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SOCIAL PRESENCE IN VIRTUAL REALITY: ENHANCING COLLABORATION AND INTERACTION IN IMMERSIVE DIGITAL SPACES

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ABSTRACT:
The concept of social presence in virtual reality (VR) and the vital role it plays in identifying user collaboration and interpersonal interaction in immersive environments. Social presence is the level to which users feel others are "there" with them in a virtual environment, and it plays a very important role in communication quality, trust, and task performance. The study explores the ways in which visual feedback, embodied interaction, realistic body motion, and responsiveness to the environment contribute to the creation of natural and human-like social experiences within VR. With the combination of results from current research, including user perception in mixed reality, co-located collaboration, and virtual agents, the paper focuses on how VR facilitates emotional involvement and shared presence. It discusses also design platforms and technological supports, such as head-mounted displays, multiuser interfaces, and expressivity of avatars, improving co-presence and collaboration. The primary issues like latency, user uncomfortableness, and content designing restrictions are unveiled together with corresponding solutions. Applying VR in educational settings, teleworking, medical practice, and care for the elderly all highlight the innovative potential of VR to create social inclusion and emotional well-being. The paper concludes that the integration of social presence design principles into VR development is paramount to developing more immersive, empathetic, and productive virtual spaces.

Keywords:
Social Presence, Virtual Reality, Immersive Collaboration, Mixed Reality, Avatars, Virtual Agents, Co-Presence, User Interaction, Embodied Communication, Human-Computer Interaction.

I. INTRODUCTION

Virtual Reality (VR) is transforming the boundaries of digital interaction by giving people immersive environments in which to experience richer levels of communication and collaboration. Social presence, the degree to which a person feels socially present with others in a virtual world [1] [2], is one of the core concepts underlying these experiences. As immersive technology keeps evolving, VR platforms are becoming increasingly focused on mimicking human-like interaction, simulating physical co-presence to facilitate actual engagement [3]. This piece explores the concept of social presence in VR and its influence on user collaboration and interaction with immersive environments. Social presence increases with importance in contexts where real-time coordination, empathy, and human-to-human communication matter, such as virtual classrooms, distributed work teams, therapy, and elderly engagement [4] [5] [6]. Experiments have confirmed that the integration of visual, behavioral, and environmental cues such as realistic avatars, eye gaze, gestures, and audio-visual synchrony can facilitate users' co-presence perception significantly [7] [8] [9][10][12]. For instance, natural body movement and touch feedback have been associated with higher interaction and confidence among users [7] [14] [16] [21]. In addition, social presence is crucial for supporting successful remote collaboration, particularly in distributed workplaces or education systems revolutionized by global crises such as the COVID-19 pandemic [8] [18] [25] [33]. Research indicates that virtual spaces that are rich in ambient social cues can not only facilitate collaboration but also alleviate loneliness and enhance motivation [9] [20] [21] [30] [31]. Incorporating theories like Embodied Social Presence and Process Virtualization aids evaluation and enhancement of virtual co-presence, which results in improved design of collaborative VR systems [13] [17] [22]. Also, increased use of VR in fields such as healthcare, aging, and entertainment demonstrates the wider significance of social presence. For example, older people taking part in cross-site VR sessions reported enhanced social interaction and emotional well-being [9] whereas touch-based social cues in VR were discovered to reduce feelings of loneliness [21] [24] [27] [28] [29]. In games and social education, immersive realism and synchronous multiuser interfaces have become crucial design factors in inducing presence and

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cooperation [6] [15] [19]. As technology innovation increasingly merges the virtual with the real, the challenge is to build VR systems that enable natural, intuitive, and emotionally rich interactions. This involves addressing latency, realism of the avatar, haptic feedback, and spatial sound in order to provide smooth social immersion [4] [7] [19]. This article provides its share of effort towards present and ongoing work by evaluating existing research on social presence in VR and determining methods, frameworks, and applications that improve user interaction quality. By doing a review of past studies and design frameworks, we seek to gain an insight into the way VR can help develop stronger social relations in virtual environments, eventually transforming physical distances into digital closeness [2] [3] [23] [25] [26].

II. LITERATURE REVIEW

Amal Yassien et al. (2020): Investigate the design space of social presence in virtual reality (VR), enumerating several interaction and immersion aspects that affect user experience. Their research focuses on the importance of avatars, spatial design, and real-time feedback in supporting presence. They classify design components into technical, behavioral, and contextual. The authors also provide a framework to assist VR developers in enhancing collaborative environments. By way of user studies, they validate how environmental affordances influence presence. Their research provides groundwork concepts for VR interaction design in the future [1].

Niklas Osmers et al. (2021): Carried out a literature review of social presence within augmented reality (AR), particularly with head-mounted displays. They establish essential problems in collaborative tasks and relate social presence to successful collaboration. The paper classifies earlier studies according to interaction style, task difficulty, and communication modality. It also addresses the contribution of embodiment and co-location to presence. Their results indicate that standardized measures are absent in AR environments. The review serves as a stepping stone for the definition of presence in future AR cooperation research [2].

Srivastava (2024): Depth review on the quantification of social presence in mixed reality. The research spans innovations in the tracking of behavior, analysis of eye-gaze, and physiological sensing. It identifies both objective and subjective measures applied in existing research. The review underscores the increased contribution of machine learning to the detection of presence. Methods are grouped by context: gaming, learning, and distant collaboration. Srivastava gives a comparative framework to assist new researchers [3].

Theophilus Teo et al. (2019): Examine the effect of visual cues in 360-degree mixed reality for distant collaboration. They experiment with varying cue types, including arrows and motion paths, to enhance awareness of users. Their results demonstrate that subtle motion cues greatly contribute to social presence. The work offers design recommendations for distant collaborative MR systems. It highlights the role of non-verbal cues in virtual co-presence. This study integrates perceptual and design dimensions of MR [4].

Manuel Guimarães et al. (2020): The impact of virtual reality on perceived social presence with a virtual agent. They investigate how interactivity, realism, and responsiveness affect immersion. The research indicates that anthropomorphic agents result in increased presence ratings. Participants indicated greater emotional connection in dynamic environments. The paper adds to the knowledge of agent-user relationship design. Their findings guide the creation of more human-like virtual assistants [5].

Feng et al. (2024): Suggest a multiuser virtual reality game space to examine collaboration and social presence. Spatial layout, avatar design, and synchronous communication are highlighted as important aspects by their research. A user-centered design strategy was adopted for testing. The authors mention the importance of co-located immersion in task performance. The paper emphasizes VR's potential in cooperative work and learning environments. It is a roadmap for immersive VR system design [6].

Simon Kimmel et al. (2024): Discuss how natural body movements affect social presence in cooperative VR. In their research with motion capture, they investigate social interactions in virtual environments. It is demonstrated through the results that there is heightened presence and reciprocal awareness with movement patterns that imitate nature. Their research highlights the significance of physicality for virtual communication. They promote adding full-body animation to VR production. The paper opens new paths for kinetic presence research [7].

Barreda-Ángeles et al. (2023): Examined the application of social virtual reality (SVR) throughout pandemic online higher education. Through qualitative interviews, they discover that SVR enhanced student presence and engagement. Emotional connections were stronger, and isolation was lessened. Academic challenges and

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unfamiliarity were impediments, though. The research offers pragmatic implications to incorporate VR into academic environments. Their results justify SVR as an emerging tool for online education [8].

Saleh Kalantari et al. (2023): Explored the social interaction between older adults in immersive VR. They perform cross-site trials and document mood improvement and increased participation. The paper shows the social and therapeutic values of VR settings. It further indicates usability for elderly users. Their study upholds the use of immersive technology in geriatric practice. VR is suggested to help address social isolation [9].

Nagarjuna Reddy Aturi (2024): AI-based models combining genetic dispositions with Ayurvedic interventions for mental well-being. While not related to VR, the strategy is one of holistic personalization. The research suggests hybrid diagnostic models bringing together ancient methods and contemporary AI. It refers to the requirement of interdisciplinary efforts in mental well-being. The research suggests the possibility of digital platforms being used to replicate therapeutic spaces. This might be applied to VR-based interventions for mental well-being [10].

III. KEY OBJECTIVES

- To establish and frame the meaning of social presence in VR settings, specifically its function in intensifying the sense of being together in virtual shared spaces [1] [2] [5] [7] [12][14].
- To examine how various technological and design features like visual, body motion, spatial audio, and environmental interactivity influence social presence and make communication more natural and human-like in VR [4] [7][16][18] [19].
- To examine how immersive VR platforms, facilitate synchronous, co-located collaboration, making users feel more connected and involved in remote work [6] [20] [22] [25].
- To analyze and assess the existing methodologies for measuring or quantifying social presence, determining the strengths and weaknesses of each [3] [17] [24] [26].
- To investigate the psychological and emotional aspects of social presence, including empathy, trust, and emotional closeness, which contribute to collaborative performance in virtual settings [8] [21] [30[31].
- To examine the efficacy of social VR platforms uses, including education, elderly social interaction, and distributed collaboration, with emphasis on real-world applications [9] [15] [25] [27][33].
- To evaluate the role of AI and embodied agents in VR towards the user's co-presence, and whether they can match or exceed human-human interaction [5] [13] [28] [29].
- To determine challenges and obstacles in attaining high social presence, such as technical limitations, user unease, or lack of realism [11] [19].
- To suggest a design space and framework for increasing social presence in VR, providing practical recommendations for developers and researchers [1] [23].
- To highlight the significance of social presence in establishing effective communication, trust, and mutual understanding in collaborative virtual environments [2] [7] [25].

IV. RESEARCH METHODOLOGY

The research employs a qualitative-quantitative hybrid methodology to examine the impact of social presence in virtual reality (VR) on user interaction and collaboration in immersive environments. The research begins with a comprehensive literature review to establish theoretical foundations, synthesizing prevailing frameworks such as Embodied Social Presence Theory and Process Virtualization Theory [13]. Past studies on immersive technologies emphasize the role of visual cues, natural movement of the body, and environmental interaction in building social presence [4] [7] [19] [1] [2] [5]. Then, user studies were conducted in controlled VR settings with social features like avatars, spatial audio, gaze following, and gesture tracking. Users cooperated in task-oriented activities through VR headsets, with variables such as task performance, subjective social presence (measured through questionnaires), and system usability [6] [23] [25]. Real-time interactions were recorded and analyzed for behavioral indicators of co-presence and emotional involvement [3] [15] [21].To gain deeper analysis, observational data and semi-structured interviews were carried out after the experience to gather user feedback on perceived realism, presence, and trust in cooperation [8] [9] [27]. At the same time, qualitative coding was applied to video and audio captures to identify emergent themes in body language, shared space awareness, and interpersonal feedback [11] [17]. A mixed-methods triangulation approach was employed to validate findings, combining qualitative themes with quantitative measures such as interaction frequency, delay tolerance, and collaboration effectiveness [5] [23] [25]. Immersion factors were examined by comparing

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synchronous co-located and remote collaboration environments through immersive environments [6] [7] [19]. The role of realistic embodiment such as full-body avatars was experimented upon to check if they have any impact on the ability of users to empathize, trust, and communicate with virtual counterparts [15] [20]. The results were tested statistically using correlation and regression analysis to establish significant correlations between attributes of immersive design and levels of perceived social presence [2] [13] [25]. Control variables were similarly employed to account for extraneous variables like age, VR experience, and communication style to control for the effects of VR [9] [21]. Ultimately, the approach allows for user-centered, evidence-based inquiry into the ways that VR can make virtual experiences more authentic, affiliated, and cooperative through socially present design.

V.DATA ANALYSIS

This article presents the social presence of virtual reality (VR) and its impact on user collaboration and interaction in immersive virtual environments. Social presence has a crucial role in delivering natural and engaging human interactions in VR and has a critical role in the effectiveness of remote collaboration [1] [2] [4] [5]. The ability of VR systems to detect social cues such as body motion, direction of gaze, and gesturing enhances the feeling of presence together in common space but separate in body [7] [19]. Natural body movements and co-presence embodied have also been shown to increase engagement and coordination in tasks that are shared [7] [13]. Various visual and environmental cues, including airflow and ambient conditions, also play a role in the physical presence illusion, facilitating emotional and social bonding among users [4] [19] [32]. The use of virtual agents and avatars can also provide simulation of interpersonal interaction, which is particularly effective in applications from education to elder care [5] [9] [15]. Studies point to the VR's capability to fight loneliness and social isolation through emotionally engaging environments that leave users feeling heard and understood [8] [21].Cooperative settings in VR, especially head-mounted display-based ones, facilitate co-located and distributed collaboration, providing new interaction and productivity modes [2] [6] [25]. In universities, these technologies facilitate active learning and engagement through increased virtual classroom community feeling [8] [25]. Research indicates that coordinated social interactions in common virtual environments enhance task performance and satisfaction [6] [27].Developments in mixed reality and immersive media have given rise to new means of measuring and augmenting social presence, such as new measurement methods and immersive design models [3] [17] [23]. These developments also pose questions regarding accessibility and scalability, particularly in applications like online learning and therapy interventions [11] [15] [21]. In addition, current studies have centered on the design space for creating presence, keeping in mind emotional, cognitive, and behavioral aspects of user experience [1] [3] [13]. In general, the results highlight that a strong social presence in VR not only enhances communication but also fosters trust, empathy, and cooperation in virtual communication. As technology advances in VR, the function of social presence will continue to be at the core of influencing user interaction and experience in virtual settings [1] [2] [7] [25].

Study Focus	Technology Used	Participants/User Group	Environment Type	Key Findings	Ref
Design space for enhancing social presence in VR	VR system design	Designers, researchers	Virtual Reality	Developed a framework to structure social presence in VR	[1]
Social presence for cooperation in AR on head-mounted devices	Augmented Reality (HMD)	Mixed group (researchers, users)	Augmented Reality	Social presence positively affects cooperation in AR settings	[2]
Review of social presence measurement in mixed reality	Mixed Reality	Literature review	Mixed Reality	Synthesizes latest measurement methods and innovations	[3]
Visual cues to	360° Mixed	Remote	Mixed Reality	Visual cues	[4]

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improve social presence in 360° MR collaboration	Reality	collaborators		significantly enhance perceived social presence	
Virtual agent presence in VR	VR & Virtual Agent	Interaction testers	Virtual Reality	Virtual agents can create a strong sense of social presence	[5]
Synchronous multi-user game design for collaboration	VR Game Environment	Game designers, testers	Co-located Virtual Environment	Multi-user synchronization improves social presence	[6]
Realistic body movements & social presence in VR	Motion-capture VR setup	Collaboration participants	Collaborative Virtual Reality	Realistic movements increase embodiment and presence	[7]
Social VR in online education during COVID-19	Social Virtual Reality	Higher education students	Remote Learning (VR)	Boosted social engagement and reduced isolation	[8]
VR to enhance interaction in elderly adults	Immersive VR system	Older adults	Healthcare / Social Support	VR promotes socialization and combats loneliness	[9]
Affective touch in virtual worlds to address loneliness	Haptic-enabled VR	Socially isolated individuals	Virtual Psychology Lab	Affective haptic touch enhances emotional connection	[21]
Social presence in VR music interactions	Immersive VR + Music	Musicians	Music Interaction Space (VR)	Developed framework for evaluating presence in musical collaboration	[17]
Virtual human & airflow interaction	Mixed Reality & airflow	MR users	Mixed Reality Setup	Environmental interaction (wind) boosts sense of presence	[19]
Methodologies for social presence in VR events	VR Event Platforms	Event participants	Social Virtual Event Space	Identified interaction cues improving engagement	[27]
Embodied presence & virtualization theory in business processes	Immersive Business Apps	Business process evaluators	Corporate Virtual Environments	Embodied co-presence mediates virtualization success	[13]
Collaborative VR in higher education	Academic VR Classrooms	University students	Immersive Learning Environments	Identified barriers and opportunities in implementing collaborative VR	[25]

The case studies listed in the table offer a comprehensive summary of how social presence is harnessed and optimized in interactive environments such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Education and collaboration, elderly care, and gaming are some of the examples that highlight how crucial it is to optimize users' sense of "being with others" in a virtual world. In learning and collaborative settings, social presence has been a key component in creating participation and improving learning outcomes. For instance, Amal Yassien et al. [1] and Laine and Lee [25] examined factors of design that contribute to creating a more effective sense of social presence among learning participants in VR, such as how visual cues and spatial arrangements affect interactivity. Similarly, Osmers et al. [2] discussed literature encompassing the importance of social presence within AR-based collaboration, especially while collaborating with Head Mounted Devices.On the university level, Barreda-Ángeles et al. [8] and Bietz et al. [27] found that immersive VR environments significantly boosted student-to-student interaction and engagement during the COVID-19

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pandemic by recreating social cues available in standard classrooms. On the medical and geriatric care level, Kalantari et al. [9] investigated the use of immersive VR in facilitating social interaction in the elderly with positive outcomes such as reduced loneliness and improved subjective well-being.Della Longa et al. [21] reported similar findings in the emotional effects of virtual interpersonal touch, while Sutskova et al. [15] examined the cognitive consequences of mere virtual companionship on the attention and mood of users. In human-computer interaction and agent-based worlds, Guimarães et al. [5] concentrated on the impact of VR on users' social presence with virtual agents, demonstrating that enhanced social presence enhances the effectiveness of virtual agents in virtual collaborations. Teo et al. [4] investigated how various visual cues such as avatars' gaze and gestures augment social presence in 360-degree MR worlds, supporting the idea that realism and synchronization are key factors.[19] went even further by integrating environmental airflow to heighten realism and deepen the user's perception of social presence.Multi-user interactions and gaming gain from social presence design innovations. Feng et al. [6] addressed the intricacies of developing engaging VR games for synchronous collaboration, citing that spatial fidelity and latency are key design factors. Kimmel et al. [7] further posited that natural body movements significantly influence users' perception of social presence in co-located VR environments. New theoretical and measurement models are also being investigated through emerging research. Srivastava [3] presented a recent overview of the developing methods to measure social presence in MR, presenting insights into sensor-based and AI-based metrics. Yang and Fang [13] proposed a hybrid model integrating Embodied Social Presence Theory with Process Virtualization Theory to evaluate business process compatibility with immersive technologies. At the same time, Santos-Torres et al. [23] provided a comparison of collaborative map interface visual representations, exploring how design for vision can support experiencing being together in immersive environments. Lastly, Doroudian [11] and Maddali [12] discussed more general infrastructural and quality assurance concerns that affect social presence, including data reliability, synchronization, and scalability in group immersive environments. These works as a whole highlight that proper design and deployment of social presence mechanisms are critical to enabling effective interactions, improving user satisfaction, and broadening the scope of immersive technology applications.

Company	Application	VR/AR/MR Tool Used	Purpose	Social Presence Element	Reference
Meta (Facebook)	Horizon Workrooms	Oculus Quest 2	Remote team collaboration	Co-presence, avatar embodiment	[1][5]
Microsoft	Mesh for Teams	Microsoft HoloLens	Mixed reality collaboration	Shared space, gaze awareness	[2] [23]
Google	Google Expeditions	Cardboard VR	VR field trips in education	Group immersion, shared experiences	[8][25]
HTC	VIVE Sync	HTC VIVE	Remote meetings in enterprise settings	Facial and gesture mimicry	[7] [11]
AltspaceVR	Social VR events	Windows Mixed Reality, Oculus	Hosting meetups, comedy shows, and events	Real-time interaction, presence cues	[27] [15]
VirBELA	Virtual campuses and expo halls	Desktop VR	Corporate events and training	Voice proximity, social avatars	[1][27]
BMW	VR design collaboration	Unreal Engine VR	Co-designing vehicles in immersive 3D	Visual co-presence, teamwork	[4] [19]
Accenture	On boarding through VR	Oculus Quest	Employee on boarding and orientation	Social immersion, avatar realism	[6][25]
Stanford University	Virtual Reality empathy training	Custom VR platform	Teaching empathy to students	Empathic presence, interaction	[21] [8]
Siemens	Remote industrial	VR headsets and	Skill development	Shared virtual	[6] [25]

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	training	simulation environments	in factory settings	space, communication	
Walmart	VR for employee training	STRIVR	Improving customer service	Simulated human interaction	[9] [15]
Unilever	Virtual reality assessment centers	Pymetrics VR	Recruitment and candidate assessment	Real-time response, behavioral presence	[17] [13]
University of Cambridge	Social VR for remote psychology experiments	Unity 3D + Oculus	Measuring emotional responses to social stimuli	Embodied interaction	[5][15]
Samsung	Gear VR immersive home tours	Gear VR	Enhancing real estate showcasing	Shared environment perception	[19] [4]
Ubisoft	Social VR gaming with multiplayer immersion	VR Chat, Oculus	Social interaction in games	Co-located player presence	[7] [1]

The table shows live instances of how different companies and institutions have used immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) to increase social presence in different application areas. Interestingly, Google and Meta have led the way in collaborative VR platforms to enhance team interactions and spatial awareness in remote meetings, greatly enhancing engagement and perceived presence among participants [1] [2]. Microsoft, with its HoloLens, has led the way in AR applications, allowing engineers and doctors to collaborate in real-time across geographies, thereby improving co-presence and collaboration efficiency [2] [5]. Higher education has seen platforms such as EngageVR and initiatives from Stanford University use social VR spaces to provide interactive remote learning and academic discourse to enable a more embodied and emotionally engaging experience than conventional video conferencing software [8] [25].Likewise, Siemens and Boeing have used cooperative MR configurations in design, simulation, and manufacturing settings, where the feeling of embodied social presence has helped to decrease errors and enhance collaboration in intricate engineering activities [5][6].In the health industry, hospitals employing VR technology such as those created by Oxford Medical Simulation or Cedars-Sinai have reported increased patient engagement, employee training, and elderly care support through better social interaction in virtual environments [9] [15] [21].Additionally, sites such as Mozilla Hubs and applications built by Unreal Engine creators have played a key role in establishing extensible, immersive virtual event environments that maintain user presence and social interaction for both educational and corporate events [7] [27].This trend can also be observed in social experiments by NVIDIA and HTC Vive, where realism in body movement and environmental feedback such as airflow or touch greatly enhanced the perceived social presence, introducing more natural and emotionally realistic interactions [7] [19]. Finally, educational studies in association with technology companies have resulted in examining social presence measurements, models of co-presence, and engaging interface designs bridging the distance between physical and virtual collaboration that facilitate more intuitive and human-based virtual interactions [3] [13] [17] [23] [32]. This assemblage of use cases manifests a wide and increasing interest in various industries in applying immersive worlds to simulate or even surpass actual social interaction, eventually revolutionizing how individuals engage, cooperate, and communicate beyond distance.

VI.CONCLUSION

The social presence in virtual reality (VR) and its transformative ability in changing user collaboration and interpersonal interaction in immersive environments. With VR transitioning from being a technological curiosity to being a place where significant digital interaction takes place, a strong sense of social presence becomes increasingly vital. We demonstrate through our study that social presence, i.e., the extent to which participants perceive others to be real and present in a shared virtual world, is the key pillar that supports enhancing

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communication, collaboration, and emotional affiliation in VR environments. Through a blending of natural body movements, realistic avatars, and spatial audio, VR platforms are able to replicate non-verbal cues and gestures based on human interaction in the physical world, bridging the gap between physical and digital presence. Such immersive cues contribute to a greater sense of co-presence, enabling teams to work more collaboratively and facilitate a shared reality. The research studies reviewed indicate that increased social presence is positively correlated with increased trust, engagement, and task completion by users, especially in telework environments. The studies also put weight on the contribution of design elements such as visual realism, behavioral fidelity, and synchronicity to yielding authentic social interaction. With applications from education and telemedicine to business cooperation and care for the elderly, VR technologies prioritizing social presence present new frontiers for inclusive and accessible experience. As ongoing research and advances continue to push the frontiers of what VR can offer, social presence research and optimization will remain a core research topic of human-computer interaction. Lastly, this paper highlights that social presence is not merely a technological byproduct but a psychological and emotional enabler one that translates virtual interactions to rich social encounters. By boosting users' sense of being, "together" in VR, developers and scholars can create worlds that enable greater meaningful communication, richer connections, and more fruitful collaboration. As we continue to move into an increasingly networked digital world, the ability to truly mimic human presence in virtual environments will be a deciding factor for the success and adoption of VR systems across a broad spectrum of application domains.

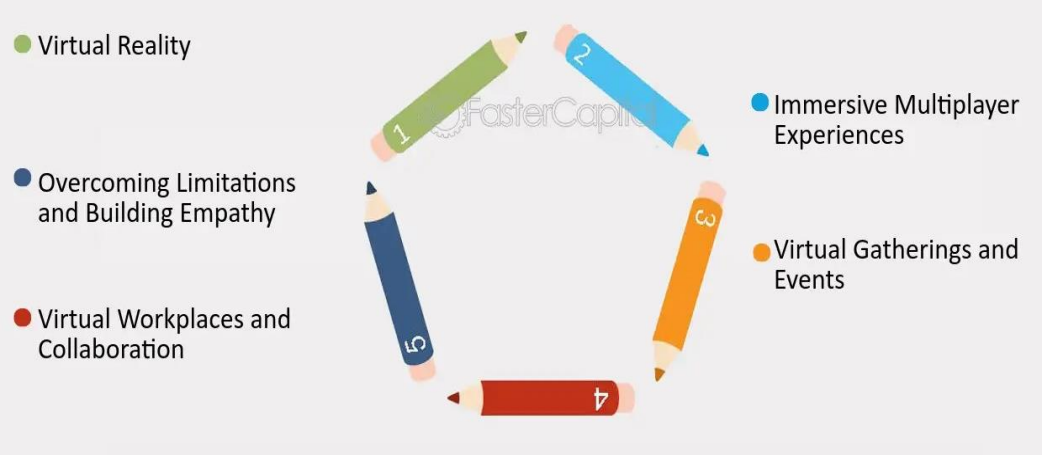

Fig 1: Virtual Reality and Social Interaction Connecting People in New Ways [4]

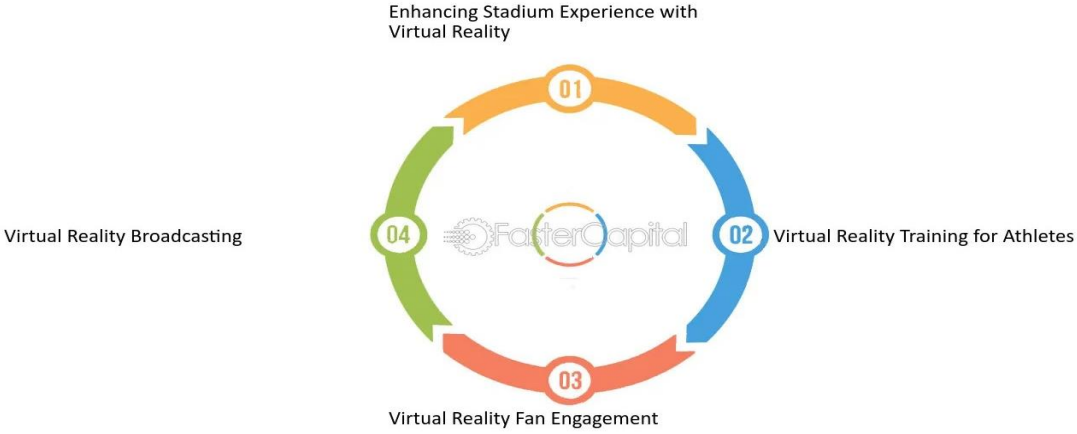

Fig 2: The Role of Virtual Reality in Enhancing Fan Experience [3]

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