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Being where, with whom, and when it happens: spatial, interpersonal, and temporal presence while viewing live streaming of collegiate sports in virtual reality

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Introduction: Although virtual reality (VR) is most popularly known for its applications to gaming, other entertainment applications are increasingly being explored including in the sports media industry, but little research has so far examined the experiences induced by VR viewing of a live sporting event.

Materials and methods: Participants (n = 93) were university students who were approached in the context of a field study from a nearby community eatery area on the university campus to watch brief segments of a 360° live stream of the home games of their university volleyball and basketball teams both while wearing and not wearing an inexpensive smart-phone based head-mounted display (HMD). Immediately afterward, participants then reported on their relative experience of spatial, interpersonal, and temporal presence, as well as their satisfaction-preference with each of the two viewing modalities, in response to brief face-valid screening questions.

Results: The majority of participants experienced greater presence while wearing the VR headset, and approximately one in every two reported preferring to watch the games in VR. Participants' experience of spatial presence independently correlated with preferring to watch the games in VR.

Discussion: Media vendors should offer VR viewing of sports including via inexpensive, smart-phone mediated VR as an additional, cost-effective alternative means of heightening fans' experience of virtual presence at the games when fans are unable to go to the games in person.

KEYWORDS

virtual reality, sports, presence, spatial presence, temporal presence, social presence, 360-degree video

Introduction

Virtual reality (VR) is most popularly known for its applications to gaming, and the National Football League (National Hockey League, 2019) has recently announced their endorsement of VR software to simulate the experience of gameplay. Comparably, while some of us may as yet still dream of one day being a NFL player, other sports fans may be

satisfied with another entertainment application for VR in the sports media industry that has been chiefly taken up by the National Basketball Association (NBA), that is, immersive sports viewing of live games. Here, the effort is not as much to create an experience of being on the basketball court as a player as it is to simulate the experiential depth of in person attendance at sporting events as a fan (e.g., the experience of sitting courtside at the game) more than is possible by watching the games via traditional media (e.g., television or flatscreen computer). Nevertheless, the NBA live-streamed only 5 of its 82 games in its most recent 2022-23 regular season (NBA, 2023), and earlier attempts at attracting VR viewers to other professional sports (e.g., the National Hockey League [NHL]) that were active in recent years are no longer available as of this writing (e.g., National Hockey League, 2019). These circumstances draw some concern to the size of the current market for viewing of sports in VR. Indeed, little is known from peer-reviewed empirical research regarding the satisfaction levels of viewers of live sporting events using head-mounted displays (HMD). To provide a case for further industry investment, more research on the experiences of live streaming sports in VR is critically needed.

To effect an immersive experience for the sports fan in VR, recording of gameplay can be undertaken simultaneously in 360-degrees, thereby providing an immersive viewing experience inclusive not only of the sporting area (e.g., the basketball court) that would normally be the focus of attention directly in front of fans' eyes, but also of other fans in physical attendance at the game that are situated to the left, right, and behind the camera. As a result, the video footage acquired by 360-degree cameras, when viewed through HMD, can potentially offer the viewer an experience of *presence* in at least two of its most well studied forms, that is, the *spatial* and *social* senses of presence (e.g., Skarbez et al., 2018; Felton and Jackson, 2022). In the case of sports viewing, the feeling of spatial presence is akin to the sense of "*being there*" at the game, while the feeling of social presence is akin to the sense of "*being together*" with other fans. In other words, these experiences constitute the so-called *place* and *co-presence* illusions, that is, the feelings of "being in a place [e.g., at the basketball arena] in spite of the sure knowledge that you are not there" (Slater, 2009) and "of 'being together' in a virtual or mediated space [e.g., with other fans at the arena]" despite knowing that one is not (Skarbez et al., 2018).

Besides creating an increased sense of presence in the established spatial and social-interpersonal senses of this term, a recent study of an educational application of VR by Frewen et al. (2022) described a third *temporal* sense of presence that may also apply especially in the case of viewing 360-degree videos in VR by HMD. In these cases, the events that were being viewed in 360-degree videos seemed to be occurring in the present (i.e., *now*) more so when viewed through HMD. This was found even when participants knew fully well that the educational videos that they were watching had been recorded at an earlier date, thus constituting an illusion of "nowness" in VR when viewing pre-recorded videos. Comparably, in the case of live streaming videos, there is less of a logical basis for a temporal *illusion per se*, but we hypothesize that the VR viewer may nevertheless experience an enhancement of the feeling of temporal presence while wearing a HMD when compared with viewing the same live streams on a standard flatscreen.

Here, we conjecture that this may be due, at least in part, to the increased spatial presence commonly experienced in VR, or the unframed or in other terms *externally non-mediated* sense in which one seems to be viewing and aware of media via HMD (Lombard and Ditton, 1997; Skarbez et al., 2018; Hartmann and Hofer, 2022). Since the advent of television, humans have become accustomed to watching both present (i.e., live) events (e.g., usually the case in sports viewing), as well as past (i.e., pre-recorded) events (e.g., movies), within the borders of a framed screen that exists only as an object within one's greater field of view. In either case, normally we will not have the place illusion that we are inside the environment depicted on a television screen, due to the unframed purview of our physical surroundings. Comparably, viewing 360-degree videos through HMD simultaneously occludes one's natural surroundings while providing an unframed viewing of the virtual space, thereby creating a false perception that what one is seeing are things that are situated directly in front of one's eyes. But normally when we see things that are happening right in front of our own eyes, and they take up our whole field of view, we will not only be physically located in the place that we are seeing, but we will also consider that the things that we are seeing are happening "right now" (i.e., we do not live in the past). Such normal and logical circumstances thus create the potential for an illusory increased experience of "nowness" when pre-recorded videos are viewed in VR as was found by Frewen et al. (2022). More, the same arguments provide a basis for hypothesizing that experiences of temporal presence should be mediated, at least in part, by experiences of spatial presence.

In other words, the more that I feel like I am *where* things are happening, the more I should also feel like what I am seeing is happening *now*. VR may thus create the perceptual circumstances for an increased experience that the events I am perceiving are occurring both in the "*here and now*". Together with the experience of social presence, we may thus define a contextualized experience of presence in VR through the senses of *where* (Spatial), *who* (Interpersonal) and *when* (Temporal) events are perceived to be occurring in relation to a self. We will call this the SIT framework for understanding presence in VR which is used as a simple psychological model for understanding a viewer's response to viewing 360-degree videos, including those of sporting activities.

Unfortunately, to our knowledge, very few prior research studies have so far examined the experiences induced by VR viewing of sporting events, making it uncertain whether the aforementioned theoretical potentials for VR to increase satisfaction and presence during sports viewing are indeed realizable with current technologies. Kim and Ko. (2019) found that VR (in comparison to standard flatscreen) viewing of brief (5 min) segments of previously recorded NBA games increased undergraduate students' experience of presence partly by increasing perceived vividness and interactivity which in turn increased flow and overall satisfaction with sports broadcasting. More, Wilson and Mayhorn. (2019) provided similar, preliminary study results for increased spatial presence to be experienced while viewing similarly brief and pre-recorded segments of a university football game. While intriguing, both studies measured presence only in its spatial aspects (e.g., "I felt I was in the arena", p. 351) to the neglect of other multidimensional aspects of presence, such as the aforementioned interpersonal-social and recently established temporal senses.

More, on a practical level, both studies used purpose-built VR hardware, which currently remains cost-prohibitive and may be one reason behind the seemingly small current market for use of VR in sports viewing among the current general public. Thus it remains

unknown whether these prior study results are extendable to lower cost alternatives such as smartphone-based VR that is available simply by inserting phones into low-tech HMD, and may be a more financially accessible means of accessing VR by the general population. Finally, the use of pre-recorded videos in these prior studies limits generalizability to live streamed games, that is, those recorded as they are taking place in real time, surely the more typical circumstances for most sports fans to watch gameplay. Further research is clearly needed to evaluate the satisfaction with VR viewing of sports to provide a multidimensional, contextualized experience of presence through lower cost HMD in the case of live-streaming.

Here, we sought to extend the results of Kim and Ko. (2019) involving viewing previous games of a single men's professional sport (NBA), and Wilson and Mayhorn. (2019) involving viewing of a single short segment of a single men's collegiate sport (football), to the VR of media consumption of live-streamed collegiate athletics programming inclusive of multiple sports (volleyball and basketball) and participating athletes of both biological sexes. Further, we articulated a brief yet multidimensional approach to screening for the contextual experience of presence that queried not only about the *where* (spatial) but also about the *who* (interpersonal-social) and *when* (temporal) senses to establish a contextualized yet relatively simple and translatable measurement of this otherwise complex psychological construct. Further, to overcome potential translational barriers as a result of the affordability of VR experiences of sports viewing to the broader public, we utilized smartphone mediated VR as perhaps the most cost-effective means of implementing VR currently available. We hypothesized that real-time viewing of livestreamed sporting events through HMD would increase the spatial, interpersonal-social, and temporal experience of presence in comparison with viewing the same games through a standard flatscreen. We also hypothesized that participants' experiential ratings of spatial, interpersonal-social, and temporal presence would be positively correlated. Finally, we inquired of participants' preference for viewing the games in VR as compared with standard screens and predicted that an increased preference for viewing sports in VR would be associated with an increased experience of presence in VR.

Materials and methods

Participants

Participants (n = 93) were university students who were approached during the games from a nearby community eatery area on the university campus in the context of a field study. Participants were evenly split between the binary genders (Female: N = 47, Male: N = 46) without any participant identifying as non-binary.

Materials

360° Camera

A Kandao QooCam 8K camera was used to live stream the sporting games. This camera comes equipped with an aperture of F2.0 and a field of view of 200°. The video specifications were set to 7,680*3,840 (dual lens) at 30 fps with a bitrate up to 200 Mbps. The camera was set to 4K live streaming with footage outputted to YouTube with privacy settings (videos were unlisted).

Smartphone inserted into HMD

A Samsung Galaxy S21 smartphone was inserted into a head-mounted display (HMD) using the standard YouTube application for Android set to VR viewing (duplicate circular view). The smartphone has a dynamic AMOLED 2X screen with a refresh rate of 120 Hz, HDR10+, and a resolution of 1,080 × 2,400 pixels, 20:9 ratio (~421 ppi density). The phone was inserted into a SkyMall Virtual Reality 3D Glasses Headset, which is a standard, plastic enclosure offering a 90° field of view. Use of the smartphone inserted into the HMD provided for the VR viewing condition.

Computer

The Samsung Galaxy Ultra S8 tablet computer was also used, using the standard YouTube application for Android set to normal, full screen viewing. This is a large 14.6" tablet with the following display specifications: super AMOLED, 120 Hz refresh rate, HDR10+, and a resolution of 1848 × 2,960 pixels, 16:10 ratio (~240 ppi density). Use of the tablet provided for the non-VR viewing condition.

Survey

Participants answered six brief and face-valid screening questions via an online survey hosted on Qualtrics that was administered immediately after participants viewed portions of the games in each modality. The first four questions and their answers appeared in a randomized order to control for ordering effects and were answered in a forced choice format with the following response options: "VR headset," "Computer," "About the same," or "Decline to answer" (the latter a requirement for ethical purposes).

Three questions screened for which viewing condition was more impactful on their experience of spatial, interpersonal, and temporal presence as follows: Spatial: "Which way of viewing made you feel more like you were in the same physical space or location as where the sporting activity was taking place?", *Interpersonal*: "Which way of viewing made you feel more like you were interpersonally a part of what was happening in the sporting activity?", and *Temporal*: "Which way of viewing made you feel more like the sporting activity was occurring in the present, rather than sometime in the past?". Spatial and social (interpersonal) dimensions of presence are well established in the literature (e.g., Felton and Jackson, 2022) while the concept of temporal presence is lesser known but was recently introduced and found relevant to the scholarship of teaching and learning in VR which showed that, even when participants were knowingly watching pre-recorded psychology teaching videos, they reported feeling more like what they were watching was occurring in the present tense when viewed through HMD (Frewen et al., 2022). A fourth question inquired straightforwardly about participants' relative satisfaction-preference with the two viewing formats: *"Which way of viewing was more satisfactory? Which one did you like more?"*. Finally, participants were also asked about their gender identification and to indicate the sporting event they had observed as a simple attention check.

We note that whereas many prior lengthier questionnaires have been validated for measuring presence (comprehensively reviewed by Felton and Jackson, 2022; Skarbez et al., 2018), for example, the frequently used *Witmer-Singer Presence Questionnaire* (Witmer and Singer, 1998) and *ITC-Sense of Presence Inventory* (Lessiter et al., 2001), due to our study using a field research design, it was not feasible to utilize such questionnaires due to their length of administration. However, the screening questions that we used, as phrased using the aforementioned plain language, were modelled after existing items from these and other extensively validated questionnaires, and had also been extensively piloted to ensure ease of understanding prior to the conduct of the current study. More, precedent for brief measurement of these constructs in the context of sports viewing was provided by Kim and Ko. (2019) who used only three items for the measurement of spatial presence. While a more comprehensive assessment of presence would have been desirable, the feasibility of conducting the current research under the conditions we had available to us required the use of a briefer screening approach to measuring presence as we have conducted herein.

Procedure

The study procedure was approved by the institutional research ethics board of Western University, Canada (protocol #121880) and pre-registered on the Open Science Framework (Vincent and Frewen, 2023). Of note, the current study utilized a field research design where data was collected in a public rather than private lab setting. Out of 93 participants, 22 attended the study during a women's basketball game, 23 attended during a men's basketball game, 18 attended a men's volleyball game, and 30 attended during a women's volleyball game. Two volleyball and three basketball games were attended with each biological sex of players, thus 10 games in total. Women's games were always scheduled to play at 6:00 p.m., before the men's games at 8:00 p.m.

Two researchers were involved in data collection during each game. The principal investigator set up a Kandao 360-degree video camera on a four-foot-tall camera tripod to record the sports events from the front row seating area approximately at center court of the major sporting arena located on campus. The warm-up for each game and the games themselves were streamed live through YouTube Live at 4K resolution using privacy settings such that the games could only be viewed by the researchers.

A second, supervised student researcher recruited participants during game time at the University Community Centre café and eatery area. Note therefore that the current research was an instance of a field research method and that participants were not tested in the usual circumstances for similar research of this kind, such as in a private VR psychology laboratory. Students were asked if they were interested in participating in the study using a script and to provide written informed consent. Participants who consented (approximately 50%) then either first viewed the game with the VR headset or with the tablet for approximately 1 minute before subsequently viewing the game for the same duration via the other device. Ordering of viewing modalities was counterbalanced across participants. Participants were free to move in their chairs or while standing during both conditions and encouraged to interact with both technologies as they desired (e.g., adjusting viewing angle by moving head while wearing VR headset or rotating or panning tablet touchscreen).

Participants answered the survey questions immediately after they had viewed the gameplay using both devices. Participants tended to complete the 6-item questionnaire portion of the study relatively quickly, consistent with its brevity, as measured by the Qualtrics survey software (M = 55 s, SD = 36 s, Range = 19–345 s). Only a single participant elected to "Decline to Answer" the Spatial and Interpersonal-Social Presence questions; there was no other missing data.

Statistical analysis

Planned statistical analyses were pre-registered in the OSF (Vincent and Frewen, 2023). The hypothesis that spatial, interpersonal, and temporal presence ratings, and satisfaction-preference for viewing device, would not be equally distributed across the response options was evaluated with the McNemar chi-square test. Correlations between these ratings and with satisfaction-preference were also calculated and compared with Kendall's tau statistic by recoding the ordinal response options in increasing favor of the VR headset: "VR" = 3, "About the same" = 2, and "Computer" = 1. Finally, a single-step multiple regression equation was calculated with these recoded presence ratings as predictors and the recoded satisfaction-preference rating as the outcome. All statistical analyses were undertaken using standard SPSS software.

Results

Accuracy was perfect in the question of what sporting activity was observed and correct in all but a single instance regarding indication of the biological sex of the players thus confirming that participants had attended to the videos.

Frequency statistics

As predicted, spatial, interpersonal, and temporal presence ratings were unequally distributed across response options, suggesting that viewing device (VR headset vs. tablet-computer) had an effect on the experience of presence (all p's $< .001$). McNemar chi-square statistics obtained were as follows: *spatial*, χ^2 (2, N = 92) = 134.11; *interpersonal*, χ^2 (2, $N = 93$) = 106.98; *temporal*, χ^2 (2, $N = 93$) = 47.81. Figure 1 shows that the majority of participants reported that viewing the sporting events through the VR headset produced more experience of spatial (89%), interpersonal (83%), and temporal (67%) presence; the ratings for spatial and interpersonal presence do not sum to 100% given that a single participant declined to answer such questions.

Satisfaction-preferences also significantly differed from equivalency across the response options: χ^2 (2, N = 93) = 10.52, $p < .01$. Nearly one of every two participants ($n = 45$, 48%) preferred viewing the games in VR, while the remaining participants either

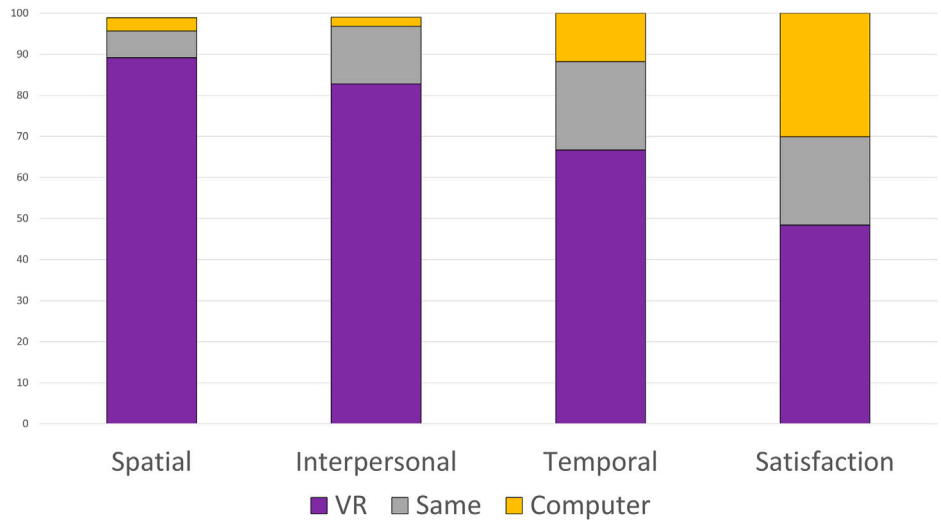

FIGURE 1
Presence and Preference for VR vs. standard flatscreen viewing of a University Sporting Event Notes. *Spatial*: "Which way of viewing made you feel more like you were in the same physical space or location as where the sporting activity was taking place?", *Interpersonal*: "Which way of viewing made you feel more like you were interpersonally a part of what was happening in the sporting activity?", *Temporal*: "Which way of viewing made you feel more like the sporting activity was occurring in the present, rather than sometime in the past?", *Satisfaction-Preference*: "Which way of viewing was more satisfactory? Which one did you like more?" Forced choice response options were: "VR" (scored 3) or "About the Same" (scored 2) or "Computer" (scored 1) or "Decline to Answer" (unscored). Percentages do not quite sum to 100% in the case of spatial and interpersonal ratings due to a single participant declining to answer.

TABLE 1 Correlations between presence and preference selection in favour of VR viewing of a University Sporting Event.

	1	2	3	4
1. Spatial	--			
2. Temporal	.25*	--		
3. Social	.07	−.05	--	
4. Satisfaction-preference	.27*	.23*	.15	--

Note: *$p < .01$ (1 tailed). Correlation represented by Kendall's Tau (r_τ).

TABLE 2 Regression analysis summary for predicting preference.

Variable	*b*	SE_b	*B*	*t*	*p*
Satisfaction-preference (Constant)	−.322	.775	---	−0.416	.678
Spatial	.515	.217	.253	2.377	.020
Temporal	.162	.133	.128	1.219	.226
Social	.221	.199	.113	1.114	.268

Note: R^2 adjusted = .013. *b* = beta, SE_b = standardized error of beta, *B* = standardized beta.

expressed no preference ("About the same"; n = 20, 22%) or preferred viewing the games via the tablet-computer (n = 28, 30%).

Correlations

Table 1 reports the correlations observed between spatial, interpersonal, and temporal presence ratings, as well as between the presence ratings and satisfaction-preference for use of the VR headset. Statistically significant positive correlations ($p < .01$) were observed in the form of Kendall's tau-statistic between spatial and temporal presence (r_τ = .25), and between satisfaction-preference and each of spatial (r_τ = .27) and temporal (r_τ = .23) presence. However, correlations with interpersonal presence were non-significant. Table 1.

Regression

A multiple linear regression was calculated to predict satisfaction-preference based on spatial, temporal, and interpersonal presence all entered in a singular step. A significant regression equation was found that accounted for 12% of the variance in satisfaction-preference [$F(3,88) = 4.03$, $p = .01$]: $y = = .322\ b_0 + .515b_1$ (Spatial) + $.162b_2$ (Temporal) + $.221b_3$ (Interpersonal). Results are presented in Table 2. Only the spatial presence rating was a statistically significant predictor of satisfaction-preference in this equation: t (88) = 2.38, p = .02.

Discussion

VR has been touted as providing a virtual means of bringing participants experientially closer to where sporting events are happening, although participants' experience and satisfaction with VR as a means of viewing live sporting events has actually received surprisingly little research attention to date. To our knowledge, we are the first to document participants' multidimensional experience of presence and preference for VR viewing in comparison with standard viewing of live collegiate sporting events. We broadened

the research base beyond prior investigations of brief segments of previously recorded games involving either men's professional basketball (NBA) (Kim and Ko, 2019) or a college football game (Wilson and Mayhorn, 2019) to live coverage of university athletics programming, specifically men's and women's basketball and volleyball games. In brief, the majority of participants indicated that they felt more spatially, socially, and temporally present when watching the games in VR, and an increased experience of spatial and temporal presence was associated with an increased preference for viewing the games in VR, with about half of participants expressing a preference favoring viewing of the live sports in VR. These findings are discussed in turn.

Nearly nine of every ten participants reported that the VR viewing condition involving use of a smart-phone inserted into a low-tech HMD was associated with a greater sense of *spatial* presence, that is, the experience of "being there", where the sporting event was actually taking place. Moreover, the experience of greater spatial presence, while not greater social or temporal presence, was independently associated with an increased preference for the VR over the non-VR viewing condition in the multiple regression analysis. Our results regarding spatial presence were anticipated by those of Kim and Ko. (2019) and Wilson and Mayhorn. (2019), the former researchers also further emphasizing that spatial presence was partly increased through an experience of vividness and interactivity while watching an NBA game. It is possible that our VR conditions were also perceived as being more vivid than the flatscreen condition, although from a technical standpoint, the flatscreen viewing medium actually evidenced the higher screen resolution in the current study, and a previous meta-analysis suggests that field-of-view may be more impactful on the experience of spatial presence than vividness of visual stimuli *per se* (Cummings and Bailenson, 2015). More, a greater sense of interactivity was also reported by Kim and Ko. (2019) during VR viewing of NBA games, specifically, the feeling that one "had a lot of control over the content of the game", that the game could be watched in an "interactive way", and that "visual perspective" could be controlled during viewing (p. 351). It was unclear, however, how much interactivity was present under the VR viewing conditions afforded by the commercial platform of delivery used in their study. Further, while the non-VR (2D) viewing conditions used in prior research would not readily afford changing of visual angle, our use of a tablet computer with gyroscope addressed this confound by equating the ease of doing so between the VR and non-VR conditions (i.e., head vs arm-body movements). Thus, apart from this, due to our simply relying on a passive video recording, there was no obvious way in which a differential level of interactivity was present between our VR and non-VR conditions, yet we still found that viewing in VR produced a stronger feeling of spatial presence while watching the games, as if participants were actually in the stands watching the games at the locations where they were actually being played. Future studies could possibly record the changing viewpoints mediated by HMD vs. the use of tablets via the gyroscopes of each device to inform the amount of interactive use of each device during sports viewing. It is possible that differential interactivity might account for the difference to some degree, but at least part of the differences observed seem to be attributable to the immersive nature of VR. Other interpretations of the increased spatial presence afforded by VR viewing include that participants may have experienced less opportunity for visual distractions from their actual physical environment while watching the live stream due to occlusion from the HMD. Future research should investigate other possible mediators of the increased experience of spatial presence afforded by VR viewing of live sporting events including by modifying the field-of-view (Cummings and Bailenson, 2015).

Further, about four of every five participants also felt as if the VR viewing condition provided them with a greater sense of social presence, that is, like they were interpersonally a part of the crowd of fans who were actually physically present at the game. However, a greater experience of social presence during VR viewing was *not* correlated with either spatial or temporal presence in our study, nor with satisfaction-preference ratings for viewing in VR. Our results therefore suggest that, even under entirely passive viewing conditions, a greater feeling of collective spectatorship, the increased feeling of being "a part of the crowd" and of *what* is happening at the game, can be induced by viewing sporting events in VR. Nevertheless, at least in the context of the current study circumstances that involved passive viewing of the live camera recordings, this increased experience of social presence seems unlikely to be mediated through the ability of VR to also induce the sense of being spatially or temporally present, that is, the sense that things are happening in the *here* and *now*. The reasons why people experience more social presence in VR while viewing livestreamed sporting events in 360° therefore requires further study.

Finally, nearly two of every three participants reported that the VR viewing condition was also associated with a greater sense of *temporal* presence, that is, experiencing the live sporting event as if it was happening *now*. While still in the majority, relative to the standard viewing condition, fewer participants perceived VR to induce greater temporal presence than the number that perceived VR to induce greater spatial or social presence. Comparing spatial and temporal presence, our design presented an interesting discrepancy between virtual and actual reality: while in *neither* viewing condition was the participant actually in the same physical space or location as where the sporting activity was taking place (i.e., spatial presence), in *both* viewing conditions the sporting activity *was* truly occurring in the present, as is normally the case when people watch sporting events, rather than sometime in the past (i.e., temporal presence), as had been used in prior studies. This may have limited the extent to which the experience of temporal presence could be further modulated through VR, in other words, being that all participants knew clearly that the footage they were viewing was being recorded live. A future study could further investigate this by assessing spatial and temporal presence in response to both VR and non-VR viewing of both live and past (i.e., pre-recorded) sporting events. Indeed a similar design has been advocated for in researching response to synchronous vs asynchronous university teaching (Frewen et al., 2022). Given that cultural norms involve viewing of fuller sports games at the time of gameplay (i.e., when they are actually taking place), rather than viewing previous games at a later date, the use of live streaming as conducted here perhaps has the highest external validity for viewing of more lengthy segments or entire games. Nevertheless, pre-recorded videos could extend the life of use of live streams when used for watching some of the choice highlights of gameplay, such as the example used in Wilson and Mayhorn's (2019) research involving viewing of an endzone touchdown catch in a football game. Research should also consider the effects of latency on the experience of temporal presence while livestreaming in 360-degrees; we estimated this to be between 30 and 40 s with the normal latency setting in YouTube.

Despite that the majority of participants will experience more spatial, interpersonal-social, and temporal presence while watching live sporting events in VR, this will not always lead to a clear preference for watching the games in VR overall, and not all

participants are likely to opt for watching the games in VR even if they have the opportunity. Instead, in the current study about half of participants did not state a preference for VR viewing, and correlations associating increased presence during VR viewing with a preference for VR viewing were only small-to-moderate in effect size, with only 12% of the variance in increasing preference for viewing sports in VR accounted for by presence ratings, and independently only by spatial presence. Clearly further research beyond the experience of spatial, interpersonal-social, and temporal presence (at least as defined and measured in our study) is required if we are to fully understand individual differences in preference for VR vs. non-VR viewing of sports and other forms of entertainment. Here, future research could also measure other forms of the multidimensional experience of presence. For example, there was no effort to depict a self-stimulus within the recorded environment in our study, and thereby a means by which one could experience embodying and owning a perceptible physical form within the VR was not engendered. Instead, the user was essentially "invisible" during viewing of the current videos, which of course sets an upper limit on presence as well as the realism of the entire encounter. More, since we used 360-degree videos of real-world events, we only assumed but did not directly confirm in our measurements the degree to which participants actually experienced the videos as realistic, an experience that exhibits some lack of clarity in its relationship with other measures of presence (e.g., Jung and Lindeman, 2021). Future studies should also extend the assessment of presence during sports viewing in VR to measures of realism. Finally, physiological measurements could be used, beyond self-reported satisfaction with and preference for VR viewing of sports, as additional, objective means of assessing sports fans' emotional responses to the games (e.g., Halbig and Latoschik, 2021).

Limitations

We recognize several limitations of our study, many of which relate directly to our use of a field experiment design. Most obviously, our study was not conducted in a controlled environment and it is unclear to what degree environmental factors might have interacted with the study procedure to produce the pattern of results we observed. Specifically, participants watched the livestream in a relatively busy and noisy cafeteria-type community eatery over the late dinner and early evening hours in the context of a field experiment, and only the internal speakers of the phone and tablet-computer were used. Use of noise-cancelling headphones would be preferable to decrease auditory interference and other potential distractions and to increase the overall level of immersion possible when videos are watched in public settings, and such responses could also be compared with those obtained when videos are viewed in private settings (e.g., participants' homes, confidential VR psychology labs) in future research. Moreover, perhaps of greatest concern to some readers, for feasibility reasons when considering the field-related nature of our research, we also opted for use of singular face-valid forced-choice survey questions to measure sense of presence in a brief manner rather than using a more lengthy and psychometrically validated questionnaire. As a result, while our results clearly demonstrate that participants experienced more spatial, interpersonal-social, and temporal presence while watching the games in VR, we cannot say how *much* more presence they experienced in VR as compared with standard viewing; use of a psychometrically-validated quantitative rating scale could better ascertain effect size in future studies. Together with use of a short questionnaire, the feasibility of the current field research also led us to use only a short video viewing time of about a single minute, and this limited timespan likely also set an upper limit on the degree of immersion and interest possible in the activity (e.g., participants' had limited exposure to the cumulative development of gameplay, what team was winning, etc.). Even when considering previous studies also used brief (albeit longer, 5 min) viewing periods (Kim and Ko, 2019; Wilson and Mayhorn, 2019), participants may need more time to "*get into*" the activity of the game and more lengthy video viewing periods could be evaluated in future studies. Recruitment numbers also varied by game type, partly owing to the fact that our university routinely schedules men's games after women's games, and recruitment numbers were too small to explore possible statistical interactions of study outcomes by sporting event type (e.g., men's vs. women's sports, basketball vs. volleyball).

Other limitations of our study relate to its likely generalizability. For example, we explored response to only two sports, partly in recognizing that sports for which gameplay occurs over a limited playing space would be more conducive to viewing of footage via 360-degree cameras due to the fact that such cameras offer relatively poor resolution for objects distanced from the camera. For example, the ability to see the ball from center court in a 360-degree video of basketball and volleyball game (small court) will be better as compared with seeing it from center field in a football, soccer, or baseball game (larger fields), a matter that was taken into consideration in a prior study that investigated response to a scene specifically involving "scoring a touchdown . . . close to where the 360-degree camera is placed" (Wilson and Mayhorn, p. 1979). Thus our results cannot be assumed to generalize to other sports, especially those played outdoors on larger fields. We also lacked the comparison condition of actual in-person attendance at any of the games, and so just how much presence was engendered by the VR viewing when compared to actually being at the game cannot be well understood due to this omission. Our participant numbers were also too small to examine possible gender differences in response, which may partly overlap with individual differences in "sport involvement" which can be operationalized as "the degree to which a specific sport (e.g., basketball) is important and interesting to a sport media consumer" (Kim and Ko, 2019, p. 349) (i.e., a higher percentage of males than females may identify as involved sports fans). Future studies should therefore further investigate the source of individual differences in preference for viewing via VR over standard flatscreens and *vice versa*, and our results may not generalize equally well to male and female sports fans, or male and female sports players.

We also wish to re-emphasize that our study utilized smartphone mediated VR rather than a purpose-built conventional HMD, which set an upper limit on the technical quality of the VR experience. Indeed smartphone mediated VR is a somewhat outdated technology. While use of better quality HMD can be expected to provide even better results for the immersiveness of the VR condition, there may also be an upper limit where

increasing technical gains are not necessarily mirrored by linear increases in subjective experience (Cummings and Bailenson, 2015). More, the cost-effectiveness of smartphone mediated VR provides a compelling economic case for making such methods available given the current positive results. While better VR headsets may provide the most immersive and satisfactory experience, their cost may also limit the overall rate of uptake of VR viewing of sports at least in the near future.

Conclusion

Little research has so far examined the experience of virtual-online "attendance" at live sporting events through the use of VR headsets. This study found that most people will feel more spatially, socially, and temporally present when watching live collegiate athletics programming in VR as compared to when the same events are viewed on a standard flatscreen, and up to half of participants express a preference for viewing the games in VR. Such results were found through the use of inexpensive smartphone mediated VR. Practical applications of our research recommend media vendors to offer VR viewing of sports as an additional means of heightening fans' experience of virtual presence at the games. Nevertheless, traditional non-immersive viewing via standard flatscreens should also remain an option because, while many participants are likely to prefer the VR viewing medium, not everyone will. More psychological research is needed to fully understand such individual differences and to maximize virtual attendee's experience of presence at sports events when fans are unable to go to the games in person.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Western University Canada, Non-Medical Research Ethics Board (#121880). The patients/participants provided their written informed consent to participate in this study.

Author contributions

AV recruited and administered study procedures to participants including viewing of live streams via VR and tablet computer and survey data collection, participated in statistical analysis, and authored the first draft of the manuscript as an undergraduate independent study project (ISP) in psychology that was supervised by the study principal investigator PF. PF is the study principal investigator and supervised AV in the conduct of the ISP, designed the study, attended and live streamed the sports games with 360-degree camera, and was the primary author of the final draft of the manuscript that was submitted for publication. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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