BRIEF REPORT

A Cross-Cultural Study of the Influence of Environmental Factors on VR Gamers Experience of Spatial Presence, Enjoyment, and Subjective Workload: A Preliminary Study

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This study is a first step toward identifying some factors influencing spatial presence, enjoyment, and cognitive workload in virtual reality (VR) game play. The study was conducted in the Northeastern U.S. ($n = 40$) and Southwest Nigeria ($n = 40$) using a factorial experimental design with three environmental factors (i.e., lighting, flooring, and in-game sound) at two levels per factor. Participants were randomly assigned to one of eight experimental conditions, playing a VR American football game using *Oculus Rift S* on 3 separate days, under a different condition each time. Following VR game play, measures of spatial presence ($\alpha = .86$), enjoyment ($\alpha = .89$), and subjective workload ($\alpha = .78$) were collected through self-report surveys. A factorial analysis of variance (ANOVA) was used to examine the influence of environmental factors on spatial presence, enjoyment, and subjective workload. The study found main effects of (a) lighting on subjective workload for the Nigerian sample (Day 2 and Day 3), (b) flooring on subjective workload for both cohorts (Day 2), and (c) in-game sound on spatial presence and subjective workload for the Nigerian sample (Day 3) and on spatial presence for the U.S. sample (Day 2 and Day 3). An interaction effect of lighting and flooring on subjective workload was found for the Nigerian sample on Day 1 and Day 2. An interaction effect of lighting, flooring, and in-game sound on enjoyment was found for the Nigerian sample on Day 3. We present implications for theory and practice.

Keywords: environmental factors, spatial presence, enjoyment, cognitive workload, VR game**Supplemental materials:** <https://doi.org/10.1037/tmb0000064.supp>

Virtual reality (VR) is an immersive, computer-generated three-dimensional (3D) experience viewed by a user through a head-mounted display (HMD). The immersive and interactive nature of VR has seen its growing adoption in the design, marketing, education, training, and retail fields (Kim et al., 2008; Luong et al., 2020). The advent of mobile and VR devices with superior capabilities has opened up lucrative growth opportunities in the gaming and entertainment industries. For example, the global VR gaming and entertainment market has been projected to grow to \$70.6 billion in 2026, up from \$4.2 billion in 2018 (Fortune Business Insights,

2019). Further growth of the market is expected, as VR HMDs have become more affordable and available for a mass market (Industry Research, 2019).

Immersion within VR refers to the extent to which a user is absorbed in the virtual environment, to the exclusion of the outside world (Pasch et al., 2009). *Interactivity*, meanwhile, refers to the user's direct active interface with the virtual environment with little or no mediation. Both immersion and interactivity influence the depth of experience that a user has within VR. Playing sports requires rigorous physical movements and an increased agency,

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as sports video games aim to simulate the real experience. VR simulations of sports video games would therefore require high-technological interactivity with motion-based systems (Shafer et al., 2012). As VR systems are more immersive and interactive than standard computer systems, VR sports video games would be expected to be more interactive and immersive.

For VR to be embraced by users and thus to satisfy the training, promotion, or advertising goals of the games' sponsors, it is important that the experience be enjoyable and not considered a burden to the users. One measure of enjoyment in playing sports video games is the users' perception of accuracy through mimicry when they simulate a real sports experience (Pasch et al., 2009). VR sports games potentially magnify gamers' experience as it affords them a wider view of the virtual environment as well as more agentic control over their movements, all of which heighten their perception of being in an actual sports arena with real athletes.

Yet, while deep immersion and interactivity in sports video games could be viewed very positively by users, there are potential risks as well. For instance, such experiences may place significant demand on the user's mental and physical attention and involvement, potentially leading to physical or mental strain, which would manifest either as "gamer-fatigue" or mental overload (Lin & Wang, 2010). Furthermore, there are some general risks associated with the way in which VR simulates 3D experiences. For instance, because of various types of sensory mismatch, some players experience symptoms of motion sickness, such as sweating, disorientation, and nausea (Rosa et al., 2016). It is thus necessary to have a better understanding of the nature and extent of cognitive workload experienced by users when they play VR sports games.

The environment and its effect on people have long been studied in the fields of psychology, retail environment, and consumer behavior (Dad et al., 2016). According to the Stimulus-Organism-Response (S-O-R) model, the environment influences those human beings present in it (Mehrabian & Russell, 1974). Marketing studies for example have found that the retail environment plays a substantial role in how enjoyable a shopping experience is (Varley & Rafiq, 2014). Several studies have also shown that environmental factors such as music, lighting, and the nature of the flooring can influence consumer behavior (Dad et al., 2016; Ju & Ahn, 2016; Loureiro & Rosch, 2014). Considering the novelty of VR, however, there is still very little research on the factors affecting human-VR interactions. VR can be played stationary or in a wide-open ("room-scale") space. There is thus a lot of interaction with the (mostly external) environment. This study is designed to identify and delineate the environmental factors that influence VR gaming experiences.

Finally, VR is nearly as new in western developed cultures, as it is in less developed ones. The fast rate of adoption of VR across the world, therefore, makes it meaningful to investigate whether the influence of the environmental factors on users' experience varies by culture. A major intent of this study is, therefore, to provide design and human factors insights to VR hard- and software developers so that they may better serve their consumers and leverage the business opportunities offered by the technology.

Literature Review

Stimulus-Organism-Response (S-O-R) Model

The S-O-R model, originally developed by Mehrabian and Russell (1974) and modified by Jacoby (2002), explains the

influence of environmental factors, on the human emotional and cognitive condition, which in turn, prompts behavioral responses (Islam & Rahman, 2017; Kamboj et al., 2018). The framework has in the last decade been applied to studies on user experience and interface (UX/UI) design (Suh & Prophet, 2018). The S-O-R model may thus provide more understanding of the different factors interacting in the VR gaming context such as how external cues (e.g., lighting, flooring, and in-game sound) can modify user experience and gamer behavior.

The model consists of three elements: *stimulus*, *organism*, and *response*. "Stimulus" here refers to "the influence that arouses the individual" (Eroglu et al., 2001, p. 179). Researchers have reported that certain features of immersive systems, such as auditory modality (Lin et al., 2017), visual display (Goh et al., 2019; Polys et al., 2011), and haptic interface (Jin, 2013), prompt users' cognitive and affective responses (Suh & Prophet, 2018). VR sports games naturally expose gamers to various stimuli that come from both inside and outside of the gaming system. In VR sports games, internal and external environmental factors can arouse VR gamers' cognitive and affective reactions. Despite what we know thus far, research has yet to focus on the nature and extent of the influence that internal and external gaming environments have on the gaming experience, nor have studies examined the extent to which these factors facilitate or impede the VR experience. Therefore, in this study, we posit that several internal and external environmental factors surrounding the VR gamers will influence gamers' cognitions and perceptions about their gaming experience.

"Organism" refers to the cognitive and affective condition (Loureiro & Ribeiro, 2011), where cognitive condition is "everything that goes on in the individuals' minds concerning the acquisition, processing, retention, and retrieval of information" (Eroglu et al., 2001, p. 181). "Affective condition" refers to the feelings and emotions that individuals express in response to the stimuli (Kamboj et al., 2018). This study considers both the cognitive and affective aspects of the "organism," proposing that an individual's VR gaming experience as an "organism," will be affected by the environmental factors.

The last element of the S-O-R framework is "response," which is the outcome in the form of individuals' approach or avoidance behaviors (Islam & Rahman, 2017). In S-O-R-based consumer behavior studies, approach behaviors were used to represent the positive responses that individuals show in specific settings in the form of positive communications or purchasing behavior, while avoidance behaviors were used to reflect the opposite responses such as negative communications with no intention to purchase (Eroglu et al., 2001; Islam & Rahman, 2017). Even though this study does not focus on actual behaviors following a gaming experience, the response element still applies since we intended to measure gamers' reactions to the gaming environment when playing a VR game. We, therefore, propose that an individual's assessment of their VR gaming experience (considered as a "response") will be affected by environmental factors.

Spatial Presence

Spatial presence refers to the user's subjective feeling of "being there" in the space implied by a particular medium (Hartmann et al., 2016; International Society for Presence Research, 2000). That is, VR users experience a sensation of leaving their current location and transporting to the VR environment. Spatial presence is an important

consideration in mediated environment studies (Cummings & Bailenson, 2016; Hartmann et al., 2016; Steuer, 1992), and aids the assessment of the depth of a user's experience in VR systems (Kim & Ko, 2019; Shin, 2018). In VR, the sense of spatial presence makes the individual act as if they were physically "there," perceiving virtual individuals or objects as real (Servotte et al., 2020; Slater, 1999; Slater & Sanchez-Vives, 2016).

Immersion is one of the factors that affect the degree of spatial presence. It is a measure of an individual's increasing "involvement" inside the mediated environment (e.g., Jennett et al., 2008; Shin, 2018; Shin & Biocca, 2018). While some studies differentiate between spatial presence and immersion, others suggest that spatial presence depends on how immersive the system is (Slater & Wilbur, 1997), or that immersion in VR facilitates the sense of presence (Kim & Ko, 2019; Shin, 2018). Our working use of spatial presence in this study is that it reflects the user's subjective feeling of being inside a VR game "world" (Seibert & Shafer, 2018) and of being completely involved in a game activity (Shin, 2017; Teng, 2010).

Steuer (1992) argued that when using technology, a user is obliged to simultaneously observe and pay attention to both the mediated environment (such as VR) and the physical environment. Since individuals require the same senses to attend to these multiple stimuli, the greater the extent to which a particular media technology is able to reproduce familiar sensory information, the greater the level of presence a person experiences within the media environment (Shih, 1998), to the detriment of the stimuli from the physical environment. Perceptions in VR are created by surrounding the user with images, sounds, or other stimuli which contribute to creating an absorbing and engrossing total environment (Shin, 2017). While some studies have focused on the effect of the mediated environment on users' spatial presence, research is still scarce on the influence on the user of external (e.g., light and floor texture) and internal (e.g., in-game sound) VR environmental characters on gamers' perception of spatial presence.

Enjoyment

The more enjoyable a VR experience, the greater the engagement of the user and this contributes to attaining the goal of deploying the technology in entertainment, advertising, training, and simulation. The VR industry has, therefore, made great efforts to ensure that the content is more enjoyable and engaging (Shelstad et al., 2017). According to Shin and Biocca (2018), although a VR experience may involve cognitive effort, users would nonetheless be intrinsically motivated to engage in and enjoy such experiences if they find them worth their while. It is no surprise (and literature bears this out) therefore that researchers have been very interested in what factors influence the level of enjoyment an individual derives from a given experience.

For example, some researchers have suggested that the ability to move and interact naturally, rather than technological advances are key determinants of gamers' enjoyable experience (e.g., Limperos et al., 2011; McGloin et al., 2011; Pasch et al., 2009). Furthermore, McGloin and Embacher (2017) suggested that the more a video game embedded exercise technology provides realistic experiences for users, the more immersed users feel when working out, and as a result, the more they enjoy the exercise. Although several studies addressed video gaming features as antecedents to enjoyment, little research has been conducted to examine the influence of

environmental factors on video gamers' perception of enjoyment in VR gaming.

Subjective Workload

VR can impose substantial levels of cognitive demands, which may result in distraction, fatigue, frustration, and errors, as well as influence the task performance of users (Reinhardt et al., 2019). This relationship can be found in various human-computer interactions (HCI) in the work and training contexts and is why studies have examined cognitive or subjective workload. Lee et al. (2020), for example, examined the pause effect, using a computerized simulation game in emergency medicine, and found that although both cognitive workload and performance were higher in the condition with pauses than in the one without, pausing temporarily lowered cognitive load, especially during intense moments.

Although most studies on subjective workload have been conducted outside of the video gaming area, this concept is also applicable to the noneducational, entertainment video gaming setting. According to McGloin et al. (2011), gamers make a mental and physical connection between the controller interface and the virtual environment when playing a video game. Considering that VR is still new in the entertainment industry, it should be assumed that gamers would need to adjust to this new gaming environment on a cognitive level. Bouchard et al. (2018) suggested that the level of subjective workload depends on the gamer's level of expertise; those expert gamers perceived gaming as less mentally and physically challenging compared to nonexperts.

The Ecological Approach to the Influence of Environmental Factors on Perception

Another theory that supplements the S-O-R model is Gibson's (1977) theory of affordances. Based on an ecological approach to perception and action, it suggests that objects have properties that may arise from their design and hence the destination of their use, but that the user may or may not perceive these possibilities. Affordances can, therefore, be actual (based on the design) or perceived (based on how a user interprets the object's possibilities). According to Gibson (2015), affordances are consistent and always there to be perceived by individuals, directly and immediately. In his words, "the affordances of things for an observer are specified in stimulus information" (Gibson, 2015, p. 131).

Affordances have traditionally been applied in the physical world. Recent research suggests the theory of affordances can also apply in virtual environments (Regia-Corte et al., 2013). Norman (1988) conceived of the term "perceived affordances" to indicate the tendency of a user to ascribe possibilities to an object based on its design. In virtual environments, such as VR, the perception ascribed to an object's design may be real or not real, due to the perceptual confusion the user may have in interpreting the realism of the VR environment. Turchet (2015) investigated the properties of the environment and an individual's body in VR as key elements of affordances, as they relate to locomotion, using floor-foot interactions as an example. The brush of the actor's feet in shoes, heels, toes, or other body parts against the floor produces affordances, which the user may misinterpret in comparison with the actual design or reality. Thus, the theory of affordances and the findings

from these floor-haptic studies suggest that the texture of the physical floor during VR game play may affect the individual's perception of reality. The experiences of spatial presence, enjoyment, and workload of the user in VR may be influenced by the users' perception of affordances. On the other hand, the perception of affordances may in turn influence how the user experiences spatial presence, enjoyment, and workload.

Light is an example of a visual cue that can be used to suggest affordances. Light in VR can highlight or exclude objects to which the user is expected to pay attention. When it is intentionally utilized as a part of the VR experience, a lighted object grabs the attention of the user, who may then interpret its presence and use, correctly or incorrectly. In the absence of light, such objects may disappear from view. Besides lighting up focus areas of VR game play, the presence or absence of light affects the immersion of the player in the environment depending on whether it supports or causes a distraction from the main focus. In either case, this may affect perception affordance, especially when comparing the user's perception with actual reality.

In ecological optics, sensations of brightness do not constitute elements of perception, as inputs to the retina are considered sensory elements on which the brain acts when the stimuli contain information (Gibson, 2015). VR HMDs are theoretically designed to block out ambient light. The fact is though, that most of the HMDs in use are not entirely successful in doing so, instead, there is seepage of light from the outside. Based on the ecological approach, lighting external to the VR system may affect the degree to which individuals perceive spatial presence, enjoyment, and subjective workload when playing a VR game depending on their knowledge of the gaming content. More specifically, when an individual has preknowledge of the gaming content, the individual may be able to tell that the light coming from inside the VR gaming system has stimulus information while the external light does not. Thus, the individual may focus on the game to complete tasks regardless of (the distraction of the) external light and thus experience a high level of spatial presence, enjoyment, and a low level of cognitive workload. The external light may however disturb the experience of those who do not have preknowledge of the gaming content, as they may need more focus and effort to complete their VR game tasks. That is, the light from both inside and outside of the VR gaming system may be perceived as stimulus information that they must interpret. This dispersion of attention across multiple stimuli may thus result in a lower level of spatial presence, enjoyment, and a higher level of subjective workload than those who have preknowledge of the gaming content.

Sound is another critical component of VR systems as it has the potential to provide users with a realistic experience through the simulation of real-life ambient noise. André et al. (2014) examined how users estimated the distance to virtual sources in the auditory, visual, and auditory-visual modalities. In this way, they addressed an issue regarding 3D sound scenes that are spatially coherent with the visual content of a stereoscopic-3D (S-3D) movie, concluding that background noise allowed individuals to correctly match the sound from the movie with the image in motion.

Johnson and Coxon (2016) reported that the concurrent use of a VR game and supplementary sound increased the pain tolerance of a player as a result of an increased focus on the gaming experience with reduced distraction from the real world. Shin et al. (2019) also found that 3D sound enhanced a sense of social presence and positively influenced the enjoyment of a concert video. Therefore,

in this study, in-game sound is considered an internal environmental factor of a VR gaming system which helps us examine its effect on video gamers' experience.

The Role of Culture

The theory of affordances has been key in HCI and has been described as the "language" with which individuals interact with the technology environment. Affordance in HCI refers to the property of the technology artifact that communicates its purpose, a property that can be correctly or incorrectly interpreted by the user (Gibson, 2015). Individuals rely on their culture (the shared meaning about context and experiences) to make meaning (communicate with) the cues provided by the technology they are using (Gibson, 2015). Wellington (2015) thus argued that culture is an essential component of the communication dialogue between a user and technology and that the design of the gaming device is linked to how the user interprets their experience, which can be positive or negative. Along this line, we argue that the cultural experiences of the VR game player (such as whether a particular sport is traditional to them or unfamiliar) will likewise determine how they make meaning of the cues in the VR sporting game. Since the meaning they ascribe may be true or false, it may determine whether the game play is enjoyable or a cognitive burden.

Based on the review of literature, the following research questions will guide this study:

1. What is the role of environmental factors in VR gamers' perception of spatial presence, enjoyment, and cognitive workload?
2. Do individuals' VR gaming experiences vary by culture?

We further specify these research questions in the proposed seven hypotheses presented in Table 1.

Method

Participants

A total of 80 individuals (64 male; mean age = 24.45, $SD = .56$, age range 18–36; 56 students) from Southwest Nigeria ($n = 40$) and the Northeastern U.S. ($n = 40$) participated in this study (see Supplemental Material 1). According to Gough (2019), males between the ages of 21 and 35 account for the largest segment in the global video game market. Additionally, students are significant consumers of sports and sports video games (Brownlee et al., 2015). Students are also considered to be a main target market for the VR sports games and VR headsets, as more than half of the most frequent video gamers are familiar with VR and are likely to play video games in VR (Entertainment Software Association, 2017). Therefore, the study participants fit the demographics of those who play sports games using VR headsets.

Participation in the study was voluntary. Some U.S. participants participated in exchange for extra course credit. The Nigerian participants were entered for a raffle drawing where three winners received either movie tickets or shopping vouchers worth \$10 each. The study was implemented in accordance with guidelines and regulations approved by the Institutional Review Board (IRB) of each institution.

Table 1
Hypotheses of the Study

	Hypothesis
H1a	The level of spatial presence that gamers perceive will be higher when playing a VR game without the external light than with the light.
H1b	The level of enjoyment that gamers perceive will be higher when playing a VR game without the external light than with the light.
H1c	The level of subjective workload that gamers perceive will be higher when playing a VR game with the external light than without the light.
H2a	The level of spatial presence that gamers perceive will be higher when playing a VR game on a soft floor than on a hard floor.
H2b	The level of enjoyment that gamers perceive will be higher when playing a VR game on a soft floor than on a hard floor.
H2c	The level of subjective workload that gamers perceive will be higher when playing a VR game on a hard floor than on a soft floor.
H3a	The level of spatial presence that gamers perceive will be higher when playing a VR game with the in-game sound than without the in-game sound.
H3b	The level of enjoyment that gamers perceive will be higher when playing a VR game with the in-game sound than without the in-game sound.
H3c	The level of subjective workload that gamers perceive will be higher when playing a VR game without the in-game sound than with the in-game sound.
H4	There will be an interaction effect of lighting and flooring on (a) spatial presence, (b) enjoyment, and (c) subjective workload.
H5	There will be an interaction effect of lighting and in-game sound on (a) spatial presence, (b) enjoyment, and (c) subjective workload.
H6	There will be an interaction effect of flooring and in-game sound on (a) spatial presence, (b) enjoyment, and (c) subjective workload.
H7	There will be an interaction effect of lighting, flooring, and in-game sound on (a) spatial presence, (b) enjoyment, and (c) subjective workload.

Note. VR = virtual reality.

Research Design

We employed a factorial design experiment using three factors each at two levels and no midpoints: Lighting (bright: Radiant light on vs. dark: Radiant light off); flooring texture (hard: Monolithic floor vs. soft: Antifatigue mat), and sound (in-game sound on vs. in-game sound off). As seen in Table 2, the combinations of these conditions resulted in a total of eight experimental conditions. Based on this design, our factorial analysis of variance (ANOVA) was focused on identifying interactions between the factors and levels, as well as significant main effects. Study participants played an American football game called *VR Sports Challenge* using the *Oculus Rift S* VR HMD at three time points, under a different condition each time. As 10 participants were assigned to each of the eight experimental conditions each time, every participant was, therefore, exposed to three different experimental condition combinations resulting in 240 runs in total.

To avoid potential confounds, we ensured that (a) the data collection sequence was randomized using Minitab, (b) experimental conditions were consistent within each of the labs, and (c) blocking was done by randomly varying the dates between data collections (see Table 3).

At each research location, each participant was assigned a unique identifying number, ranging from 1 to 40 upon their arrival at the lab on the first day. This unique identifying number was then used to

assign them to a predetermined run order of three experimental conditions (see Table 3). As the run orders were in groups of eight, it meant that every first individual from the initial eight participants was assigned to run order number 1; the first of the next group was assigned to number 9; the first of the following group was assigned to number 17, and so on, until all 40 participants in each location were assigned. Thus, run order number 1 represented the experimental condition B during the first trial (see Figure 1), condition ABC for the second trial (see Figure 2), and condition AC for the third trial (see Figure 3). In other words, participants with run order number 1 played the VR game (a) with the light off in the lab (i.e., dark), (b) on an antifatigue mat (i.e., a soft floor), and (c) without the in-game sound for their first trial. These participants played the VR game in condition ABC for their second trial and in condition AC for their third trial.

Procedure

When recruiting participants, those who had epilepsy were excluded due to the potential health risks of VR for that category. Participants (a) had normal or corrected to normal vision, (b) wore footwear, and (c) were oblivious to the hypotheses of the study when participating in the study.

A total of 16 participants (i.e., eight from each university) were recruited from Sports Management, Engineering, and MBA programs for a pilot study. The aim of the pilot study was to determine experimental parameters and prior research considerations and to identify modifications that may be needed in the main study.

In the main study, the authors recruited the participants via in-class announcements, in-person contacts, and emails. See Supplemental Material 2 for the detailed intervention protocols. Data are not publicly available due to IRB requirements and the nature of the data directly collected from participants that include students. However, the authors are willing to share a summary of anonymized data upon request.

Measures

The assessment of VR gamers' experiences was based on examining Spatial Presence, Enjoyment, and Subjective Workload (see Table 4). The previously validated items used were adapted in the present study for the *VR Sports Challenge* context. All scale responses were based on a 7-point Likert scale (1 = *Strongly disagree*; 7 = *Strongly agree*). Spatial Presence ("the feeling of

Table 2
Factorial Design Matrix: Experiment Conditions

Experimental condition label	Experimental condition description		
	Lighting	Flooring	In-game sound
(1)	Dark	Hard	Off
A	Bright	Hard	Off
B	Dark	Soft	Off
C	Dark	Hard	On
AB	Bright	Soft	Off
AC	Bright	Hard	On
BC	Dark	Soft	On
ABC	Bright	Soft	On

Note. A total of 10 participants were in each condition above.

Table 3*Randomization Table: Run Order*

Run order	Experimental condition		
	Time 1	Time 2	Time 3
1	B	ABC	AC
2	ABC	A	AB
3	A	AC	(1)
4	AB	(1)	BC
5	BC	AB	A
6	C	BC	B
7	(1)	C	C
8	AC	B	ABC

Note. A total of 10 participants were in each condition above.

physical immersion within a virtual environment,” McGloin et al., 2011, p. 312) of the VR video game was measured with 13 items adapted from McGloin et al. (2011) and Skalski et al. (2011, $\alpha = .86$). Enjoyment (“the extent to which the activity of playing a VR sport video game is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated.” Davis et al., 1992, p. 1113) was measured with three items adapted from Davis et al. (1992, $\alpha = .89$). Subjective Workload of participants was assessed with the National Aeronautics and Space Administration (NASA) Task Load Index (Hart, 1986) which consists of six items ($\alpha = .78$). Descriptive statistics are provided in Tables 5 and 6.

Results

Using JASP, a factorial ANOVA was conducted to determine: (a) the main effects of the three environmental variables of lighting, flooring, and in-game sound at two different levels apiece, on Spatial

Figure 1*Experiment Condition B* **Figure 2***Experiment Condition ABC*

Presence, Enjoyment, and Subjective Workload and (b) the interaction effects of these environmental factors on the response variables.

Main Effects of Lighting

Nigerian Sample

Day 1. A main effect of lighting on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the Nigerian participants on Day 1 (see Table 7).

Day 2. A main effect of lighting was significant on Subjective Workload for the Nigerian participants on Day 2, $F(1, 38) = 5.71$,

Figure 3*Experiment Condition AC*

Table 4
Measured Response Variables and Survey Items

Variable	Item
Spatial presence ($\alpha = .86$)	1. How much did it seem as if you could reach out and touch the objects you saw/heard?
	2. To what extent did you experience a sense of “being there” inside the environment you saw/heard?
	3. To what extent did it seem that sounds came from specific, different locations?
	4. How often did you want to or try to touch something you saw/heard?
	5. Did the experience seem more like looking at the objects on a movie screen or more like looking at the objects through a window?
	6. How often did you make a sound out loud (e.g., laugh, speak) in response to someone you saw/heard in the video game environment?
	7. How often did you smile in response to someone you saw/heard in the game environment?
	8. How often did you want to or speak to a person you saw/heard in the game environment?
	9. To what extent did you feel mentally immersed in the experience?
	10. How involving was the video game play experience?
	11. How completely were your senses engaged?
	12. To what extent did you experience a sensation of reality?
	13. How relaxing or exciting was the experience?
Enjoyment ($\alpha = .89$)	1. I found playing this football game to be enjoyable.
	2. The actual process of playing this football game was pleasant.
	3. I had fun playing this football game.
Subjective workload ($\alpha = .78$)	1. How mentally demanding was the task?
	2. How physically demanding was the task?
	3. How hurried or rushed was the pace of the task?
	4. How successful were you in accomplishing what you were asked to do? ^a
	5. How hard did you have to work to accomplish your level of performance?
	6. How insecure, discouraged, irritated, stressed, and annoyed were you?

^a Subjective Workload item 4 was removed for data analysis due to its low correlation with other items.

$p < .05$, $\eta^2 = .11$. Post hoc analysis showed a negative relationship, such that playing the VR game with the light on ($M = 3.79$, $SD = .97$) significantly decreased Subjective Workload compared to playing the game with the light off ($M = 4.62$, $SD = 1.12$) for the Nigerian sample (see Table 8 and Figure 4). However, a main effect of lighting did not have a significant effect on Spatial Presence nor on Enjoyment on Day 2.

Day 3. A main effect of lighting on Subjective Workload was significant for the Nigerian participants, $F(1, 38) = 4.47$, $p < .05$, $\eta^2 = .11$. Post hoc analysis showed a negative relationship, such that playing the VR game with the light on ($M = 4.21$, $SD = 1.02$) significantly decreased Subjective Workload compared to playing

the game with the light off ($M = 4.89$, $SD = 1.01$, see Table 8 and Figure 5). However, a main effect of lighting on Spatial Presence nor on Enjoyment was not significant for the Nigerian sample on Day 3.

U.S. Sample

A main effect of lighting on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the U.S. participants on Day 1, Day 2, and Day 3 (see Supplemental Material 3).

Main Effects of Flooring

Nigerian Sample

Day 1. A main effect of flooring on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the Nigerian sample on Day 1 (see Table 9).

Day 2. A main effect of flooring was significant on Subjective Workload for the Nigerian sample on Day 2, $F(1, 38) = 7.36$, $p < .05$, $\eta^2 = .14$. More specifically, as presented in Table 10, post hoc analysis showed a positive relationship such that playing the VR game on a hard floor ($M = 4.67$, $SD = 1.30$) significantly increased Subjective Workload compared to playing the game on a soft floor ($M = 3.74$, $SD = 1.03$) for the Nigerian participants (see Figure 6). However, a main effect of flooring did not have a significant effect on Spatial Presence nor on Enjoyment on Day 2.

Day 3. A main effect of flooring on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the Nigerian participants on Day 3.

U.S. Sample

Day 1. A main effect of flooring on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the U.S. samples on Day 1 (see Table 11).

Day 2. As illustrated in Table 11, a main effect of flooring was significant on Subjective Workload for the U.S. participants on Day 2, $F(1, 38) = 5.23$, $p < .05$, $\eta^2 = .12$. More specifically, post hoc analysis showed that playing the VR game on a hard floor ($M = 2.99$, $SD = .94$) significantly decreased Subjective Workload compared to playing the game on a soft floor ($M = 3.73$, $SD = 1.10$) for the U.S. participants (see Table 12 and Figure 7).

Table 5
Means and Standard Deviations of Spatial Presence, Enjoyment, and Subjective Workload (Nigerian Sample)

Experimental condition	Spatial presence		Enjoyment		Subjective workload	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
(1)	5.54	.85	6.11	.80	4.72	1.04
A	5.02	1.11	5.49	1.51	4.09	.98
B	5.42	.63	5.76	.86	4.35	.89
C	5.54	.95	6.19	.92	4.27	1.28
AB	5.42	1.22	6.00	1.52	4.03	.95
AC	4.87	1.27	5.71	1.38	4.20	1.31
BC	5.61	.87	5.91	.95	3.45	1.11
ABC	5.60	.82	6.00	.69	5.31	.71

Note. $n = 15$ in each condition.

Table 6

Means and Standard Deviations of Spatial Presence, Enjoyment, and Subjective Workload (U.S. Sample)

Experimental condition	Spatial presence		Enjoyment		Subjective workload	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
(1)	4.83	.82	6.85	.42	3.11	.82
A	4.63	1.11	6.67	.58	3.13	1.08
B	4.52	1.07	6.69	.90	2.99	1.24
C	5.08	.77	6.49	.71	3.60	1.40
AB	5.49	.60	6.73	.69	3.51	1.18
AC	4.88	1.02	6.42	1.04	3.57	1.00
BC	5.35	.95	6.33	1.50	3.55	1.11
ABC	5.45	.93	6.16	1.05	3.31	.88

Note. $n = 15$ in each condition.

Day 3. A main effect of flooring on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the U.S. samples on Day 3.

Main Effects of In-Game Sound

Nigerian Sample

Day 1 and Day 2. A main effect of in-game sound on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the Nigerian sample on Day 1 and Day 2 (see Table 13).

Day 3. A main effect of in-game sound was significant on Spatial Presence for the Nigerian participants on Day 3, $F(1, 38) = 5.93$, $p < .05$, $\eta^2 = .14$. More specifically, post hoc comparisons using the Tukey test indicated that the level of Spatial Presence that participants perceived significantly decreased when the in-game sound was off ($M = 5.04$, $SD = 1.09$) compared with having the game sound ($M = 5.85$, $SD = 1.03$) while playing the VR sports game (see Table 14 and Figure 8).

A main effect of in-game sound was also significant on Subjective Workload for the Nigerian participants on Day 3, $F(1, 38) = 5.42$, $p < .05$, $\eta^2 = .13$. Post hoc comparisons indicated that the level of Subjective Workload that participants perceived significantly

Table 7

Main Effects of Light: Means, Standard Deviations, and Factorial ANOVA in Spatial Presence, Enjoyment, and Subjective Workload (Nigerian Sample)

Measure	Time	Bright		Dark		<i>F</i>	η^2
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Spatial presence	Day 1	5.38	.99	5.35	.87	.01	.00
	Day 2	5.33	.95	5.31	.96	.00	.00
	Day 3	5.35	1.10	5.55	1.16	.32	.01
Enjoyment	Day 1	5.87	1.50	5.52	1.26	.43	.00
	Day 2	5.93	1.05	6.13	.75	.50	.00
	Day 3	5.77	1.18	6.15	.73	.23	.04
Workload	Day 1	4.55	.97	4.42	1.05	.69	.00
	Day 2	3.79	.97	4.62	1.22	5.71	.11*
	Day 3	4.21	1.02	4.89	1.01	4.47	.11*

Note. $n = 20$ in each condition.

* $p < .05$.

Table 8

ANOVA Post Hoc Result: Main Effect of Light (Nigerian Sample)

Day	Dependent variable	Group	Comparison	Mean difference	<i>SE</i>
2	Subjective workload	Bright	Dark	-.83*	.35
3				-.68*	.32

Note. ANOVA = analysis of variance.

* $p < .05$.

decreased when the in-game sound was off ($M = 4.18$, $SD = .96$) compared with having the game sound ($M = 4.92$, $SD = 1.05$) while playing the VR sports game (see Table 14 and Figure 9). However, a main effect of in-game sound on Enjoyment was not significant for the Nigerian sample on Day 3.

U.S. Sample

Day 1. A main effect of in-game sound on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the U.S. participants on Day 1 (see Table 15).

Day 2. As presented in Table 15, a main effect of in-game sound was significant on Spatial Presence for the U.S. participants on Day 2, $F(1, 38) = 4.28$, $p < .05$, $\eta^2 = .10$. More specifically, post hoc comparisons indicated that the level of Spatial Presence that participants perceived significantly decreased when the in-game sound was off ($M = 4.68$, $SD = .96$) compared with having the game sound on ($M = 5.27$, $SD = .85$) while playing the VR sports game (see Table 16 and Figure 10). However, a main effect of in-game sound on Enjoyment and Subjective Workload was not significant for the U.S. participants on Day 2.

Day 3. A main effect of in-game sound was significant on Spatial Presence for the U.S. sample on Day 3, $F(1, 38) = 14.99$, $p < .001$, $\eta^2 = .28$. More specifically, post hoc comparisons using the Tukey test indicated that the level of Spatial Presence that the U.S. participants perceived significantly decreased when the in-game sound was off ($M = 4.27$, $SD = 1.11$) compared with having the

Figure 4

Main Effect of Light on Subjective Workload: Nigerian Sample (Day 2)

Figure 5

Main Effect of Light on Subjective Workload: Nigerian Sample (Day 3)

game sound on ($M = 5.42$, $SD = .74$) while playing the VR sports game (see Table 16 and Figure 11). However, a main effect of in-game sound on Enjoyment and Subjective Workload was not significant for the U.S. participants on Day 3.

Interaction Effects of Lighting and Flooring

Nigerian Sample

Day 1. As presented in Table 17, an interaction effect of lighting and flooring on Subjective Workload was significant for the Nigerian participants on Day 1, $F(1, 36) = 4.74$, $p < .05$, $\eta^2 = .12$. Specifically, as illustrated in Figure 12, the Nigerian participants perceived a higher level of Subjective Workload when they played the VR game (a) on a hard floor with the light off ($M = 4.84$, $SD = .63$) than on the hard floor with the light on ($M = 4.30$, $SD = .55$), and (b) on a soft floor with the light on ($M = 4.80$, $SD = 1.24$) than the soft floor with the light off ($M = 4.00$, $SD = 1.25$). However, an interaction effect of lighting and flooring on Spatial Presence and

Table 9

Main Effects of Flooring: Means, Standard Deviations, and Factorial ANOVA in Spatial Presence, Enjoyment, and Subjective Workload (Nigerian Sample)

Measure	Time	Hard		Soft		<i>F</i>	η^2
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Spatial presence	Day 1	5.25	1.03	5.48	.81	.64	.00
	Day 2	5.42	.85	5.22	1.04	.48	.00
	Day 3	5.51	1.18	5.38	1.09	.14	.00
Enjoyment	Day 1	5.53	1.49	5.85	1.28	.52	.00
	Day 2	6.23	.87	5.82	.92	2.05	.03
	Day 3	5.93	1.07	5.98	.92	.02	.00
Workload	Day 1	4.57	.64	4.40	1.28	.28	.00
	Day 2	4.67	1.13	3.74	1.03	7.36	.14*
	Day 3	4.37	1.30	4.73	.75	1.16	.03

Note. $n = 20$ in each condition. ANOVA = analysis of variance.

* $p < .05$.

Table 10

ANOVA Post Hoc Result: Main Effect of Flooring (Nigerian Sample)

Day	Dependent variable	Group	Comparison	Mean difference	<i>SE</i>
2	Subjective workload	Hard	Soft	.93**	.34

Note. ANOVA = analysis of variance.

** $p < .01$.

Enjoyment was not significant for the Nigerian participants on Day 1.

Day 2. An interaction effect of lighting and flooring on Subjective Workload was significant for the Nigerian participants on Day 2, $F(1, 36) = 4.30$, $p < .05$, $\eta^2 = .08$. As illustrated in Table 18, post hoc comparisons using the Tukey test revealed that the level of Subjective Workload that the Nigerian participants perceived was significantly higher when playing the VR game on a hard floor and with the light off ($M = 5.40$, $SD = .53$) than on (a) a hard floor and with the light on ($M = 3.94$, $SD = 1.10$), (b) on a soft floor with the light on ($M = 3.64$, $SD = .52$), and (c) on a soft floor with the light off ($M = 3.84$, $SD = 1.23$) while playing the VR sports game (see Figure 13). However, an interaction effect of lighting and flooring on Spatial Presence and Enjoyment was not significant for the Nigerian participants on Day 2.

Day 3. An interaction effect of lighting and flooring on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the Nigerian participants on Day 3.

U.S. Sample

An interaction effect of lighting and flooring on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the U.S. participants on Day 1, Day 2, and Day 3 (see Supplemental Material 4).

Figure 6

Main Effect of Flooring on Subjective Workload: Nigerian Sample (Day 2)

Table 11

Main Effects of Flooring: Means, Standard Deviations, and Factorial ANOVA in Spatial Presence, Enjoyment, and Subjective Workload (U.S. Sample)

Measure	Time	Hard		Soft		F	η^2
		M	SD	M	SD		
Spatial presence	Day 1	5.18	.91	5.36	.66	.47	.00
	Day 2	5.01	.98	4.94	.93	.06	.00
	Day 3	5.10	.98	4.58	1.18	2.28	.06
Enjoyment	Day 1	6.55	.86	6.63	.60	.13	.00
	Day 2	6.63	.62	6.35	1.43	.66	.00
	Day 3	6.62	.79	6.47	1.02	.27	.01
Workload	Day 1	3.15	.87	3.09	1.01	.04	.00
	Day 2	2.99	.94	3.73	1.10	5.23	.12*
	Day 3	3.65	1.07	3.46	1.40	.23	.01

Note. $n = 20$ in each condition. ANOVA = analysis of variance.

* $p < .05$.

Interaction Effects of Lighting and In-Game Sound

An interaction effect of lighting and in-game sound on Spatial Presence, Enjoyment, and Subjective Workload was not significant for both Nigerian (see Supplemental Material 5) and U.S. participants (see Supplemental Material 6) on Day 1, Day 2, and Day 3.

Interaction Effects of Flooring and In-Game Sound

An interaction effect of flooring and in-game sound on Spatial Presence, Enjoyment, and Subjective Workload was not significant for both Nigerian (see Supplemental Material 7) and U.S. participants (see Supplemental Material 8) on Day 1, Day 2, and Day 3.

Interaction Effects of Lighting, Flooring, and In-Game Sound

Nigerian Sample

Day 1 and Day 2. An interaction effect of lighting, flooring, and in-game sound on Spatial Presence, Enjoyment, and Subjective Workload was not significant for the Nigerian participants on Day 1 and Day 2 (see Tables 19 and 20).

Day 3. An interaction effect of lighting, flooring, and in-game sound on Enjoyment was significant for the Nigerian participants on Day 3, $F(1, 32) = 5.08$, $p < .05$, $\eta^2 = .12$. More specifically, as illustrated in Figure 14, they perceived a higher level of Enjoyment when they played the VR game on a soft floor with the light on and with the game sound off ($M = 6.20$, $SD = .77$) than on the soft floor with the light off and with the game sound off ($M = 5.60$,

Table 12

ANOVA Post Hoc Result: Main Effect of Flooring (U.S. Sample)

Day	Dependent variable	Group	Comparison	Mean difference	SE
2	Subjective workload	Hard	Soft	-.74*	.32

* $p < .05$.

Figure 7

Main Effect of Flooring on Subjective Workload: U.S. Sample (Day 2)

$SD = 1.07$). The Nigerian participants also reported a higher level of Enjoyment when they played the VR game on a hard floor with the light off and with the game sound off ($M = 6.33$, $SD = .62$) than on the hard floor with the light on and with the game sound off ($M = 5.00$, $SD = 1.58$).

Additionally, Figure 15 illustrates that the Nigerian participants enjoyed the VR game more when they played the game on a soft floor with the light off and with the game sound on ($M = 6.47$, $SD = .51$) than on the soft floor with the light on and with the game sound on ($M = 5.67$, $SD = 1.18$), while the level of Enjoyment was not different when they played the VR game on a hard floor with the light off and with the game sound on ($M = 6.20$, $SD = .45$) and on the hard floor with the light on and with the game sound on ($M = 6.20$, $SD = .96$).

U.S. Sample

An interaction effect of lighting, flooring, and in-game sound on Spatial Presence, Enjoyment, and Subjective Workload was not

Table 13

Main Effects of In-Game Sound: Means, Standard Deviations, and Factorial ANOVA in Spatial Presence, Enjoyment, and Subjective Workload (Nigerian Sample)

Measure	Time	Sound on		Sound off		F	η^2
		M	SD	M	SD		
Spatial presence	Day 1	5.34	1.02	5.39	.83	.03	.00
	Day 2	5.43	.76	5.21	1.11	.53	.00
	Day 3	5.85	1.03	5.04	1.09	5.93	.14*
Enjoyment	Day 1	5.78	1.48	5.60	1.30	.17	.00
	Day 2	6.16	.62	5.92	1.11	.69	.00
	Day 3	6.13	.82	5.78	1.13	1.26	.03
Workload	Day 1	4.51	.98	4.46	1.05	.02	.00
	Day 2	4.03	1.12	4.38	1.21	.89	.00
	Day 3	4.92	1.05	4.18	.96	5.42	.13*

Note. $n = 20$ in each condition. ANOVA = analysis of variance.

* $p < .05$.

Table 14

ANOVA Post Hoc Result: Main Effect of In-Game Sound (Nigerian Sample)

Day	Dependent variable	Group	Comparison	Mean difference	SE
3	Spatial presence	Sound off	Sound on	-.81*	.33
3	Subjective workload	Sound off	Sound on	-.74*	.32

Note. ANOVA = analysis of variance.

* $p < .05$.

significant for the U.S. participants on Day 1, Day 2, and Day 3 (see Supplemental Material 9).

Discussion

Factors internal and external to the VR game influence the degree of immersion and presence of the player. They include the quality of graphics rendering, realism of the gaming environment, and objects and the level of interactivity of the experience. Shin (2018) suggested that users play an active agency role in the type, quantity, and quality of their affective and cognitive experiences within VR and that the embedded technological properties of VR have little influence on users' immersive experience. Kim and Ko (2019) added, however, that context also determines a VR user's level of engagement and satisfaction. The relative novelty of VR means that there is a limited understanding of the factors that affect the user's experience. This study set out to identify and evaluate the influence of certain environmental factors on the VR gaming experiences of perceived spatial presence, enjoyment, and subjective workload.

We focused on VR sports gaming because of the increasing use of VR for sports viewing, for training, as well as to foster fan affinity for a sport (Miah et al., 2020). Whether users enjoy an experience or not will influence the rate and extent of adoption of a particular technology as well as its continuous use, by individuals, by sport organizations, or by advertisers who would consider VR as a marketing platform. An improved understanding of the interplay

Figure 8

Main Effect of In-Game Sound on Spatial Presence: Nigerian Sample (Day 3)

Figure 9

Main Effect of In-Game Sound on Subjective Workload: Nigerian Sample (Day 3)

between these internal and external, individual and environmental factors, and how they influence presence would have theoretical and practical consequences for VR usage.

The Main Effect of Lighting on Subjective Workload

The finding within the Nigerian sample that playing the VR game in the lights off condition increased subjective workload on Day 2 and Day 3 is supported by previous research (e.g., Pomplun & Sunkara, 2003). The absence of radiant light contributes to shutting out external distractions and may increase and channel the player's focus inwards toward the VR environment, contributing to the experience of realism. Faced with an unfamiliar game (American football to the Nigerian participants), an increase in realism may demand more attention and focus from the player to perform expected tasks, thus resulting in an increased cognitive load. Our finding here is also supported by Bouchard et al.'s (2018) suggestion that cognitive workload may depend on the expertise of the game player. Their lack of expertise in a novel sport and using a novel technology further explains the increased workload they experience, as they struggle to fulfill assigned in-game tasks.

Lighting had no effect on the cognitive workload of the American participants. This is likely because the U.S. participants were familiar with American football and found it easy to follow the game irrespective of the lighting condition. Light as an ambient factor was therefore not strong enough to cause any disturbance nor induce strain.

The Main Effect of Flooring on Subjective Workload

The main effect of flooring on subjective workload for the Nigerian and U.S. participants on Day 2 was in opposite directions. The Nigerian participants perceived a higher level of subjective workload when playing the VR game on a hard floor than on a soft floor (i.e., while stepping on the antifatigue mat). Conversely, the U.S. participants perceived a lower level of subjective workload when playing the VR game on the hard floor than on the soft floor.

The experience of the Nigerian players can be explained by Witmer and Singer (1998) finding that any factor that isolates the user from the physical environment would increase their experience

Table 15

Main Effects of In-Game Sound: Means, Standard Deviations, and Factorial ANOVA in Spatial Presence, Enjoyment, and Subjective Workload (U.S. Sample)

Measure	Time	Sound on		Sound off		F	η^2
		M	SD	M	SD		
Spatial presence	Day 1	5.34	.89	5.20	.69	.29	.00
	Day 2	5.27	.85	4.68	.96	4.28	.10*
	Day 3	5.42	.74	4.27	1.11	14.99	.28***
Enjoyment	Day 1	6.43	.92	6.75	.46	1.91	.02
	Day 2	6.35	1.31	6.63	.85	.66	.00
	Day 3	6.50	.88	6.58	.94	.08	.00
Workload	Day 1	3.33	1.10	2.91	.69	2.09	.03
	Day 2	3.22	1.05	3.50	1.11	.70	.00
	Day 3	3.92	1.17	3.19	1.22	3.74	.06

Note. $n = 20$ in each condition. ANOVA = analysis of variance.

* $p < .05$. *** $p < .001$.

of immersion and presence. A greater immersion is likely to mean a greater involvement in the in-game activity, with the engagement of more cognitive resources. The Nigerian participants played an unfamiliar sport in a new medium and on a hard floor. The unfamiliarity with the sport and medium imposes a cognitive load, while the hard floor is a distraction that hinders their isolation from the virtual world, making immersion even more difficult to achieve. This creates tension between the goals of the *VR Sports Challenge*, their inexperience with both the sport and the medium, and the floor texture. The result would be increased cognitive load.

Even though the hard floor hinders the isolation of the American participants from the physical environment, their familiarity with the sport may be sufficient such that they are still able to achieve the level of immersion and presence needed to accomplish the VR task. There is thus less cognitive demand and hence subjective workload on them.

The Main Effect of In-Game Sound on Spatial Presence and Subjective Workload

Presence is crucial to the feeling of really “being” in an environment. In a virtual environment, this would be a perception of a near-total detachment from the physical environment as to consider VR to be for the present moment the main reality: The notion of non-mediation (Lombard & Ditton, 1997). We observed significant positive relationships between in-game sound and players’ perception of spatial presence for the Nigerian participants on Day 3 and

Table 16

ANOVA Post Hoc Result: Main Effect of In-Game Sound (U.S. Sample)

Day	Dependent variable	Group	Comparison	Mean difference	SE
2	Spatial presence	Sound off	Sound on	-.59*	.29
3			Sound on	-1.15***	.30

Note. ANOVA = analysis of variance.

* $p < .05$. *** $p < .001$.

Figure 10

Main Effect of In-Game Sound on Spatial Presence: U.S. Sample (Day 2)

for the U.S. participants on Day 2 and Day 3 and a negative relationship between in-game sound and players’ perception of subjective workload for the Nigerian participants on Day 3.

Sounds in games may either be a part of the game play, such as those produced by player characters, avatars, or the player themselves (spoken words, objects falling, etc.) (McArthur et al., 2017). This is referred to as diegetic sound. Nondiegetic sound, on the other hand, is not heard by the in-game characters, but introduced by the game designers as part of the story-telling cues, to add drama, or to evoke certain emotions (McArthur et al., 2017). According to our findings, both diegetic and nondiegetic sounds are heard by the game player and contribute to the feeling of immersion and sense of spatial presence. Research has shown that in movies, this can affect the viewer’s interpretation of the reality in the scene (Tan et al., 2017). We make the same arguments for VR, that both Diegetic and non-Diegetic sounds increase the depth of sensory information available to the auditory perceptual channel which in turn may result in a greater level of vividness and ultimately “presence.” This finding agrees with Pettet et al. (2010) who argued that aural effects contribute to a greater experience of “telepresence.”

Figure 11

Main Effect of In-Game Sound on Spatial Presence: U.S. Sample (Day 3)

Table 17

Interaction Effects of Light and Flooring: Means, Standard Deviations, and Factorial ANOVA in Spatial Presence, Enjoyment, and Subjective Workload (Nigerian Sample)

Measure	Bright & hard		Bright & soft		Dark & hard		Dark & soft		F	η^2
	M	SD	M	SD	M	SD	M	SD		
Spatial presence										
Day 1	5.21	1.21	5.54	.74	5.28	.87	5.42	.91	.11	.00
Day 2	5.19	1.05	5.46	.87	5.65	.55	4.97	1.18	2.58	.04
Day 3	5.26	1.35	5.43	.86	5.76	.98	5.33	1.34	.68	.00
Enjoyment										
Day 1	5.53	1.97	6.20	.79	5.53	.89	5.50	1.60	.63	.00
Day 2	6.10	1.14	5.74	.97	6.37	.48	5.90	.92	.04	.00
Day 3	5.60	1.39	5.93	.87	6.27	.52	6.03	.91	.81	.00
Workload										
Day 1	4.30	.55	4.80	1.24	4.84	.63	4.00	1.25	4.74	.12*
Day 2	3.94	1.10	3.64	.85	5.40	.53	3.84	1.23	4.30	.08*
Day 3	3.94	1.14	4.48	.86	4.80	1.35	4.98	.57	.31	.00

Note. $n = 10$ in each condition. ANOVA = analysis of variance.

* $p < .05$.

This finding was, however, significant in the U.S. sample on Days 2 and 3, but only on Day 3 in the Nigerian sample. On Day 3, the Nigerian cohort reported that they had a more immersive but also a more mentally and physically demanding experience when playing the VR game with the gaming sound on than with the gaming sound off. We surmise that as the U.S. participants were more familiar with American football, they were therefore used to and expecting the in-game sounds, which includes the shouts and calls from other team members within the game, commands from the referee or coach, as well as clamor from the audience in the virtual stadium. Previous experience connected to the actual sport may have prepared them for the exact cues that these sounds signify. They would thus be more immersed in the game. The Nigerian participants, on the other hand, for whom American football was mostly unfamiliar, would have missed most of the meanings from the in-game sound (and thus, for all practical purposes, most of the sounds could be considered noise).

Figure 12

Interaction Effect of Light and Flooring on Subjective Workload: Nigerian Sample (Day 1)

The Interaction Effect of Lighting and Flooring on Subjective Workload

We found a significant interaction effect between lighting and flooring on subjective workload for the Nigerian participants on Day 1 and Day 2. As discussed in the main effect of light, it is possible that flooring texture affected the players' sense of isolation, workload, and distraction when playing the VR game. Furthermore, while the radiant light in the "off" state may contribute to increased realism and immersion because it blocks outside non-VR stimuli, the absence of the cushioning effect of the antifatigue mat on the feet (hard floor) may present an alternate, external reality to the user, which contrasts and competes with the VR. The cognitive load theory (Sweller et al., 1998) also suggests that an increase in extraneous cognitive load has a detrimental effect on working memory. This contrast with the desired focus on the in-game experience, along with the user's repeated effort to split attention between the distracting environment and the tasks within the virtual environment may result in increased perceived stress and an increased cognitive workload.

The interaction between lighting and flooring did not, however, have any effect on the cognitive workload of the American participants. This difference in sample response may be attributed to the increased familiarity of the U.S. participants with the sport, whereby there is less cognitive processing of the VR activity and hence less stress.

Interaction Effect of Lighting, Flooring, and In-Game Sound on Enjoyment

We found an interaction effect of lighting, flooring, and in-game sound on enjoyment for the Nigerian sample on Day 3. It is noticeable that both internal (in-game sound) and external (lighting and flooring) factors played a significant role altogether in influencing the level of perceived enjoyment for the Nigerian participants. Although these factors did not seem to individually affect Nigerian participants' level of enjoyment, a collective influence of these factors cannot be overlooked in their gameplay experience. This finding suggests that the earlier findings of the influence of these environmental factors on the Nigerian participants' sense of subjective workload, may not necessarily equate with a negative gameplay experience. It would instead seem that they were able to overcome the dual learning challenges (familiarity with the technology and with the sport) and despite the impact of the environmental factors, were eventually able to enjoy the game.

The interaction between the three factors of lighting, flooring, and sound, however, had no significant effect on the outcome variables for the U.S. participants. One likely reason is that the factors either counteracted one another's effects or there are other (yet unknown) confounding variables at play. Some of these may include individual factors such as personality traits or other psychosocial variables.

Theoretical and Practical Implications

The present study makes useful contributions to VR theory and practice. Two of the most important adjectives used to describe HMD based VR are "immersive" and "interactive," both of which imply and assume the perception of full "presence" in the virtual environment. The more immersed and involved one is, the more the

Table 18*ANOVA Post Hoc Results: Interaction Effect of Light and Flooring (Nigerian Sample)*

Day	Dependent variable	Group	Comparison	Mean difference	SE
1	Workload	Bright, hard	Dark, hard	-.54	.44
			Bright, soft	-.50	.44
			Dark, soft	.30	.44
		Dark, hard	Bright, soft	.04	.44
			Dark, soft	.84	.44
			Dark, soft	.80	.44
2	Workload	Bright, soft	Dark, soft	-1.47**	.43
		Bright, hard	Dark, hard	1.76**	.43
		Dark, hard	Bright, soft	1.56**	.43
			Dark, soft		

Note. ANOVA = analysis of variance.

** $p < .01$.

interaction with in-game features, avatars, and tasks. Realistic sound effects provide gamers with a successful immersive VR experience, as they enhance the depth of their experience. This is particularly so for those who have knowledge and experience of American football in the real world, as they would have expectations from their real-life experience. In-game sound is an immediate environmental factor for gamers. This study demonstrates and confirms that in-game sound is a prominent stimulus that prompts gamers' immersive and interactive experience. The closer the expectations from real-life match the VR experience, the greater the realism and the more immersed players are. Hence VR application developers need to prioritize the realism of VR experiences.

The experience of sound is crucial to a good VR experience. It provides information about the nature of the action and its location as well as draws the attention of the user to key events in the VR scene. Our findings provide justification for the recent increased efforts in the VR industry to improve spatial and binaural sounds as a key component of VR. More specialized devices are being produced that provide an almost 360-degree depiction of sound.

Different findings, depending on the cultural context, highlight the importance of individual agency, background, knowledge, and perception, on the distress experienced during VR use. As shown by the Nigerian results, the absence of external light increased their

perception of subjective workload. The Nigerian participants' limited experience of American football required a high level of attention when playing the game. Although they received instructions for playing the VR game, the level of their understanding of the sport was minimal. Therefore, a game play that required body movement and locomotion while perceiving darkness in the lab may have imposed substantial stress on the participants as they worked to complete game tasks. This finding extends the applicability of the ecological approach to visual perception (Gibson, 2015), as it indicates that both internal and external light information of the VR gaming system may be perceived as stimulus information to those who lack preknowledge of the game.

Individuals will experience VR differently depending on factors internal to them, internal to the game, or in the external environment. This should influence considerations in setting up VR rooms in homes, VR labs, or other locations where VR may be used in learning or entertainment. It should also provide some guidance to manufacturers of HMDs who want to ensure that their equipment contributes to a more immersive experience. Our findings should also suggest to VR app or game designers' optimal ways to use diegetic and nondiegetic sound to manipulate emotion, provide feedback or communicate with the VR user.

Although most VR "actions" come in through the HMD, the texture of the play area floor affects gamers' experience, in particular their perception of subjective workload. A hard floor imposed a higher level of physical and mental exertion than a soft floor to the Nigerian participants, while a soft floor imposed a greater physical and mental exertion to the U.S. cohort, than a soft floor. Therefore, VR sports game developers and their partnering sport organizations could advise their customers and game users (unfamiliar with the sports or game) to play the game on a floor, made of a shock-absorbing material, for a sense of comfort and safety. However, as their learning curve flattens out, the nature of the flooring material may become less relevant to their gaming experience. At that point, playing on a hard floor may even contribute an additional, healthy challenge during VR game play.

Limitations and Future Research

We collected cross-sectional data from two different demographic regions. The factorial and random design of our experiment compensated for this, however, and we do not believe that the cross-sectional design compromised our findings. Nevertheless, considering the often-opposing findings from the different sample

Figure 13

Interaction Effect of Light and Flooring on Subjective Workload: Nigerian Sample (Day 2)

Table 19

Interaction Effect of Lighting, Flooring, and In-Game Sound: Means, Standard Deviations, and Factorial ANOVA in Spatial Presence, Enjoyment, and Subjective Workload (Nigerian Sample)

Group	Spatial presence			Enjoyment			Workload		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Bright, hard, no sound									
<i>M</i>	5.14	5.17	4.76	5.60	5.87	5.00	4.24	4.31	3.72
<i>SD</i>	1.25	1.06	1.23	1.52	1.63	1.58	.73	1.15	1.12
Bright, hard, sound									
<i>M</i>	5.28	5.22	5.77	5.47	6.33	6.20	4.36	3.56	4.16
<i>SD</i>	1.04	1.16	1.39	2.53	.41	.96	.39	1.01	1.25
Bright, soft, no sound									
<i>M</i>	5.52	5.22	5.51	5.80	5.27	6.20	4.64	4.00	4.40
<i>SD</i>	.63	.76	.59	.84	.86	.77	1.20	.83	.51
Bright, soft, sound									
<i>M</i>	5.56	5.72	5.35	6.60	6.33	5.67	4.96	3.28	4.56
<i>SD</i>	.91	.98	1.14	.55	.82	1.18	1.34	.80	1.17
Dark, hard, no sound									
<i>M</i>	5.48	5.80	5.34	5.47	6.53	6.33	4.92	5.40	3.84
<i>SD</i>	.53	.76	1.23	.90	.51	.62	.36	.66	1.28
Dark, hard, sound									
<i>M</i>	5.09	5.51	6.19	5.60	6.20	6.20	4.76	5.40	5.76
<i>SD</i>	1.16	.23	.45	.98	.45	.45	.87	.45	.41
Dark, soft, no sound									
<i>M</i>	5.41	4.66	4.55	5.53	6.00	5.60	4.04	3.80	4.76
<i>SD</i>	.85	1.66	1.20	2.04	1.11	1.07	1.54	1.62	.59
Dark, soft, sound									
<i>M</i>	5.43	5.28	6.11	5.47	5.80	6.47	3.96	3.88	5.20
<i>SD</i>	.98	.39	1.03	1.26	.80	.51	1.05	.88	.51
<i>F</i>	.17	.14	1.89	.38	.16	5.08	.01	.01	1.05
η^2	.00	.00	.05	.00	.00	.12*	.00	.00	.02

Note. $n = 5$ in each condition. ANOVA = analysis of variance.

* $p < .05$.

contexts (the U.S. and Nigeria), it would be interesting to see if a longitudinal design would show within-country consistency or confirm the variability. A further limitation might be the relative

unfamiliarity of the Nigerian cohort with American football. This may also account for the results which in some cases, differed from the U.S. sample. This lack of experience with the sport by the

Table 20

Hypotheses Test Results

Hypothesis	Nigeria			U.S.		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
H1a						
H1b						
H1c		Not supported	Not supported			
H2a						
H2b						
H2c		Supported			Not supported	
H3a			Supported		Supported	
H3b						Supported
H3c			Not supported			
H4a						
H4b						
H4c	Supported	Supported				
H5a						
H5b						
H5c						
H6a						
H6b						
H6c						
H7a						
H7b			Supported			
H7c						

Figure 14

Interaction Effect of Light, Flooring, and In-Game Sound on Enjoyment—In-Game Sound Off: Nigerian Sample (Day 3)

Nigerian cohort is clearly a confounder that makes it unclear if the observed effects would have been different had they played a simulation of a sport they were familiar with, such as soccer.

Other issues worth considering include the fact that the participants took part in the experiments where external noises were controlled, and in-game sound was found as a factor influencing their VR gaming experience. However, VR gamers are likely to be surrounded by outside sounds (i.e., background noise) coming from various sources, such as TV, phones, people, etc., while playing a VR game. While this factor was not covered in this study, these outside sounds may also hinder or enhance their gaming experience. Therefore, future studies are advised to also consider external sounds when investigating its role in VR gaming experiences. Additionally, despite the cautionary measures taken in our experimental design, there still exists a certain measure of uncertainty about the effect that lighting would have had on subjective workload if this confounding factor was not present.

We also believe that concepts like spatial presence may benefit from greater conceptual clarity and would thus encourage future studies to delineate them better as well as attempt to measure them

Figure 15

Interaction Effect of Light, Flooring, and In-Game Sound on Enjoyment—In-Game Sound On: Nigerian Sample (Day 3)

separately, especially if those concepts are confirmed to be distinct constructs. In all, as a first step in understanding the influence of environmental factors on the user's VR in-game experience, the study helps to understand the impact of external light, play floor texture, and in-game sound on the users' experiences of spatial presence, enjoyment, and subjective workload. It would be good in the future to measure how successful the individuals were at the VR task, as a measure of game play expertise, as this was the object of the desired in-game attention. This would provide an idea of how powerful the (sometimes distracting) factors were.

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