/10.1145/958432.958477

[31] Luigi Pagliarini and Henrik Hautop Lund. 2009. The development of robot art. *Artificial Life and Robotics* 13, 2 (March 2009), 401–405. https://doi.org/10.1007/s10015-008-0620-7

[32] Hua Peng, Changle Zhou, Huosheng Hu, Fei Chao, and Jing Li. 2015. Robotic Dance in Social Robotics—A Taxonomy. *IEEE Transactions on Human-Machine Systems* 45, 3 (June 2015), 281–293. https://doi.org/10.1109/THMS.2015.2393558 Conference Name: IEEE Transactions on Human-Machine Systems.

[33] Simon Penny. 2016. Robotics and Art, Computationalism and Embodiment. In *Robots and Art: Exploring an Unlikely Symbiosis*, Damith Herath, Christian Kroos, and Stelarc (Eds.). Springer, Singapore, 47–65. https://doi.org/10.1007/978-981-10-0321-9_4

[34] Jon Cedric Roxas, Deborah Richards, Ayse Bilgin, and Nader Hanna. 2018. Exploring the influence of a human-like dancing virtual character on the evocation of human emotion. *Behaviour & Information Technology* 37, 1 (Jan. 2018), 1–15. https://doi.org/10.1080/0144929X.2017.1386714 Publisher: Taylor & Francis.

[35] Tina M. Schwender, Sarah Spengler, Christina Oedl, and Filip Mess. 2018. Effects of Dance Interventions on Aspects of the Participants' Self: A Systematic Review. *Frontiers in Psychology* 9 (July 2018), 1130. https://doi.org/10.3389/fpsyg.2018.01130

[36] A. C. Scott. 1975. Reflections on the Aesthetic Background of the Performing Arts of East Asia. *Asian Music* 6, 1/2 (1975), 207–216. https://doi.org/10.2307/833849 Publisher: University of Texas Press.

[37] Anselm L. Strauss and Juliet M. Corbin. 1998. *Basics of qualitative research: techniques and procedures for developing grounded theory* (2nd ed ed.). Sage Publications, Thousand Oaks.

[38] Ryosuke Suzuki and Yoichi Ochiai. 2022. Dance Through Visual Media: The Influence of COVID-19 on Dance Artists. In *Universal Access in Human-Computer Interaction. Novel Design Approaches and Technologies*, Margherita Antona and Constantine Stephanidis (Eds.). Springer International Publishing, Cham, 360–378.

[39] Oscar Thörn, Peter Knudsen, and Alessandro Saffiotti. 2020. Human-Robot Artistic Co-Creation: a Study in Improvised Robot Dance. In *2020 29th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. 845–850. https://doi.org/10.1109/RO-MAN47096.2020.9223446 ISSN: 1944-9437.

[40] Jutta Toelle and John A Sloboda. 2021. The audience as artist? The audience's experience of participatory music. *Musicae Scientiae* 25, 1 (March 2021), 67–91. https://doi.org/10.1177/1029864919844804 Publisher: SAGE Publications Ltd.

[41] Lea Vergine. 2000. *Body Art and Performance: The Body as Language*. Milan: Skira Editore S.p.A.

[42] Marx Boyuan Wang, Zachary Duer, Scotty Hardwig, Sam Lally, Alayna Ricard, and Myounghoon Jeon. 2022. Echofluid: An Interface for Remote Choreography Learning and Co-creation Using Machine Learning Techniques. In *The Adjunct Publication of the 35th Annual ACM Symposium on User Interface Software and Technology*. ACM, Bend OR USA, 1–4. https://doi.org/10.1145/3526114.3558708

[43] Liu Yang. 2022. Influence of Human–Computer Interaction-Based Intelligent Dancing Robot and Psychological Construct on Choreography. *Frontiers in Neurorobotics* 16 (May 2022), 819550. https://doi.org/10.3389/fnbot.2022.819550

[44] Sun Yuan and Peng Yu. 2018. Can't Help Myself. *Retrieved June* (2018).

[45] Wu Zhen and Lian Luan. 2021. Physical World to Virtual Reality – Motion Capture Technology in Dance Creation. *Journal of Physics: Conference Series* 1828, 1 (Feb. 2021), 012097. https://doi.org/10.1088/1742-6596/1828/1/012097

[46] Qiushi Zhou, Cheng Cheng Chua, Jarrod Knibbe, Jorge Goncalves, and Eduardo Velloso. 2021. Dance and Choreography in HCI: A Two-Decade Retrospective. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–14. https://doi.org/10.1145/3411764.3445804

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