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Evaluation of User Experience and Sense of Presence in a Multi-User Virtual Reality Conferencing System

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ABSTRACT

Virtual reality (VR) has emerged as a promising technology for enhancing remote collaboration by providing immersive communication environments that address many limitations of conventional video conferencing systems. This study experimentally evaluates a previously developed multi-user virtual reality conferencing system designed to support immersive collaboration through synchronized avatars, natural interaction, and real-time voice communication within a shared three-dimensional environment. The system was evaluated through controlled laboratory experiments involving 18 participants using a within-subject experimental design, in which each participant experienced both a conventional video conferencing platform and the proposed VR conferencing system under identical collaborative scenarios. User experience was assessed using standardized questionnaires measuring perceived presence, technical performance, and system usability. The experimental results demonstrated a statistically significant improvement in perceived presence when using the proposed VR conferencing system compared with conventional video conferencing. In addition, participants reported predominantly positive evaluations of the system's technical performance, while the usability assessment indicated a moderate level of usability, suggesting that the platform can effectively support immersive collaborative communication with opportunities for further interface refinement. Overall, the findings demonstrate that immersive visualization, synchronized avatars, and natural interaction mechanisms can substantially improve remote collaboration and user engagement. The proposed evaluation provides empirical evidence supporting the application of virtual reality conferencing systems in education, engineering, healthcare, and other distributed collaborative environments.

1. Introduction

Recent advances in virtual reality (VR) technologies have significantly transformed the way geographically distributed users communicate and collaborate within shared digital environments. Unlike conventional

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video conferencing platforms, immersive virtual reality enables users to experience three-dimensional virtual spaces in which communication extends beyond voice and video transmission to include spatial interaction, avatar-based representation, and natural body movements. These capabilities considerably enhance users' sense of presence, improve social interaction, and facilitate more effective collaborative communication than traditional two-dimensional conferencing environments (Slater, 2009; Jerald, 2015; Sherman & Craig, 2019).

The increasing demand for remote education, distributed teamwork, industrial collaboration, healthcare services, and virtual meetings has highlighted several limitations of traditional conferencing systems. Conventional platforms primarily support two-dimensional audio–video communication and provide limited opportunities for natural interaction among participants. Consequently, users often experience reduced social presence, limited non-verbal communication, decreased engagement, communication fatigue, and difficulties in maintaining collaborative awareness during prolonged virtual meetings (Radianti et al., 2020; Slater & Sanchez-Vives, 2016; Karl et al., 2021; Correia et al., 2020).

To overcome these limitations, immersive virtual conferencing systems integrate head-mounted displays, three-dimensional virtual environments, real-time networking, synchronized avatars, and natural interaction mechanisms into a unified collaborative platform. Such systems enable geographically distributed users to interact as if they were physically co-located, thereby improving communication efficiency, collaborative performance, and users' perception of presence. Earlier collaborative virtual environments demonstrated that immersive interaction substantially enhances teamwork, information sharing, and communication quality compared with conventional desktop-based collaboration (Benford et al., 2001; Churchill & Snowdon, 1998; Bailey & Bailenson, 2015).

Among the various technologies supporting immersive collaboration, natural interaction has become one of the most important factors influencing user experience. Accurate hand tracking, gesture recognition, and avatar synchronization allow participants to communicate through intuitive body movements without relying exclusively on conventional input devices. These interaction techniques significantly improve immersion, reduce cognitive workload, and enable participants to express non-verbal behaviors that are largely absent from conventional video conferencing systems (Weichert et al., 2013; Speicher et al., 2019; Hatzipanayioti et al., 2019).

Beyond technological development, evaluating user experience has become an essential aspect of immersive collaborative systems. Contemporary research increasingly considers perceived presence, usability, user engagement, cognitive workload, and interaction quality as critical indicators for assessing the effectiveness of virtual collaboration environments. Presence has been widely recognized as one of the primary determinants of successful immersive experiences because it directly influences communication quality, collaboration efficiency, and users' psychological involvement within virtual environments (Lombard & Ditton, 1997; Slater & Sanchez-Vives, 2016).

Recent advances in intelligent human–computer interaction have further expanded the capabilities of immersive collaborative systems. Adaptive interaction models based on cognitive-affective architectures and natural language interfaces have demonstrated considerable potential for improving communication quality, personalization, and user engagement within virtual environments. Similarly, data-driven behavioral analysis enables collaborative systems to better understand users' interaction patterns and dynamically adapt communication according to individual behavioral characteristics (Shaykholeslami et al., 2025a)

Furthermore, intelligent engagement modeling has shown that behavioral analytics can substantially improve the design of adaptive collaborative virtual environments and support more effective human-centered interaction (Shaykholeslami et al., 2025b)

Although substantial progress has been achieved in immersive collaboration technologies, several important research gaps remain. Many existing studies primarily focus on the technical implementation of virtual environments, isolated usability assessments, or specific interaction techniques. Comparatively fewer investigations have simultaneously evaluated perceived presence, technical performance, and system usability within a fully implemented cloud-based multi-user virtual reality conferencing framework operating under realistic collaborative scenarios. Moreover, comprehensive experimental comparisons between immersive virtual conferencing platforms and conventional video conferencing systems remain relatively limited (Tan et al., 2017; Berg & Vance, 2016).

Accordingly, this study presents a comprehensive experimental evaluation of a cloud-based multi-user virtual reality conferencing system developed using Unity, immersive visualization technologies, real-time networking, synchronized avatars, and natural hand interaction. The proposed evaluation compares the developed system with a conventional video conferencing platform by examining users' perceived presence, technical performance, and system usability through controlled laboratory experiments and statistical analysis. The findings provide empirical evidence regarding the effectiveness of immersive virtual reality conferencing systems and contribute to the growing body of knowledge on next-generation collaborative virtual environments.

2. Related Works

Recent advances in immersive virtual reality have significantly expanded the capabilities of collaborative communication systems, positioning VR as one of the most promising technologies for next-generation remote interaction. Compared with conventional video conferencing platforms, immersive virtual environments provide users with a stronger sense of presence, enhanced spatial awareness, avatar-based representation, and more natural interaction. These capabilities can improve communication effectiveness, collaborative engagement, and task performance across geographically distributed teams. Previous studies have reported the successful application of immersive VR in education, engineering, healthcare, and industrial collaboration, highlighting its potential to support richer and more interactive remote communication experiences (Slater, 2009; Jerald, 2015; Sherman & Craig, 2019).

Several researchers have emphasized that the effectiveness of virtual conferencing depends not only on immersive visualization but also on the quality of interaction mechanisms and collaborative system design. Benford et al. (2001) and Churchill and Snowdon (1998) introduced early collaborative virtual environments that demonstrated the feasibility of supporting geographically distributed teamwork through shared three-dimensional spaces. More recently, Bailey and Bailenson (2015) reported that immersive collaborative environments significantly improve interpersonal communication and group interaction by increasing users' perception of co-presence and reducing communication barriers commonly observed in conventional conferencing platforms.

Educational applications have also demonstrated the advantages of immersive collaboration. Radianti et al. (2020) conducted a comprehensive systematic review showing that virtual reality learning environments consistently achieve higher engagement, motivation, and collaborative participation than traditional online learning platforms when immersive interaction is effectively incorporated. Similarly, Šašinka et al. (2018) reported that collaborative immersive virtual environments improve teamwork, knowledge sharing, and spatial understanding in geography education, highlighting the educational value of immersive communication technologies.

Natural interaction has become one of the principal research directions in immersive collaborative systems. Instead of relying exclusively on handheld controllers, recent VR conferencing platforms increasingly employ hand tracking, gesture recognition, and avatar synchronization to facilitate intuitive interaction. Weichert et al. (2013) demonstrated that accurate hand tracking substantially improves immersion and interaction quality, while Speicher et al. (2019) emphasized that realistic representation of users' body movements contributes significantly to presence and social communication. Hatzipanayioti et al. (2019) further confirmed that natural interaction mechanisms improve collaborative problem-solving performance in remote virtual reality environments by enabling more intuitive communication among geographically distributed participants.

The rapid growth of remote work has further accelerated research on virtual conferencing technologies. Karl et al. (2021) investigated virtual work meetings during the COVID-19 pandemic and reported that conventional video conferencing systems often suffer from reduced engagement, communication fatigue, and limited non-verbal interaction. Similarly, Correia et al. (2020) emphasized that communication quality and user experience remain important challenges for conventional video conferencing platforms, particularly in educational environments where prolonged interaction is required. These findings further motivate the development of immersive alternatives capable of providing richer communication experiences.

Recent advances in human–computer interaction have also introduced intelligent interaction mechanisms capable of adapting communication according to users' behavioral characteristics. Cognitive-affective architectures integrated with natural language interfaces provide adaptive communication models that improve user interaction quality and facilitate more effective collaborative experiences in immersive digital environments (Shaykholeslami et al., 2025a). Furthermore, behavioral data analysis enables researchers to identify interaction patterns, evaluate user engagement objectively, and support adaptive collaborative virtual environments capable of responding dynamically to users' behavioral characteristics (Shaykholeslami et al., 2025b).

Another important research direction concerns the practical deployment of immersive collaboration systems in industrial environments. Berg and Vance (2016) demonstrated that virtual reality technologies have become increasingly valuable for engineering design, product development, and manufacturing collaboration by enabling geographically distributed experts to work together within shared virtual workspaces. Likewise, Tan et al. (2017) proposed an immersive telepresence framework for remote conversation and collaboration, demonstrating that cloud-supported virtual communication systems can substantially improve interaction efficiency and collaborative task performance.

Despite these significant advances, several important research gaps remain. Most previous studies have concentrated either on the technical implementation of virtual reality environments, educational applications, or isolated usability assessments. Comparatively few investigations have simultaneously evaluated technical performance, perceived presence, and system usability within a fully implemented cloud-based multi-user virtual reality conferencing framework operating under controlled experimental conditions. Furthermore, direct comparative analyses between immersive VR conferencing systems and conventional video conferencing platforms remain relatively limited.

The present study addresses these limitations by conducting a comprehensive experimental evaluation of a cloud-based multi-user virtual reality conferencing system developed using Unity, immersive visualization technologies, synchronized avatars, natural hand interaction, and real-time networking. Unlike many previous investigations, the proposed research simultaneously evaluates perceived presence, technical performance, and usability through controlled laboratory experiments involving real users. Consequently, the obtained findings provide empirical evidence regarding the effectiveness of immersive virtual conferencing systems and contribute to the growing body of knowledge on next-generation collaborative virtual environments.

3. Research Methodology

This study employed an experimental research methodology to evaluate the effectiveness of a multi-user virtual reality conferencing system compared with conventional video conferencing. The proposed framework was designed and implemented as a complete collaborative platform in which geographically distributed users communicate through immersive virtual environments while interacting using natural body movements. The experimental process consisted of system implementation, participant recruitment, controlled collaborative sessions, questionnaire-based evaluation, and statistical analysis of the collected data. This methodology enabled objective assessment of user experience under identical collaboration scenarios. (Slater & Sanchez-Vives, 2016; Radianti et al., 2020)

Unlike simulation-based studies that rely exclusively on subjective observations, the present research combines software implementation with controlled human-subject experiments.

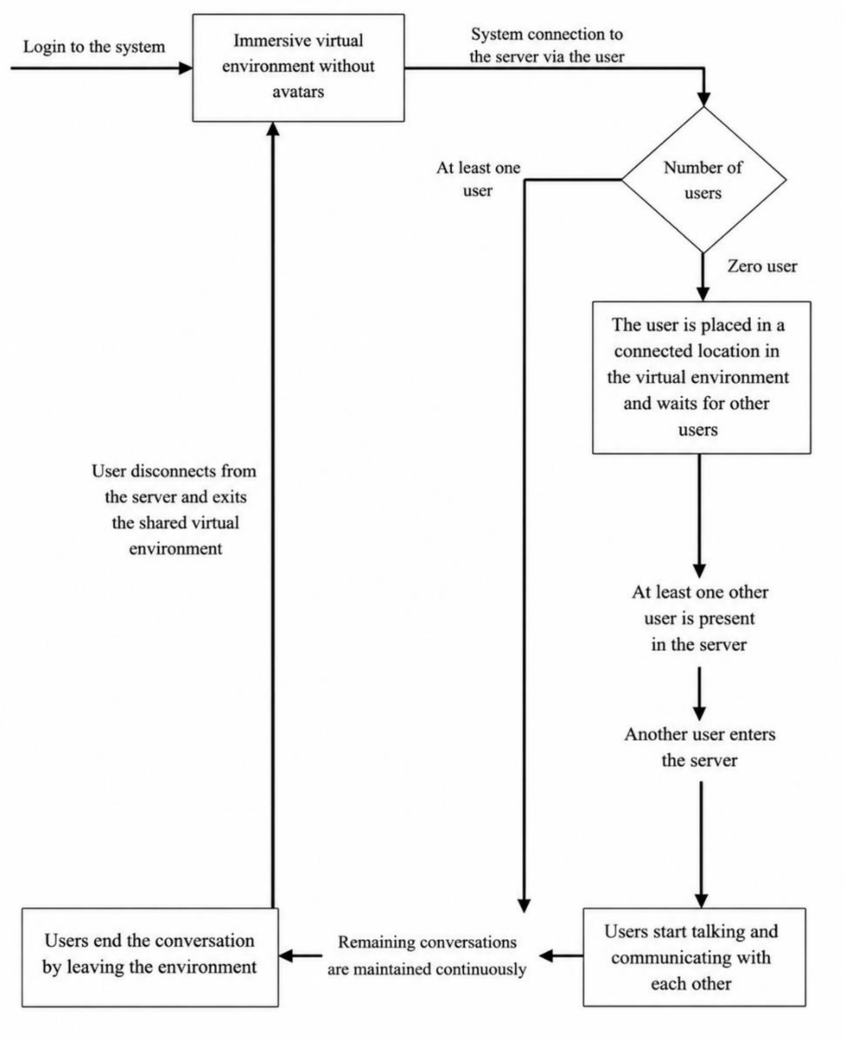

Figure 1. Overall Experimental Workflow for the Proposed VR Conferencing Evaluation

All participants experienced both conferencing environments under the same experimental conditions, allowing direct comparison of presence, usability, technical performance, and interaction quality while minimizing the influence of external variables. The within-subject design also reduced individual differences among participants and improved the reliability of the obtained results. (Bowman & McMahan, 2007)

After implementing the proposed VR conferencing platform, participants completed identical collaborative tasks in both the conventional video conferencing environment and the immersive VR environment. During each experimental session, user interactions, communication quality, and behavioral responses were recorded under standardized conditions. Finally, questionnaire responses were analyzed using descriptive statistics and inferential statistical methods to determine whether the proposed VR conferencing framework significantly improves user experience over traditional conferencing systems. (Field, 2018)

The adopted methodology integrates software engineering, immersive virtual reality technologies, experimental human-computer interaction, and quantitative statistical evaluation into a unified research framework. Such an approach provides a comprehensive basis for assessing both the technical performance of the developed system and the subjective perceptions of end users, thereby supporting rigorous evaluation of collaborative virtual environments.

3.1 Participants

A total of 18 volunteers participated in the experimental evaluation of the proposed virtual reality conferencing system. All participants completed both the conventional video conferencing session and the immersive virtual reality conferencing session under identical experimental conditions. A within-subject design was adopted to minimize individual variability and to enable direct comparison between the two conferencing environments.

Before the experiment, each participant received a brief explanation of the experimental objectives and was instructed on the operation of the virtual reality equipment, including the head-mounted display and hand interaction mechanisms. Participants were allowed sufficient time to become familiar with the system before the formal evaluation began. During each experimental session, users completed identical collaborative communication tasks to ensure consistency throughout the evaluation process.

The experimental procedures were performed under controlled laboratory conditions. Identical hardware, networking infrastructure, and conferencing scenarios were used throughout the study to reduce external influences on participants' responses. After completing both conferencing sessions, participants completed standardized questionnaires evaluating technical performance, perceived presence, and overall usability.

Table 1. Evaluation Variables Used in the Experimental Study

Variable	Description	Measurement Method	Variable Type
Technical Performance	Quality and adequacy of the system's technical components	Questionnaire	Binary (Yes/No)
Perceived Presence	Degree to which users experience a sense of presence in the virtual environment	Questionnaire	Five-point Likert Scale (1–5)
Usability	Ease of learning, operating, and interacting with the conferencing system	System Usability Scale (SUS)	Composite score (0–100)

Table 1 summarizes the evaluation variables employed in the present study. Three principal dimensions were considered during the assessment process: technical performance, perceived presence, and system usability. These variables were selected because they collectively represent the most important indicators of user experience in immersive collaborative virtual environments.

Technical performance reflects the stability and operational quality of the conferencing platform, whereas perceived presence measures the extent to which users experience the feeling of physically being inside the shared virtual environment. Finally, usability evaluates the ease of learning, interaction efficiency, and overall user satisfaction while operating the proposed conferencing system. Together, these evaluation dimensions provide a comprehensive assessment of the effectiveness of the developed virtual reality conferencing platform.

3.2 Hardware Configuration

The experimental evaluation was conducted using two desktop computer systems with comparable computational capabilities to ensure stable execution of the proposed virtual reality conferencing platform. Both systems were connected through the same local network and operated under identical software configurations throughout the experimental sessions. Standardizing the hardware configuration minimized performance variations and guaranteed that all participants experienced the same technical conditions during the evaluation.

Each workstation was equipped with dedicated graphics hardware capable of rendering immersive three-dimensional environments in real time. The selected hardware configuration satisfied the computational requirements of the Unity-based conferencing platform, including avatar synchronization, real-time networking, voice communication, and interactive virtual environment rendering. Maintaining identical experimental settings throughout all sessions improved the validity and reproducibility of the obtained results (Jerald, 2015; Radianti et al., 2020).

Table 2. Hardware Configuration of the Experimental Platform

System	CPU	GPU	RAM
System 1	Intel Core i5 @ 4.2 GHz	NVIDIA GeForce RTX 2060	8 GB
System 2	Intel Core i7 @ 4.7 GHz	NVIDIA GeForce GTX 1070	8 GB

Table 2 summarizes the hardware specifications of the experimental computers used throughout the study. Both systems were equipped with multi-core processors, dedicated graphics processing units (GPUs), and sufficient memory resources to support real-time rendering and immersive interaction. The hardware configuration provided stable execution of the conferencing application without noticeable latency or performance degradation during collaborative sessions.

The selected hardware platform ensured smooth synchronization of virtual avatars, low-latency communication, and consistent rendering performance across all experimental sessions. Consequently, the observed differences in user experience can be primarily attributed to the conferencing environments rather than to hardware-related performance limitations.

3.3 Experimental Procedure

The experimental procedure was designed to evaluate users' experience while interacting with the proposed virtual reality conferencing system under controlled laboratory conditions. Each participant individually completed two conferencing sessions. The first session was conducted using a conventional video conferencing platform, whereas the second session employed the proposed immersive virtual reality conferencing environment. To ensure a fair comparison, identical collaborative tasks and communication scenarios were performed in both environments.

At the beginning of each experimental session, participants logged into the conferencing application and connected to the shared virtual meeting room. If no additional participant was present, the user remained in the virtual environment until another participant joined the session. Once multiple users were connected, real-time communication was initiated using synchronized avatars, voice communication, and natural interaction mechanisms. Participants collaboratively completed predefined communication tasks before leaving the virtual environment.

Following each conferencing session, participants completed standardized questionnaires evaluating three principal dimensions of user experience, including technical performance, perceived presence, and system usability. The collected responses were subsequently analyzed using descriptive statistics and paired-sample statistical tests to determine whether significant differences existed between the proposed virtual reality conferencing system and conventional video conferencing.

Figure 2 illustrates the sequence of operations performed during the experimental evaluation. Participants first entered the conferencing platform, connected to the shared virtual environment, and interacted with other users through synchronized avatars and real-time voice communication. After completing the collaborative activities, users exited the virtual meeting and completed the evaluation questionnaires. This standardized workflow ensured that every participant experienced identical experimental conditions, thereby improving the reliability and reproducibility of the obtained experimental results.

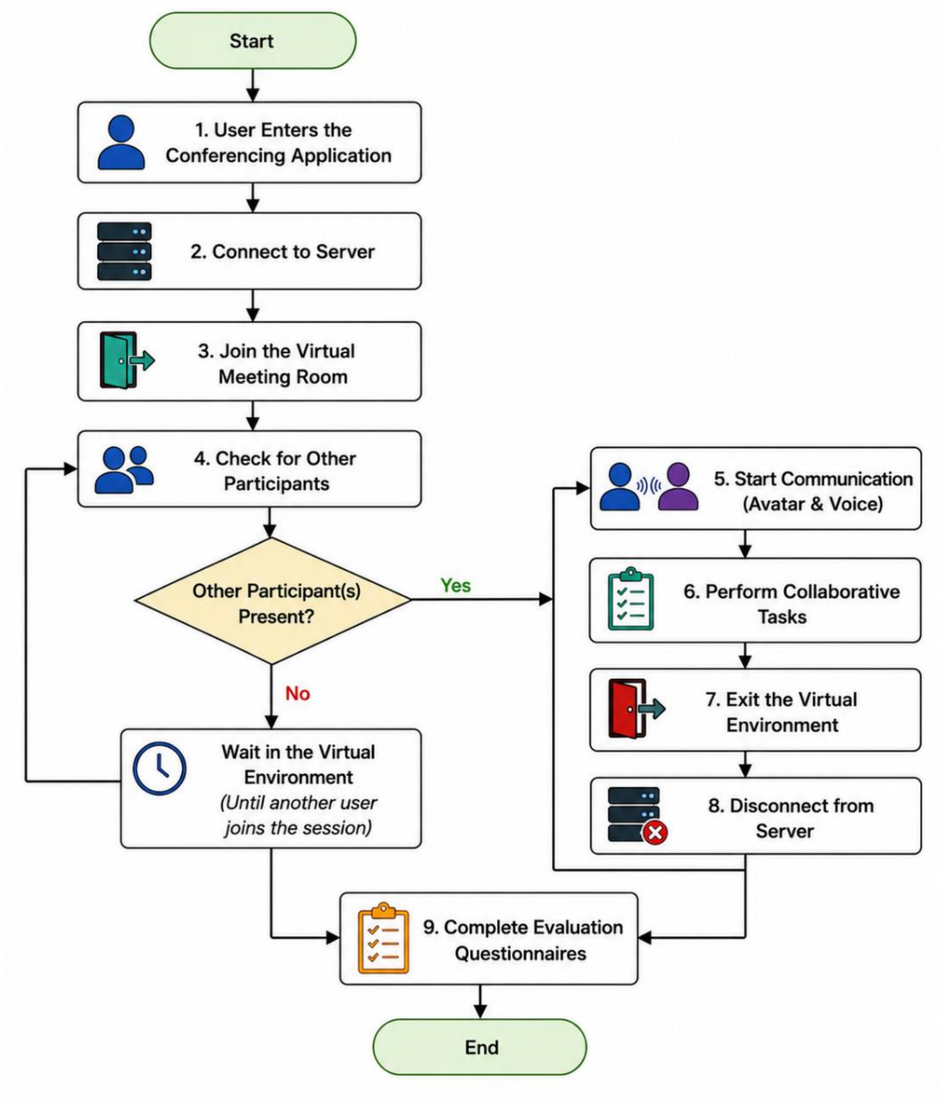

Figure 2. Experimental Procedure of the Proposed Virtual Reality Conferencing System

4. Experimental Results

The experimental evaluation was conducted to compare users' experiences in the proposed virtual reality conferencing system with those of a conventional video conferencing platform. Both conferencing environments were evaluated under identical laboratory conditions using the same collaborative tasks and communication scenarios. The collected data included participants' subjective assessments of perceived presence, technical performance, and overall usability.

The evaluation process consisted of two consecutive experimental sessions. In the first session, participants performed collaborative communication tasks using a conventional video conferencing platform. In the second session, the same participants completed identical tasks within the proposed immersive virtual reality conferencing environment. After each session, participants completed standardized evaluation questionnaires, enabling direct comparison between the two conferencing approaches.

To ensure consistency throughout the experiments, all evaluation sessions were conducted using identical hardware configurations, networking infrastructure, and environmental conditions. The experimental procedure minimized external influences and ensured that the observed differences resulted primarily from the conferencing environments rather than uncontrolled variables.

Figure 3. Physical Experimental Setup in Laboratory Room 1

Figure 3 illustrates the physical experimental setup used in the first laboratory room during the evaluation of the proposed virtual reality conferencing system. The participant interacted with the immersive conferencing platform using a head-mounted display connected to a dedicated workstation. This laboratory configuration provided a controlled environment for assessing user interaction, communication quality, and overall system performance.

Figure 4. Physical Experimental Setup in Laboratory Room 2

Figure 4 presents the second laboratory room used during the experimental evaluation. Similar hardware and networking configurations were employed to ensure consistency between the two experimental locations. Participants accessed the same shared virtual conference through synchronized avatars while remaining physically separated, enabling realistic evaluation of remote collaborative communication under controlled laboratory conditions.

4.1 Presence Evaluation

The first stage of the experimental evaluation focused on measuring participants' perceived sense of presence while using the proposed virtual reality conferencing system. Presence represents one of the most important indicators of immersive virtual environments, reflecting the extent to which users experience the feeling of being physically located inside the shared virtual space rather than interacting through a conventional communication platform. Participants completed standardized presence questionnaires immediately after finishing each experimental session.

The collected responses were statistically analyzed to compare the conventional video conferencing environment with the proposed virtual reality conferencing system. Descriptive statistics were first calculated to summarize the distribution of participants' responses, followed by inferential statistical analysis to determine whether the observed differences were statistically significant.

Table 3. Descriptive Statistics of Presence Evaluation

Group	Sample Size (N)	Mean	Standard Deviation (SD)
Conventional Video Conferencing	18	2.90	0.95
Virtual Reality Conferencing	18	4.61	1.25

Table 3 summarizes the descriptive statistics obtained from the presence evaluation. Participants reported considerably higher presence scores after using the proposed virtual reality conferencing system than after using the conventional video conferencing platform. The increase in the mean score indicates that the immersive environment successfully enhanced users' perception of spatial presence and collaborative engagement.

Although a moderate level of variability was observed among participants, the overall results consistently favored the proposed virtual reality conferencing system. These findings suggest that immersive visualization, synchronized avatars, and natural interaction mechanisms substantially improve users' sense of presence during remote collaboration.

Table 4. Paired Samples t-Test Results for Presence Evaluation

Comparison	Mean Difference	Standard Deviation (SD)	t-value	Degrees of Freedom (df)	p-value
Conventional Video Conferencing vs. Virtual Reality Conferencing	−1.70	1.41	−5.12	17	< 0.001

The paired-samples *t*-test was conducted to determine whether the difference in perceived presence between the conventional video conferencing platform and the proposed virtual reality conferencing system was statistically significant. The analysis demonstrated a significant improvement in participants' presence scores when using the proposed immersive conferencing environment.

The obtained *p*-value was considerably lower than the significance threshold of 0.05, indicating that the observed improvement was unlikely to have occurred by chance. Therefore, the null hypothesis was rejected, confirming that the proposed virtual reality conferencing system significantly enhances users' sense of presence during remote collaboration.

The statistical findings are consistent with previous research demonstrating that immersive virtual reality environments provide higher levels of spatial presence, engagement, and communication quality than conventional two-dimensional video conferencing systems (Slater & Sanchez-Vives, 2016; Radianti et al., 2020). The integration of synchronized avatars, real-time interaction, and immersive visualization contributed substantially to participants' perception of being physically present within the shared virtual environment.

4.2 Technical Performance Evaluation

In addition to users' perceived sense of presence, the technical performance of the proposed virtual reality conferencing system was evaluated to determine whether the developed platform could provide stable and efficient communication during collaborative sessions. The technical assessment focused on participants' perceptions regarding system reliability, rendering quality, network stability, and the overall performance of the conferencing platform.

Participants completed a technical evaluation questionnaire immediately after the experimental sessions. The collected responses were analyzed using descriptive statistics, including frequencies and percentages, to examine participants' perceptions of the operational performance of the proposed virtual reality conferencing system.

Table 5. Participants' Responses to the Technical Performance Evaluation

Response	Frequency	Percentage (%)
Yes	16	88.9
No	2	11.1
Total	18	100.0

Table 5 summarizes participants' responses regarding the technical performance of the proposed virtual reality conferencing system. Overall, 88.9% of the participants reported satisfactory technical performance, whereas 11.1% indicated the presence of technical issues during the experimental sessions. These findings demonstrate that the developed platform operated reliably under the experimental conditions.

The high proportion of positive responses indicates that the proposed conferencing system successfully met the technical requirements for immersive collaborative communication. The results suggest that the implemented hardware and software infrastructure provided stable performance throughout the evaluation process.

4.3 Usability Evaluation

Usability represents one of the most important factors influencing users' acceptance of immersive virtual reality conferencing systems. In the present study, usability was evaluated to determine whether participants could effectively learn, operate, and interact with the proposed conferencing platform during collaborative sessions. The assessment focused on users' overall satisfaction, ease of interaction, and perceived efficiency while using the developed system.

Following completion of the experimental sessions, participants completed a standardized usability questionnaire. The collected responses were analyzed to investigate users' perceptions regarding the practicality of the proposed virtual reality conferencing platform. The obtained results provide valuable insight into the overall user experience and the potential applicability of the system in real-world collaborative environments.

Table 6. Individual System Usability Scale (SUS) Scores

Participant ID	System Usability Scale (SUS) Score
1	55.0
2	62.5
3	70.0
4	70.0
5	87.5
6	70.0
7	70.0
8	57.5
9	75.0
10	52.5
11	52.5
12	57.5
13	72.5
14	55.0
15	52.5
16	65.0
17	55.0
18	52.5

Table 6 presents the individual System Usability Scale (SUS) scores obtained from the 18 participants following completion of the experimental evaluation. The scores ranged from 52.5 to 87.5, with an overall mean score of 62.92. This distribution indicates moderate usability and reflects noticeable variation in participants' perceptions of the proposed virtual reality conferencing platform.

The results suggest that participants were generally able to learn and operate the system without major difficulty. However, the mean SUS score remained below the commonly reported benchmark of 68, indicating that further improvements are needed to enhance interface clarity, interaction efficiency, and overall ease of use. Differences in participants' prior experience with virtual reality technologies may also have contributed to the variation observed in individual scores.

5. Discussion

The results of the experimental evaluation demonstrate that the proposed virtual reality conferencing system provides a substantially improved collaborative experience compared with conventional video conferencing platforms. Participants consistently reported higher levels of perceived presence, reliable technical performance, and moderate usability throughout the experimental sessions. These findings indicate that immersive virtual reality technologies can effectively overcome several limitations associated with traditional two-dimensional conferencing systems.

One of the principal advantages of the proposed framework is the integration of immersive visualization with synchronized avatars and natural interaction mechanisms. Unlike conventional conferencing platforms, where communication is primarily limited to audio and video streams, the developed system enables users to interact within a shared three-dimensional environment, thereby strengthening the perception of co-presence and facilitating more natural collaboration. These observations are consistent with previous studies emphasizing the importance of immersive interaction in enhancing communication quality and user engagement (Slater & Sanchez-Vives, 2016; Radianti et al., 2020).

The technical evaluation further confirmed that the developed conferencing platform operated reliably throughout the experiments. Most participants positively evaluated the system's technical performance, indicating that the selected networking architecture, rendering pipeline, and communication mechanisms successfully supported real-time collaborative interaction. These findings demonstrate that immersive virtual reality conferencing systems can achieve both technical stability and satisfactory user experience under controlled experimental conditions.

The usability assessment also demonstrated that participants were able to learn and operate the proposed conferencing platform with relative ease. Although individual usability scores varied among participants, the overall evaluation indicates that the developed system provides an intuitive interaction environment suitable for collaborative communication. Similar observations have been reported in recent studies investigating intelligent human–computer interaction and adaptive immersive environments (Shaykholeslami et al., 2025a).

Overall, the obtained findings demonstrate that integrating immersive virtual reality, real-time networking, synchronized avatars, and natural interaction mechanisms significantly enhances remote collaboration compared with conventional video conferencing platforms. The proposed framework therefore provides a practical foundation for future immersive communication systems applicable to education, remote teamwork, engineering collaboration, healthcare, and industrial training.

6. Conclusion

This study presented a comprehensive experimental evaluation of a previously developed multi-user virtual reality conferencing system designed to enhance remote collaboration through immersive communication technologies. The evaluated platform integrates synchronized avatars, natural interaction mechanisms, real-time networking, and immersive visualization within a unified collaborative environment.

The experimental results demonstrated that participants experienced significantly higher levels of perceived presence when using the proposed virtual reality conferencing system compared with conventional video conferencing platforms. In addition, participants reported predominantly positive evaluations of the system's technical performance, while the usability assessment indicated a moderate level of usability, suggesting that the developed platform effectively supports immersive collaborative communication with opportunities for further interface refinement. Overall, the findings confirm that immersive virtual reality technologies can substantially improve user engagement, interaction quality, and the overall remote collaboration experience.

The findings of this research demonstrate that virtual reality conferencing systems have considerable potential for supporting distributed collaboration in education, engineering, healthcare, industrial training, and professional meetings. By enabling users to communicate through immersive three-dimensional environments and natural interaction mechanisms, the proposed platform addresses several communication limitations associated with conventional two-dimensional conferencing systems.

Although the experimental evaluation was conducted under controlled laboratory conditions with a relatively small sample of participants, the obtained results provide valuable empirical evidence supporting the practical applicability of immersive conferencing technologies. Future research should investigate larger and more diverse participant groups, large-scale collaborative environments, heterogeneous network conditions, artificial intelligence-assisted interaction, adaptive avatar behavior, and enhanced user interface design to further improve the usability and effectiveness of immersive virtual reality conferencing systems.

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