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How Perceived Real-world Risk Affects Vr Experience

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Abstract

Dwelling on presence theory and breaks in presence theory, the purpose of this study is to investigate how real-world risks may affect people's use of VR devices. A two-group comparison experimental design (N=51) was adopted to test how a less ideal play environment with potential risks can affect people's experience in using virtual reality compared to an ideal VR playing set up. The results suggest that people in a less ideal play environment with potential risks tend to pay less attention to the VR content as well as enjoy the experience less compared to an ideal VR playing set up. People in a less ideal VR playing set up tend to have a higher level of concern about the risks related to the use of VR devices.

Keywords: Virtual Reality, Risk perception, Presence, Breaks in Presence

How Perceived Real-world risk affects VR experience

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Acknowledgments

While this research is in an early stage and a rough form, I would really hope this could contribute to the development of VR research in the communications field in some way.

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I.INTRODUCTION

As an effective educational and entertaining tool, Virtual Reality has been one of the main technology focuses for the past few years. With the continuous growth of the virtual reality market, it is predictable that virtual reality devices will reach more houses in the next decade. On the other hand, the potential risk that using VR may cause has long been studied. Studies have been focused on motion sickness and psychological illness. Meanwhile, potential physical damage to the human body or equipment when using a VR device as a consumer product has not gotten much attention.

On Dec 21st, 2017, a 22-year-old man was reported dead because of blood loss. He was using a virtual reality headset and accidentally fell onto a glass table (TASS, 2017, cited from pcgamer.com). Although this was the first reported fatality, injuries are not that uncommon while using virtual reality hardware. Damage to the human body while playing simulation games such as selfie tennis (Polygon, 2016) or to equipment were reported constantly on various forums. At the same time, stepping onto wires and other objects remains one of the most annoying things to happen while being inside a virtual reality environment. Virtual reality hardware manufacturers continue to develop technology such as wireless headsets and inside-out tracking methods to minimize these problems. However, what this feeling of constantly worrying about the outside environment could cause to the virtual reality experience has not been well studied.

Current virtual reality systems are not capable of delivering fully immersive experiences. The more immersed the experience is, the more expensive the devices will be (e.g., Disney's implementation of fully immersive cockpits). It is not realistic to think based on current technology for us to actually "being there" (Biocca & Delaney, 1995) therefore, it is essential to consider real-world risk as one crucial aspect of using current virtual reality systems. With real-life potential risk being considered, how people’s VR experience is affected by this perceived real-world risk is the main focus of this thesis.

Virtual reality systems

The virtual reality market is estimated to grow as much as $33.9 billion in the next several years (Marketsandmarkets.com, 2016). The immersive virtual reality platforms include Oculus Rift, HTC VIVE, and Sony Playstation VR. Current virtual reality systems use three different types of hardware, which cover three human sensations: visual (Head Mounted Display), auditory (headphones), and tactile (controllers) (Ghosh et al., 2018).

The generation of a virtual environment which makes people think they are “there” is the primary function of these virtual reality systems (F. Biocca & Delaney, 1995). With a sense of being elsewhere, a higher level of immersion is generated to contribute to this simulation process (Solak & Erdem, 2015). Current virtual reality systems achieve this goal (to create a higher level of immersion) by using a higher level of refresh rate displays (to match the resolution of a human eye) or better tracking devices (to simulate body movement in the virtual world) (Slater, 2009).

Possible dangers of VR HMD display systems

“While wearing the product's headset, you are blind to the world around you” (CNN, 2017). Virtual reality systems use head-mounted display units to display VR content towards people’s views. To create an isolated VR environment, all spaces visible to the naked eyes are blocked by this type of head-mounted display in order to increase realism. Once all visual cues are blocked by display information, there must be other ways for people to be safe in using this type of device. Earlier types of VR devices relied on outside-in tracking mechanisms (outside cameras and sensors were used to detect the location of the headset in a location), and they didn’t have the capability to track other objects within the play field. Therefore, a large, cleared play field was always recommended.

Oculus Rift recommends clearing out a play environment and mapping it within the system. Advanced solutions such as HTC VIVE include front-facing cameras to help identify the objects in real life and generate obstacle signs within the system. However, current technology has its limitations. The tracking of Oculus Rift does not adapt to real-time changes such as an immediate interruption by another person or something accidentally enter the playing area. HTC VIVE has only front-facing cameras, and they are not turned on by default, which can increase the safety risk during a virtual reality experience.

Bridging the physical-digital gap between virtual environments and the real world has always been a research focus in virtual reality research. Solutions include redesigning VR environments to suit the physical world, such as redirected walking (Suma et al., 2012), pairing real-world objects with virtual counterparts (Simeone et al ., 2015), or generating a "Reality skin" (Shapira & Freedman, 2016). Newer solutions such as using cameras that could transfer real-world environment into the virtual environment can also be found on portable devices.

The awareness of potential danger in using virtual reality has always driven researchers to develop bridging solutions while the concept itself has not been developed (more like a known knowledge). Also, companies such as Oculus or HTC have not adopted these solutions provided by the researchers. The danger of physical damage is still there, and related concepts remain to be developed.

With the technological limitations of VR systems, this paper takes another angle. Previous literature has already identified the potential real-world danger but little research has been conducted to reflect how these dangers and risks affect the people that are using it, whether the users acknowledge these dangers, as well as how these perceptions of danger (if any) has affected their using experience of these systems.

Therefore, this study will adopt a two-group comparison experimental design to test how less ideal play environments with potential risks can affect people's presence, attention, enjoyment, and perceived score for safety in using virtual reality compared to an ideal VR playing set up.

II. LITERATURE REVIEW

With the development of computer technology, current immersive virtual reality differs from a traditional virtual reality or virtual environment. In this chapter, a definition of immersive virtual reality is formed based on previous research, and critical concepts of immersion and presence are explained.

Definition of immersive virtual reality

Virtual reality systems are often treated as a collection of hardware, including computers, display systems (e.g., head-mounted displays), and motion-sensing trackers. Modern virtual reality systems are virtual reality systems with a high-quality wide field-of-view stereo head-mounted display as well as six degrees of freedom head tracking (Slater, 2018).

While a collection of hardware precisely described all the parts in a virtual reality system, it is not good for research analysis. Steuer (1992) argued that this hardware-oriented definition is not sufficient for providing a conceptual unit of analysis. Virtual reality as a concept should be referring to every single project of virtual reality experience (Steuer, 1992). The experience could also be represented by content created in virtual reality as well as experienced in virtual reality hardware systems. Therefore, a virtual reality system definition should be formed by combing content and hardware.

Simple definitions of virtual reality such as “computer-generated world” (Pan & Hamilton, 2018) are better ways to define content generated for virtual reality. Computer programs that simulate a world that is presented to people can be conceptualized in the definition of virtual reality. According to this definition, a desktop viewed VR would also be VR (Slater, 2018). So, it is essential to differentiate VR from Immersive VR.

Immersive virtual reality would be closer to the definition of an immersive virtual environment with a current virtual reality hardware system. An immersive virtual environment is a computer-generated environment that surrounds the user and increases being within it or a sense of presence in particular (Bailenson et al.,2018).

Therefore, a working definition of immersive virtual reality for this paper will be defined as follows:

"*An experience generated by computers to surround users and increase their sense of being in the virtual environment using a collection of virtual reality system hardware including a high-quality wide field-of-view stereo head-mounted display and six degrees of freedom head tracking.*"

Immersion and Presence

Immersion is a multifaceted concept involving media (medium), users, and contexts (Slater et al., 1997, Hou et al., 2012; Shin et al., 2016; Shin & Biocca, 2017). As a "quantifiable description of a technology," immersion represents "the extent to which the computer displays are extensive, surrounding, inclusive, vivid and matching" (Slater et al., 1997).

Users feel immersed within the VR content based on themselves and social contexts. This "quality of experience" (Shin & Biocca, 2017) requires both hardware and content to deliver an immersive experience. An immersive experience can be judged by its level of immersion as an ongoing procedure (Shin & Biocca, 2018).

Presence and immersion are often mentioned together in these studies. Presence is commonly defined as a sense of being in the virtual environment instead of where the people's real body exists (Sanchez-Vives, M. V., & Slater, M., 2005). Some scholars treat presence and immersion as a synonymous concept (Mcmahan, 2003), which indicates that adding presence to the concept of immersion is only confusion. Immersion can also be treated as a synchronicity of media, user, and contexts where presence is only a human consciousness of being there. Based on Slater and Wilbur's study (1997), presence is a function of user psychology of recognizing being inside a virtual setting, while immersion is the quality of this experience.

The formation of presence was treated as a two-step process by some scholars (Wirth et al., 2007). People perceive this virtual environment as a plausible space via spatial cues then experience themselves inside this space (Cummings & Bailenson, 2016). As defined in Wirth et al.'s study, presence is "a binary experience, during which perceived self-location and, in most cases, perceived action possibilities are connected to a mediated spatial environment, and mental capacities are bound by the mediated environment. instead of reality." Therefore, the presence level indicates a person's perception of this virtual environment as an actual space and his ability to act in this process.

In Bailey, Bailenson, Won, Flora, and Armel's (2012) study, researchers observed the presence level to reflect immersion level. That is to say, the presence level is a sign of immersion.

Spatial presence

The term presence is often phrased differently by different scholars, while each could have different meanings. As virtual reality generates a virtual space that contains spatiality (Jarvinen, Bernardet, & Verschure, 2011), the phenomenon of "spatial presence" is used specifically in this study to indicate a person's feeling of being spatially present in an environment.

While people can feel spatially present in natural environments (Stuer, 1992), the term spatial presence is often used to describe the feeling of being in a human/technology generated environment. (Lee, 2004). The individuals treat an artificial environment as it was real, although it is not. The feeling of being actually located in the environment but they are not is mostly the idea of spatial presence. As Harmann et al. (2015) defined the term as "the subjective experience of a user or onlooker to be physically located in a mediated space, although it is just an illusion." This feeling physically located in a mediated environment could possibly make the users less aware of the source of their experience while being fully immersed in the media environment (Steuer, 1992).

During the development of the concept of spatial presence, the factor of the source (technology source as mentioned in Harmann et al.'s study) was minimized while the broader idea of this psychological state was picked up as the definition. Examples of this early emphasis on technology source could be found in Zeltzer (1992)'s study as a "degree to which input and output channels of the machine and human participant(s) are matched." More recent definitions put more emphasis on the psychological reaction to the virtual environment (Wirth et al., 2007; Harmann et al., 2015; Bailenson, 2018). Such psychological conceptualization also leads to new approaches in studying spatial presence, such as treating spatial presence purely as feelings in Schubert's (2009) study.

The assumption in spatial presence that actions and perceptions are closely related forms most of the current spatial presence models (Harmann et al., 2015). The idea that people have to take action once they realize they are capable of doing that in a mediated environment rather than doing that in reality, is a key psychological process that users have to go through in order to form a sense of spatial presence in the virtual reality environments. There are still debates on whether that consciousness comes in a binary fashion (like an on/off switch) or in a continuous fashion. Whichever the case, researchers agreed on spatial presence as a subjective experience.

Break in presence

The concept of breaks in presence (Slater, 2000) originally proposed that as users are in a virtual environment, they are presented with both virtual streams of data and with real-world streams of data. The original concept of 'break in presence' (BIP) occurs only when the users stop processing the data stream from the virtual world and shift to attending to the data stream from the real world. Spagnoli & Gamberini (2002) later argued that these two streams of data run in parallel and that BiP occurs with the real-world data stream overrides the virtual world data stream.

Based on BIP, real-world streams of data can be treated as factors that distract users from the virtual experience. People have limited cognitive resources available to process mediated communication (Lang, 2000). Distraction factors can increase the required cognitive load, which could interrupt attention, negatively impact people's ability to recall content, and decrease their ability to perform well in a VR environment. Research has shown that real-world distractions such as telephone ringing can significantly influence people's experience in VR (Oh, Herrera, & Bailenson, 2019). However, a limited amount of research has examined other spatial distraction factors such as awareness of potential obstacles in the playing field.

Attention and spatial presence

Attention is one of the key concepts in communication theories. As suggested in the LC4MP model (Lang, 2000), people have a limited capacity for information processing. That is to say: Even though people can process several tasks simultaneously, they can only process a certain amount of information at the same time. Attention is limited not only to the capacity of attention a user may generate to an object or an environment but also limited to his or her capacity in processing them.

The engagement level of the activity also affects this allocation of attention. A higher level of engagement leads to a higher level of attentional demand of the task (Yi-An Chen et al., 2015). With high engagement required in VR-based activities, an individual needs more attention allocated in one activity than regular flat screen-based activities (Singh et al., 2012). Also, the new reference system generated by a mediated virtual environment is constantly challenging the user's existing spatial referencing system (Slater 2002; Wirth et al. 2007). In order for the new system to override the existing system based on the real world, the users may have to allocate more attention to the virtual reality environment. That is to say, an experience in a virtual reality environment naturally required people to pay more attention to it. The more attention users allocate to that, the more presence they feel (Draper et al., 1998).

VR device companies recommend using VR devices in an empty space. This "ideal" environment naturally decreases or even eliminates the impact of real-world objects to have effects on the VR experience itself. However, it is unlikely to have everything out of the way when you plan to use a VR device. Tables, chairs, cables that are lying around, or people that might get into the play field. These real-world situations created a less ideal environment, which creates real-world distractions. As referred to in BIP (Slater, 2000), these physical objects or people are very likely to distract people using the VR devices to prioritize processing real-world information. Thus, this paper formed the following hypothesis:

H1: People in an ideal play environment will report higher presence levels compared to people in a less ideal play environment.

H2: The higher the level of presence people experiences when using VR, the higher attention they will report they have during the experience.

H3: People will pay more attention in an ideal play environment compared to people in a less ideal play environment.

Utilizing this natural character of replacing people's sensations as well as drawing more attention, virtual reality systems have long been used for pain relief in the medical field as a distraction. Previous studies found that VR is a useful tool in relieving burn pain, wound care and chronic pain (Hoffman et al., 2008; Chan et al., 2007; Maani et al., 2011; Twillert et al., 2007). The patients feel less pain during a medical treatment as more of their attention was drawn by the virtual reality experience. As explained by the "gate theory" in the medical field, VR reduces the perceptions of the pain and diverts patients' attention away from the pain by providing visual and audio cues that lower patients' actual feeling of the real world (Gold, Belmont, & Thomos, 2007). These studies all treat VR as a distraction source to real-life experiences. Individuals pay attention to the virtual reality story so that they feel less of the real world.

In a way, these applications in the medical field confirmed the more attention needed in the virtual environment. However, they didn't fully explain how attention is separated from the virtual environment itself or the spatial cues provided in these environments. It is possible that users pay more attention to the spatial cues which override the feeling of the reality. Users may only pay attention to the content rather than the spatial cues. The experience itself is "immersive" but users does not feel "present" at that scene.

Thus, this paper raised the following research questions:

RQ1: How does awareness of the virtual environment affect virtual reality experiences?

RQ2: How does awareness of the lab environment affect virtual reality experiences?

Spatial Memory

Human activities depend on spatial knowledge of an environment to be efficient (Lathrop & Kaiser 2002, cited from Mania & Coxon, 2010). Scholars have been devoted to testing how effective virtual environments are to transfer spatial information generated within the virtual environment to real-world settings (Mania, Troscianko, Hawkes & Chalmers 2003, Mania, Adelstein, Ellis & Hill 2004, Fink, W., Foo, P.S., Warren, W., 2007; Bailey & Witmer 1994).

An accurate memory often involves a set of the psychological recognition process. Based on the theoretical framework of memory psychology, an accurate memory is formed when people "remember", "know", get "familiar", and "guess" during this recognition process (Conway et al., 1997). This process of memory encoding in processing information would require a certain level of recognition of the information and a coding mechanism for a memory to be sustained in a human brain.

As in the spatial memory realm, people observe the location of objects within a certain environment. By memorizing physical location, people memorize things (Patel & Vij, 2010). Within VR, this memory encoding process is enhanced when a person feels presence within the virtual environment (Järvinen, Bernardet, & Verschure, 2011).

Virtual environments have been used as an effective training medium based on the fact that spatial memory can be transferred to the real-world much more effectively when users feel present within the virtual environment. However, on the other hand, would this set of spatial memory retention override the spatial memory of the existing environment while users are using Virtual Reality is not yet studied.

Therefore, this paper raised the following research question:

RQ3: How is memory affected by the real-world environment while using VR devices.

Enjoyment and transportation

Though not widely adopted at the current stage of development, virtual reality is no doubt a media platform. The reason why people use media is that they enjoy doing so, and this makes them happy (Green et al., 2004). From an audience perspective, users wanted to be entertained by using virtual reality (Brock & Livingston, 2004).

Enjoyment is a "pleasurable affective response to a stimulus" (Cited from Green et al., 2004, Raney, 2003). Green et al. (2004) suggested that individuals enjoy a typical media experience when they feel that they away from their mundane reality and into another world. In the era of virtual reality, the sense of being elsewhere naturally generates a media experience that incorporates the key element of being away from the real world. This "transportation into a narrative world" (Green & Brock, 2002) is what makes virtual reality experience an enjoyable media experience.

Transportation theory is similar in concept to presence as it also describes how humans minimize their level of awareness of the medium rather than feel the experience directly (Biocca, 2002). The interactivity discussed in the presence theories is often treated as a key element, while the transportation theories provide more conceptualization of this same idea. While presence theories often focus on how people interact with the medium, transportation theory provides a route to understand media enjoyment of participatory narratives (Green et al., 2004).

In this paper, media enjoyment is treated as the outcome of using VR devices. Thus, this paper raised the following hypothesis:

H4: People tend to enjoy using VR more in ideal play environments than people in a less ideal play environment.

Risk perception

Risk perception is people's judgment about the likelihood some negative things can happen to them, such as injury or illness. Defined by Magessi and Antunes (2016), risk perception is a brain process where human form a subjective judgment after observing risk cues which have previously been assimilated. The judgment formation is essential for the human brain to recognize the risk, and thus take action about it. There are two main dimensions in risk perception: how much people know about the risk and how they feel about them (Pack and Hove, 2017). Based on a different judgment about the risk and how they feel about them, people took different activities towards that risk or hazards.

In a virtual reality set up, people cannot see the ongoing or existing risk in the real world. People rely on heuristic cues to assess risk levels, which helps form a proper risk perception of the existing environment (Slovic, Fischhoff, & Lichtenstein, 1981). While people observe environmental information from the virtual world, their risk perception might be generated based on what they are given in the virtual world. However, since current virtual reality technologies are not capable of delivering enough information to "replace" the real world, people might also form a risk perception of the real world as well. This risk perception is formed before they put on their virtual reality headset thus, people might rely on their memory to judge the risk level of the real world when they are in the virtual world.

Therefore, this paper raised the following hypothesis:

H5: People will assess using VR as relatively less safe in general.

H6: People will assess an ideal play environment as safer than a less ideal play environment.

H7a: People in less ideal play environments will assess using VR to be less safe after using it.

H7b: People in an ideal play environment will assess using VR to be safer after using it.

Fall, Balance, and fear of falling

When losing balance or getting trapped, there is a likelihood that human falls. The consequence of falls could include physical injury, fractures, decrease quality of life, and fear of falling (Masud and Morris, 2001; Perracini and Ramos, 2002). Falling and the fear of falling are commonly studied among older adults. For older people, falls are considered one of the most likely causes of death due to accidental injury (OMS, 2012, cited from Prata & Scheicher, 2014).

One of the consequences of falls is the fear of falling. Fear of falling defined as an intense fear of standing or waking (Bhala, O'Donnell, & Thoppil, 1982). This concern of falling would affect a person's willingness to do activity, thus affect his/her capability of performance (Tinetti & Powell, 1993). At the same time, studies regarding fear have proven that previous experience could trigger specific fear elements. Previous falls do not necessarily induce fear of falling (Maki, Holliday & Topper,1991; Howland, Peterson, Levin, Fried, Pordon, & Bak, 1991). Studies have shown that fear of falling can have negative consequences for elderly people, which include physical injuries (10 11) and reduced quality of life.

Virtual reality systems allow users to change motion according to the existing virtual environment and maintain their balance within it (Clark et al., 2010; Schiavinato et al., 2010). Studies have shown that using virtual environments could be beneficial to treat fear of falling (e.g., Nintendo Wii, 24-27). However, these systems themselves naturally block the real-world environment, thus creating an isolated environment. The possible fear of falling when using these “not safe” devices could significantly reduce the motivation, enjoyment, and outcome of the use of virtual reality systems.

Thus, this paper raised the following hypothesis:

H8: People in less ideal play environments will report a higher level of concern about falling in general compared to people in ideal play environments after use.

H8a: People in less ideal play environments will report a higher level of concern about bumping into things compared to people in ideal play environments after use.

H8b: People in less ideal play environments will report a higher level of concern about tripping over things compare to people in ideal play environments after use.

H8c: People in less ideal play environments will report a higher level of concern about falling compared to people in ideal play environments after use.

H9: People in less ideal play environments will report a significant increase in the level of concern about falling in general after use.

H9a: People in less ideal play environments will report a significant increase in the level of concern about bumping into things after use.

H9b: People in less ideal play environments will report a significant increase in the level of concern about tripping over things after use.

H9c: People in less ideal play environments will report a significant increase in the level of concern about falling after use.

III. METHODOLOGY

Description of Research Design

This between-subjects pre-test/post-test experimental study investigated how awareness of the potential danger in the real-world affects virtual reality experiences. The participants were divided into two groups and played the same stage of a VR escape room game. One condition was the "ideal VR playing condition" in which participants had an ideal cleared playing zone. The other condition was a "less ideal VR playing condition" in which participants had a less ideal playing zone. The perception of risk was heightened in the "less ideal VR playing condition" by placing objects near- but not in – the play zone. Although neither condition placed participants at greater risk, the "less ideal" condition was designed to increase individuals' awareness of the possibility of walking into objects. Attitudes about VR and perceived risk were measured before and after participants played the game.

A total of 51 participants were recruited. Participants were recruited from undergraduate communication classes and offered extra credit for participation. Upon approval by the course instructors, the course instructors distributed the recruitment script through course email lists. The recruitment script was attached to this application. Participants were asked to provide contact information for scheduling purposes if they are willing to participate in the experiment (Name, email address). After the experiment, these data were deleted.

A description of the experiment was provided and of the requirements for participants. Detailed information about the data collection process was provided. Participants were informed that experimental participants would be offered extra credits for participating in a single data collection session.

Procedures

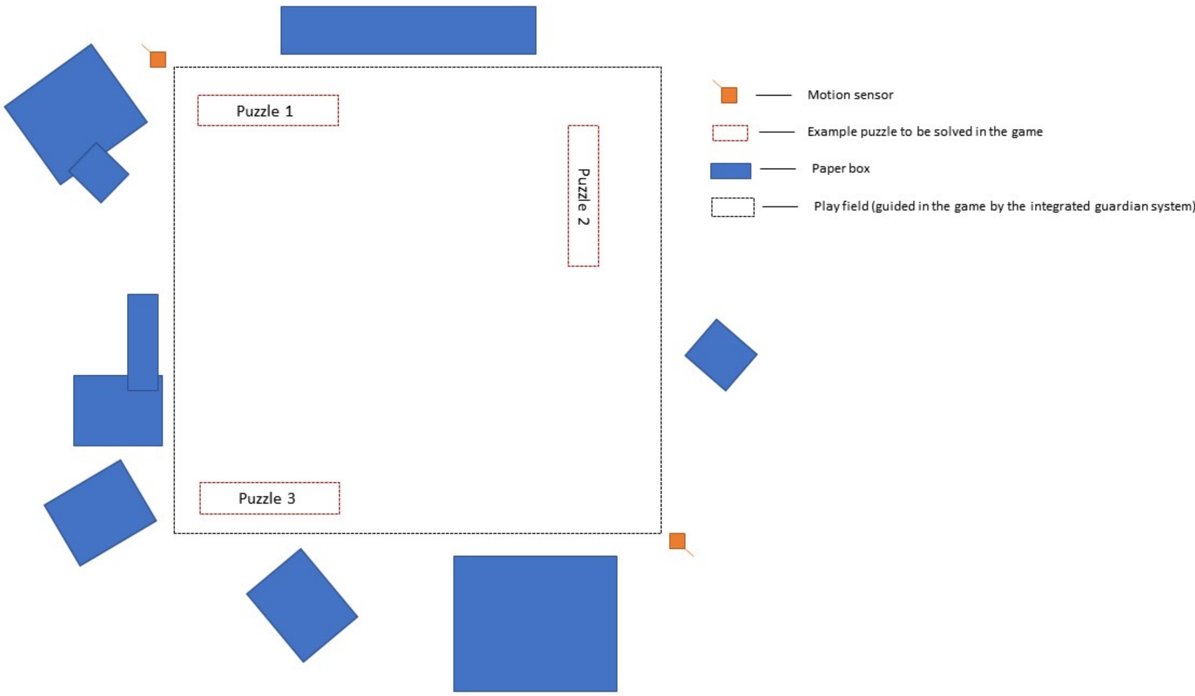
Participants were assigned randomly into two groups (ideal playing zone/less ideal playing zone). Participants were contacted individually and asked to come to the experimental room at a scheduled time. After reading and signing a consent form, researchers verbally reviewed the potential risks and procedures for the study. Participants were informed that they could discontinue the study at any time if they experienced any discomfort. They were informed that they could discontinue by informing the researcher.

The participants were then asked to finish a questionnaire regarding their general perception of risk of falling of using a VR headset.

After completing the questionnaire, the participants were asked to stand in the VR play zone for the experiment. The VR head-mounted device (HMD) was placed on the participant and tested for accuracy. During this process, the participants were instructed by the researcher to look around and pick up an item in the virtual environment to get familiar with using the VR head-mounted device.

Research sessions for both groups were conducted in the same experimental area. A dedicated play area was mapped by the researcher (See purple lines in Figure 1.). For the less ideal experimental group, several paper boxes were put around the play area (not actually in the playing field) to create a less ideal VR playing situation. For the less ideal experimental group, these paper boxes were removed, and participants were only using VR devices in the dedicated play area.

Figure 1. Experimental setup concept and Actual experimental field



Participants were asked to stand still and wait for the start of the experience. They were then asked to play VR: The Puzzle Room for 10 minutes (The participants were not able to complete the entire game session). The participants had to walk inside the virtual play area and use the handheld controller to solve the puzzles (The area inside the game is the same size as the playing field in the experimental facility). The participants were encouraged to solve as many puzzles as possible.

After the VR experience, participants were asked to finish a survey to report their sense of presence, attention, enjoyment, information recall, the awareness of the real-world (how they recognize via touch, sound, and other senses), perceived safety, and perceived fear of falling.

After completing the survey, the participants were thanked and debriefed. The entire process took no more than 30 minutes. There were at least 15 minutes of time between research appointments to attempt to protect participants' privacy.

Participants demographics and final sample

A total of fifty-one participants were recruited. Participants were recruited from undergraduate communication classes and offered extra credit for participation.

Thirty-three participants were assigned to the less ideal playing zone group, while eighteen participants were assigned to ideal playing zone group (The initial plan was to recruit an equal number of participants. However, data collection was paused due to global COVID-19 pandemic). The final sample is comprised of 29.4% males, 68.6% females, and 2% other with a median age of 18 years. Most participants identified themselves as White (72.5%), with 9.8% Black or African American, 13.7% Asian or Asian Indian, and 3.9% Hispanic, Latino, Or Spanish. Power analysis indicates insufficient power due to the small sample size (27 per group to have 0.5 effect size and .8 power).

Among the final sample, most of the participants (82.4%) reported to have medium to low (Report equal to or lower than 4 on a 7-point Likert scale question "How well do you know about virtual reality technology?") familiarity with virtual reality technology, 92.2% to have medium to low (Report equal to or lower than 4 on a 7-point Likert scale question "How much experience do you have with virtual reality?") experience with virtual reality and 94.1% to have medium to low (Report equal to or lower than 4 on a 7-point Likert scale question "How much experience do you have with VR games?") experience with VR games.

Description of Stimuli

A VR escape room game *VR: The Puzzle Room* was used as the experimental treatment. The game is an escape room game in a VR setting. An escape room game is a type of game in which players find clues and solve puzzles in a single room, thus lead to a final goal (For most escape room games, the goal is to get out of the room. Therefore, in a VR setting, the final goal is to open a virtual door in the environment). The VR: The Puzzle Room was made available on publicly available on January 1st, 2017. The game can be found on:

https://store.steampowered.com/app/576620/The_Puzzle_Room_VR__Escape_The_Room/

Measurements

Relevant demographic variables, including gender (Male/Female/Other/Don't want to tell), Age, Race (White/Hispanic, Latino, or Spanish/Black or African American/Asian or Asian Indian/American Indian or Alaska Native/Middle Eastern or North Africa/Native Hawaiian or Other Pacific Islander/Other) were included. Familiarity with virtual reality technology, experience with virtual reality technology, and experience with VR games were measured using a 7-point Likert scale from 1 (Not at all) to 7 (Very much), and they were also included as control variables.

Dependent variables

Presence

Presence was measured using a seventeen item seven-point-Likert scale questionnaire. Items were picked up from the Temple presence inventory (Lombard, Ditton & Weinstein, 2013). (e.g.," How much did it seem as if you could reach out and touch the objects?"," How often when an object seemed to be headed toward you did you want to move to get out of its way?")

Attention

Attention was measured using five items on a seven-point-Likert scale self-reported attention questionnaire revised from the Situational Self-Awareness Scale (Govern & Marsch, 2001). The original situational self-awareness scale was used to self-evaluate self-focus. To differentiate from the awareness variable, the attention variable here is to reflect attention levels that is evaluated by individuals themselves but less the overall awareness to the environment. The higher score in situational self-awareness scale, the higher level of self-reported attention participants paid. Items were adopted from the original surrounding items and revised to measure virtual environment attention (e.g., "I am keenly aware of everything in the virtual environment," "I am conscious of what was going on in the virtual world.")

Enjoyment

Enjoyment was measured using the Physical Activity Enjoyment Scale questionnaire (PACES) (Kendziersk & DeCarlo, 1991). (e.g., "I enjoy it.", "I feel bored.")

Perceived score for safety

Two five-item seven-point-Likert scale questions were developed to measure subjects' perceived score for safety before and after using VR headsets. "I feel safe to play VR games in general." was used to measure general risk perception regarding play VR games and, "I think it is safe to play VR game in this area." was used to measure experimental stimuli's effect on people's risk perception in using VR in this area.

Fear of falling (with individual items listed as bumping/tripping/falling)

Fear of falling was measured using three individual seven-point-Likert scale questions regarding potential falling in using VR. Participants rate their likelihood of falling, tripping or bumping into things before and after using VR. (e.g.," I think I might fall."," I think I might trip into something.", "I am likely to bump into something.") The mean score of the three individual items were than computed as a general fear of falling variable.

Awareness of the Lab space

Awareness of the Lab space was measured using seven items on a seven-point Likert scale revised from the items used in Witmer and Singer (1994)'s study about real-environment awareness. (e.g., "While you were in the virtual experience, how aware were you of the temperature of the Lab space?"," While you were in the virtual experience, how aware were you of the smell of the lab space?").

Awareness of the VR environment

Awareness of the VR environment was measured using six items on a seven-point Likert scale revised according to Awareness of the Lab space scale. (e.g., "While you were in the virtual experience, how aware were you of the temperature of the virtual environment?", "While you were in the virtual experience, how aware were you aware of the smell of the virtual environment?").

Perceived Real world effect on VR experience

Perceived real world effect on VR experience was measured using three questions on a seven-point Likert scale from 1 (*Not at all*) to 7 (*Very much*) developed for this study. (e.g., "How much did the feeling of the lab space affect your enjoyment in playing the VR game?")

Spatial memory about the VR environment

Spatial memory was measured using two open-ended questions. "Please briefly describe the room you were in." and" Please list the items you have seen in the room." The total number of correct (that are actually in the game) items were recorded as the spatial memory score about the VR environment. Items in the same category with different colors or names were counted as one correct item.

Index Construction

A Cronbach's alpha test was used to test the reliability of the measurements used in this study. See Table 1. Reliability. Adequate reliability was achieved in Presence (*M*=5.17, *SD*=0.83, Cronbach's α = 0.85), Attention (*M*=5.50, *SD*=1.24, Cronbach's α =0.84), Enjoyment(*M*=5.60, *SD*= .62, Cronbach's α =.90), Awareness of VR content (*M*=4.11, *SD*=.94, Cronbach's α = .66), Awareness of Lab environment (*M*=2.96, *SD*=1.33, Cronbach's α =.88) and the extent to which real-world affect VR experience (*M*= 3.26, *SD*=1.98, Cronbach's α = .94). Normality tests were conducted, and levels of skewness and kurtosis were within an acceptable range.

Table 1.Reliability

Measure	Cronbach's Alpha
Presence	0.85
Attention	0.84

Enjoyment	0.90
Fear of falling	0.94
Awareness of VR content	0.66
Awareness of Lab environment	0.88
Real World Affect VR experience	0.94

IV. RESULTS

Hypothesis testing

Pearson's correlation tests were conducted to test the correlation between the variables. The results are shown in Table 2.

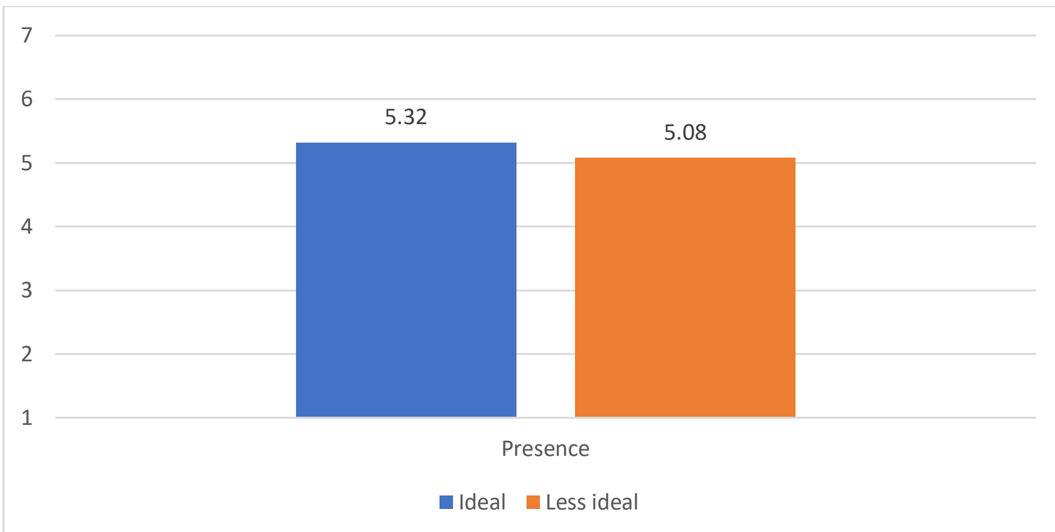
Table 2.Correlations

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	*M*	*SD*
Age	-													18.76	2.02
Gender	-	-												1.73	.49
Race	-	-	-											1.65	1.13
Familiarity	-0.06	0.13	0.06	-										3.10	1.35
Experience w/tech	0.13	-0.01	-0.12	0.54**	-									2.20	1.25
Experience w/game	0.03	-0.02	0.09	0.48**	0.71**	-								1.82	1.14
Presence	-0.08	-0.06	0.06	-0.08	-0.01	-0.12	-							5.17	.83
Attention	-0.04	0.08	0.05	0.29*	0.06	0.04	0.52**	-						5.50	1.24
Enjoyment	-0.03	0.03	-0.13	0.14	-0.07	-0.05	0.49**	0.47**	-					5.60	.62
Fear of falling	.27	-.01	.10	.01	-.08	-.12	-.16	.06	-.17	-					
Aware of VR content	0.13	-0.22	-0.03	0.07	0.06	-0.12	0.56**	0.56**	-.01	0.36**	-			4.11	.94
Aware of Lab	0.07	-0.22	0.34*	-0.09	0.13	-0.12	0.27	-0.03	-.05	0.02	0.37**	-		2.96	1.33
Real world affect	0.00	-0.12	0.26	0.08	0.15	-0.05	0.09	0.17	-.03	-0.19	0.34*	0.51*	-	3.26	1.98

Note: ***p < .001, **p < .01, *p < .05.

H1 predicted that people in an ideal play environment would report higher presence levels compared to people in a less ideal play environment. The mean of presence level reported in ideal play environment was 5.32 with SD = .87, while the mean of presence level reported in less ideal play environment was 5.08 with SD=.81 (see Figure 2). An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean of attention level reported in ideal play environment was lower than the mean of attention level reported in less ideal play environment, but not at the traditional $p < .05$ level (t =-0.93, p =0.36).

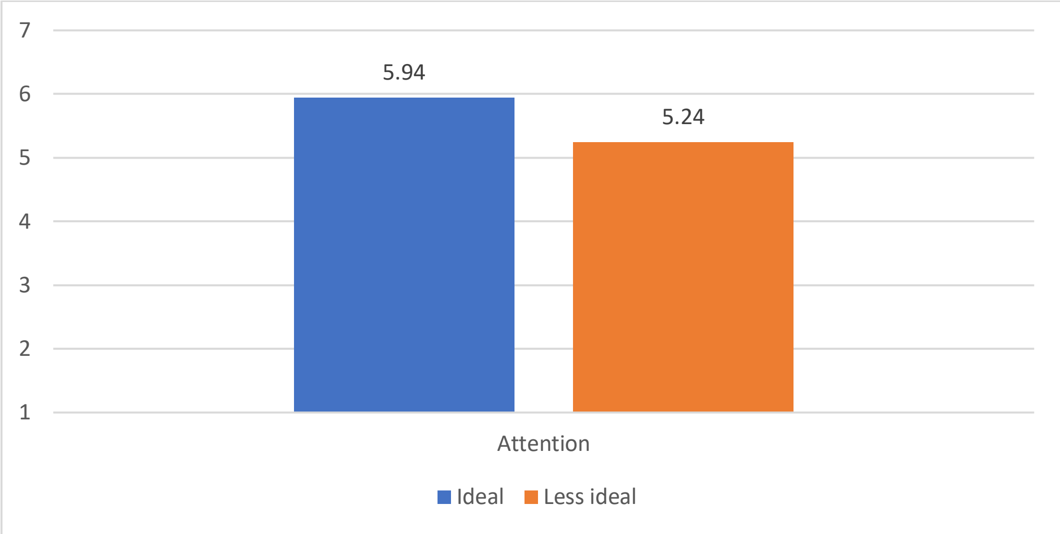
Figure 2. Presence mean comparison



H2 predicted that the higher level of presence people has when using VR, the higher attention they would report they had during the experience. A simple linear regression was used to test this hypothesis. As presence increased, people paid significantly greater attention during the experience, $b = 0.52$, $p < .001$, F (1,49) = 18. 13. Thus, H2 was supported.

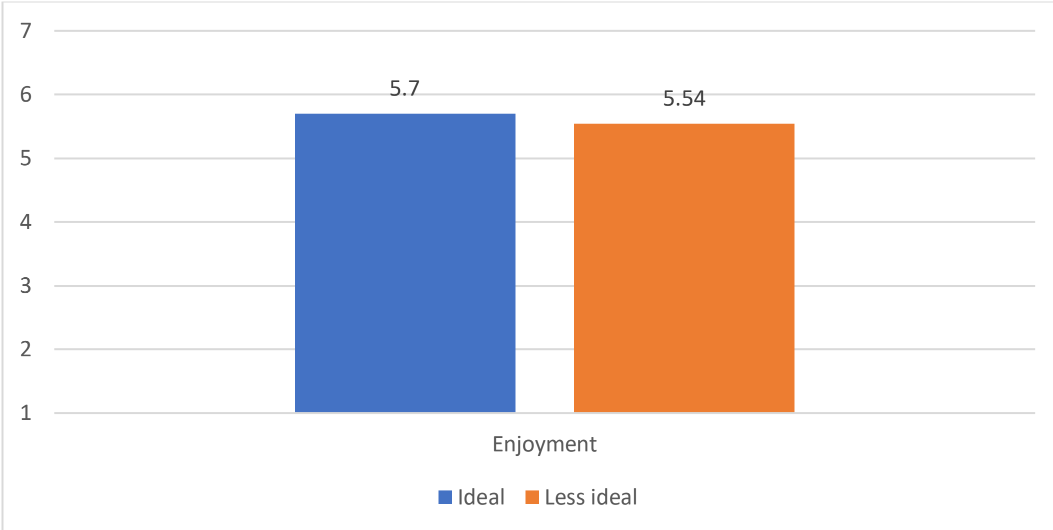
H3 predicted that people in ideal play environment would report higher attention levels compare to people in less ideal play environment. The mean attention level reported in the ideal play environment was 5.97 with $SD = .92$, while the mean attention level reported in less ideal play environment was 5.24 with SD=1.32 (see Figure 3). An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean attention level reported in ideal play environment was significantly higher than the mean attention level reported in less ideal play environment (t=-2.29, p <0.05). Thus, H3 was supported.

Figure 3. Attention means comparison



H4 predicted that people in an ideal play environment would report higher enjoyment levels than people in a less ideal play environment. The mean enjoyment level reported in ideal play environment was 5.70 with SD =.59, while the mean enjoyment level reported in less ideal play environment was 5.54 with SD=.64 (see Figure 4). An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean enjoyment level reported in ideal play environment was higher than the mean enjoyment level reported in less ideal play environment, but not at the traditional $p < .05$ level (t = -0.94, p = 0.36).

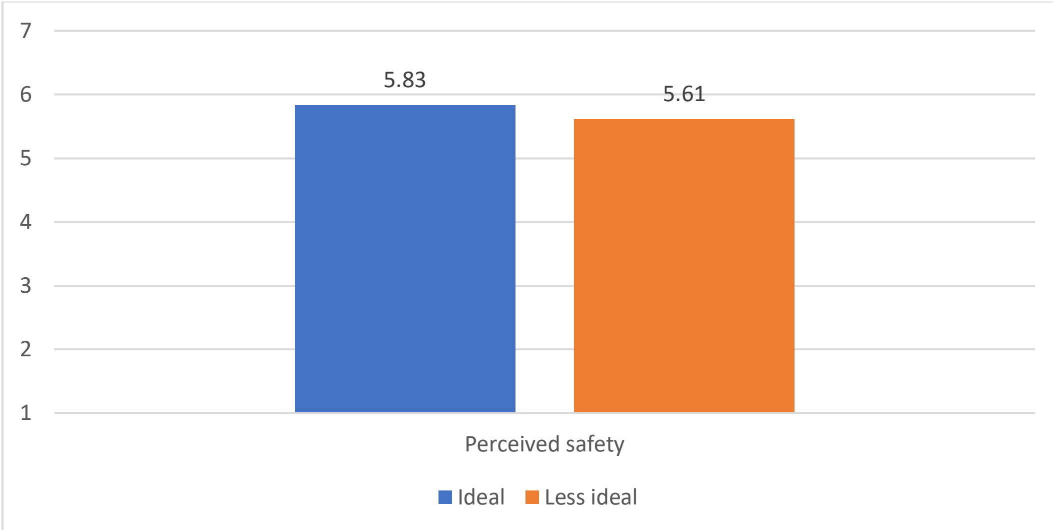
Figure 4. Enjoyment means comparison



H5 predicted that people had relatively low perceived score for safety about using VR in general. The mean score for the question "I think it is safe to play VR games in general" was 5.69 with an *SD*=1.27. As participants rated from 1 (Not at all) to 7 (very much), H5 was rejected.

H6 predicted that people in ideal play environment would report higher level of perceived score for safety of using VR in the area than people in less ideal play environment before using VR. The mean perceived score for safety in ideal play environment was 5.83 with *SD*=1.20, while the mean perceived score for safety in less ideal play environment was 5.61 with *SD*=1.32 (see Figure 5). An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean perceived score for safety in ideal play environment was higher than the mean perceived score for safety in less ideal play environment, but not at the traditional $p < .05$ level (t=-0.55, $p = 0.59$).

Figure 5. Perceived score for safety means comparison

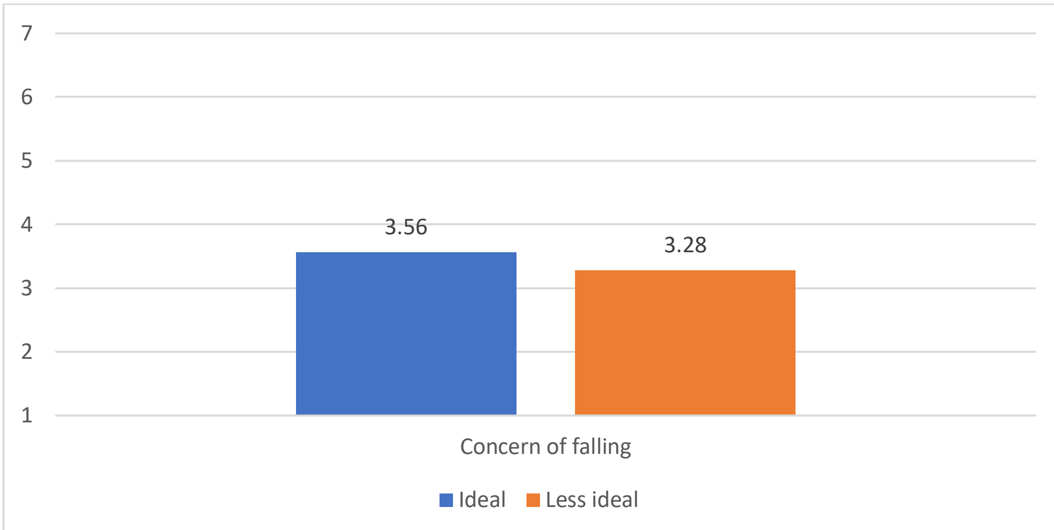


H7a predicted that people in less ideal play environment would report a significant decrease in the level of perceived score for safety of using VR in the area after using them. A paired sample t-test was used to test the mean difference between perceived score for safety before using them and after using them. The result (t (32) = -2.18, $p < .05$) indicate that there was a statistically significant decrease (M=-.58, SD =1.52) in perceived score for safety in the less ideal play environment. Thus, H7a was supported.

H7b predicted that people in ideal play environment would report a significant increase in the levels of perceived score for safety of using VR in the area after using them. A paired sample t-test was used to test the mean difference between perceived score for safety before using them and after using them. The result (t (17) = -1.37, p >.1) indicated that there is no statistically significant change in perceived score for safety in ideal play environment.

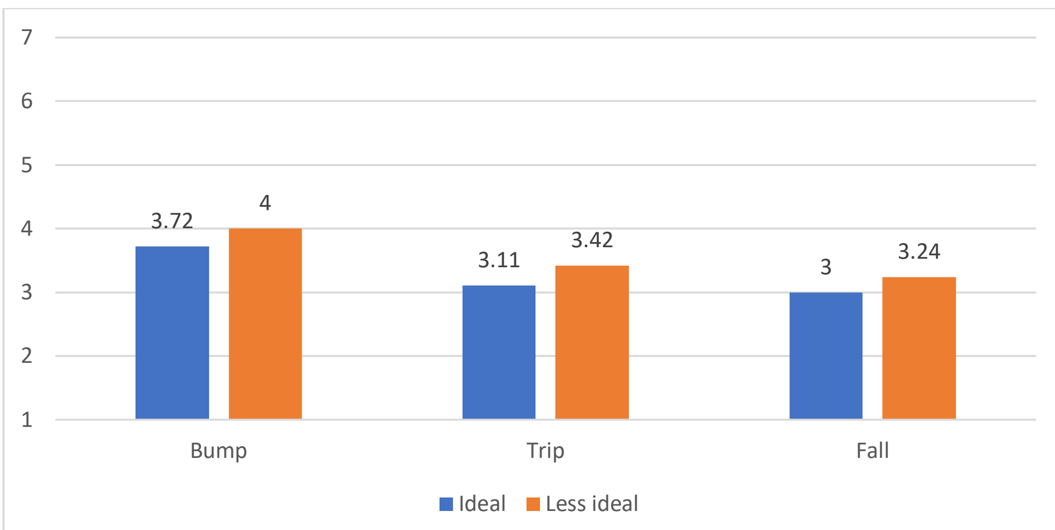
H8 predicted that people in less ideal play environments would report a higher level of concern about falling. (see Figure 6). The mean score for concern of falling in ideal play environment was 3.28 with SD = 1.81 while the mean score for concern of falling reported in less ideal play environment was 3.56 with SD= 1.71. An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean score for concern of falling reported in ideal play environment was lower than the mean score for concern of falling reported in less ideal group, but not at the traditional $p < .05$ level ($t=0.54$, $p = 0.59$).

Figure 6. Concern of falling means comparison



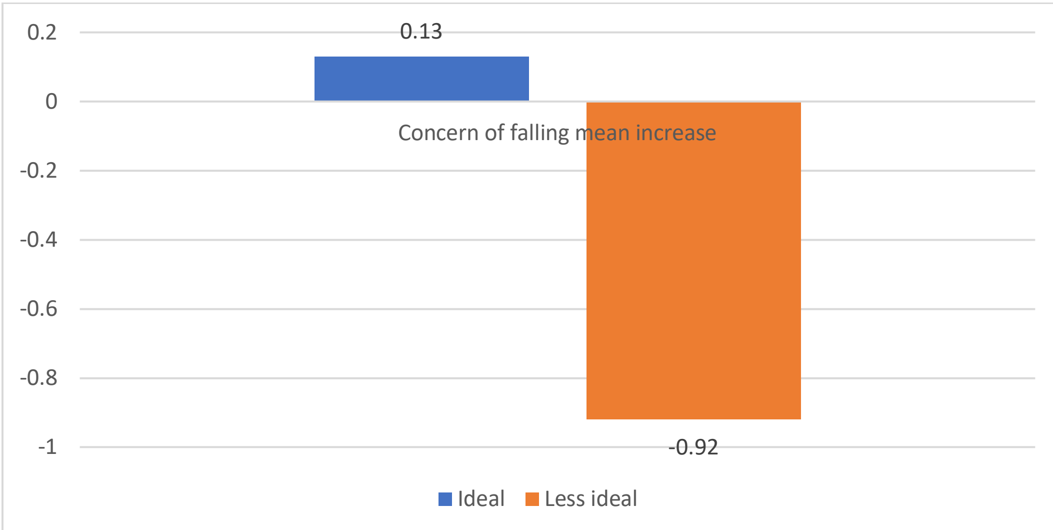
H8a-H8c predicted that people in less ideal play environments would report a higher level of concern about (a) bumping into things, (b) tripping over things, and (c) falling compare to people in ideal play environment before using them (see Figure 7). (a) The mean score for concern of bumping into things reported in ideal play environment was 3.72 with SD=2.02, while the mean score for concern of bumping into things reported in less ideal play environment was 4.00 with SD=1.84. An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean score for concern of bumping into things reported in ideal play environment was lower than the mean score for concern of bumping into things reported in less ideal play environment, but not at the traditional $p < .05$ level ($t = 0.48$, $p = 0.63$). (b) The mean score for concern of tripping over things reported in ideal play environment was 3.11 with SD=1.88, while the mean score for concern of tripping over things reported in less ideal play environment was 3.42 with SD=1.90. An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean score for concern of tripping over things reported in ideal play environment was lower than the mean score for concern of tripping over things reported in less ideal play environment, but not at the traditional $p < .05$ level (t=0.57, p = 0.57). (c) The mean score for concern of falling reported in ideal play environment was 3.00 with *SD*=1.82 while the mean score for concern of falling reported in less ideal play environment was 3.24 with *SD*=1.71 An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean score for concern of falling reported in ideal play environment was lower than the mean score for concern of falling reported in less ideal play environment, but not at the traditional $p < .05$ level (t =0.47, p = 0.65).

Figure 7. Perceived fear of (a) bumping (b) tripping (c) falling means comparison



H9 predicted that people in less ideal play environments would report a significant increase in the level of concern about falling in general after use. (see Figure 8). The mean score for concern of falling in ideal play environment increased 0.14 with SD = 1.48 while the mean score for concern of falling reported in less ideal play environment increased -0.92 (decreased 0.92) with SD= 1.71. An independent sample t-test was used to test whether these means were statistically different from each other. The result showed that the mean score increase in concern of falling reported in ideal play environment was statistically higher than the mean score increase of concern of falling reported in less ideal group ($t = -2.20$, $p < .05$).

Figure 8. Concern of falling means increase comparison



H9a-H9c predicted that people in less ideal play environment would report a significant increase in the level of concern about (a) bumping into things, (b) tripping over things, and (c) falling after use. Several paired sample t-tests were used to test the mean difference between score for concern of (a) bumping into things, (b) tripping over things, and (c) falling before using VR and after using VR. For H9a, the result (t (31) =3.17, p<.05) indicate that there was a statistically significant increase (M=1.25, SD = 2.23) in the score for concern of bumping into things in less ideal play environment. For H9b, the result (t (32) =1.03, p>.1) indicates that there was not statistically significant increase in score for concern of tripping over things in less ideal play environment. For H9c, the result (t (32) =3.38, p<.05) indicate that there was a statistically significant increase (M =.39, SD = 2.20) in the score for concern of falling in the less ideal play environment. Thus, H9a and H9c were supported.

Research Questions testing

The awareness of the environment is determined by the attention paid to the environment. Therefore, the effect of this awareness may be reflected by attention. On the other hand, enjoyment was treated as the outcome variable in this study, thus, it may also be affected by the awareness of the environment as well.

To test research question 1 on how does aware of the virtual environment affect virtual reality experiences in general, two simple linear regression were conducted. As participants' attention towards the VR content increased, people paid significantly greater awareness to VR environment, $b = 0.56$, $p < .001$, $F(1,49) = 22.23$. Also, as participants' enjoyment level when using VR devices increases, people also paid significantly greater awareness to VR environment, b=0.36, $p = 0.01$, $F(1,49) = 7.22$.

To test research question 2 on how awareness of the lab environment affect virtual reality experiences, two simple linear regression were conducted. No significant regression equation was found to predict attention from awareness to Lab space in general (b= -0.03, $p > 0.1$, $F(1,49) = 0.04$) as well as no significant regression equation was found to predict enjoyment from awareness to Lab space in general (b=0.02, $p > 0.1$, $F(1,49) = .02$).

To test research question 3 on how memory is affected by the real-world environment while using VR devices, the number of memory items were listed as the indicator of spatial memory of the virtual environment. An independent sample t-test was used to determine whether there is a difference in the number of items between the groups. There was no significant difference in the number of items between ideal play environment group and less ideal play environment group ($t = 0.57$, p = 0.39).

V. DISCUSSION

This study investigated how awareness of the real-world environment and less ideal play environment of VR might affect the actual VR experience. The first assumption was that an ideal play environment might result in higher level of user attention paid to the virtual reality environment and higher level of user enjoyment while using virtual reality devices. The second assumption was that the play environment set-up might induce higher safety concerns when using VR as well as fear of falling.

Primary Findings

In this study, two experimental groups were compared to determine whether there is a significant difference in playfield set up when using VR. Due to the COVID-19 pandemic, data collection could not be completed, resulting in an uneven distribution of study participants between conditions. This limited the statistical power of analyzing differences between these conditions. However, there are still trends to be seen in the data analysis.

H1-H3 tested whether there is a difference of people's feeling of presence and the attention paid to VR content in two different groups. H1 tested whether people will feel more presence in the VR experience when they are in the ideal play environment. As stated in previous literature, the presence level was often used to measure people's level of feeling immersed in the virtual environment (Bailey, Bailenson, Won, Flora, & Armel, 2012). Thus, the higher present the users feel, the better immersed they are in the VR experience. The result showed no statistical significance but a trend in people reporting higher level of presence in the ideal environment. That is to say, people in the ideal play environment may feel more immersed in the VR experience.

On par with the previous literature, the more users feel present in the virtual environment, the higher attention they paid to it. H3 suggested that people in ideal play environment paying more attention compared to people in less ideal play environment. The current experimental setup controls for physical objects, which is to say, the existence of these physical objects may be the reason why people paid less attention to the VR experience. Based on LC4MP theory (Lang,2000), people only have limited processing capacity. The physical objects could be the distraction factor that people paid less attention.

As an outcome variable, enjoyment is a "pleasurable affective response to a stimulus" (Cited from Green et al., 2004, Raney, 2003). The transportation theory helped explain why enjoyment could be used as a predictor of the effectiveness of a VR experience (Green et al., 2004). In this study, H4 was not supported, but there is a trend of people in ideal play environment have relatively higher enjoyment level than people in less ideal play environment. Therefore, it may be the case that the physical objects affect the VR experience.

Contrary to the original prediction, participants report relatively high perceived score for safety of using VR in general. This result indicates people's confidence in safely using VR headsets without realizing the potential danger that may be caused by using them. H6 was not supported, but there is a trend of people feeling safer when using VR headsets in an ideal play set up rather than a less ideal set up. The subjective judgment (Magessi & Antunes, 2016) based on heuristic cues (paper boxes in this case) indicates the form and existence of higher risk perception when encounter with less ideal play environment when using VR headsets.

H7a strengthened the idea of physical objects within VR environment could elicit risk perception in using VR devices. The significant decrease in perceived score for safety as supported by H7a may be an indicator of how the process within the VR experience works. The existence of physical objects when using VR devices raised people's perception of risk during the process. H7b was not supported possibly due to the lack of power of the sample. The trend indicated that people might perceive VR devices as safer used devices without real-world distractions, while in this case, physical objects. H8, H8a, H8b, and H8c were not supported. However, the overall trend was the same. Participants report a higher level of concern about bumping into/tripping over and falling in less ideal play environment than those who were in ideal play environment. The overall concerns of these issues were relatively low. This confirmed the previous findings of participants' relatively low-risk perception towards VR devices.

After using the VR devices in a less ideal play environment, participants reported a significant increase in the level of concern about bumping into things after use and falling after use, but interestingly not tripping. The significant increase in concern of bumping into things and falling may prove that the concern of falling significantly increased because of the existence of physical objects in the field. This concern about falling may explain the relatively low presence, attention, and enjoyment in the less ideal playing group, as concerns about falling would affect people's willingness to engage in activities (Tinetti & Powell, 1993). The discordance in the result of tripping may be introduced because of the nature of the VR devices that were used in the experiment. As wired VR devices were used in the experiment, participants were much likely to feel the concern of tripping during the process. Future research could utilize wireless VR devices to see whether the results would be different.

Other findings

The awareness of the VR environment is significantly different between the two groups however there is no significant difference between the two groups on recognizing the lab space as well as the information recalled from the experience. A possible explanation of that could be the issue of the measurement. The self-reported measure of the awareness of the environment may not accurately reflect the subconscious of the existence of these objects. Further research is needed to explain.

Limitations and Future Research

There are several limitations to the current research. First, this research lacks statistical power. While the trend indicated in the current sample conforms to the existing literature, there could be sampling error in the process that require more sampling. Future studies should recruit more participants to meet the requirement of statistical power. Second, this paper did not explain the inner relationships and underlying mechanisms of how and why VR experiences are interfered because of these added physical objects to the play area.

Future studies would include more self-reported measures as well as psychophysiological measures to understand how this works. Last but not least, the physical objects used in this experiment are empty paper boxes, which may not induce enough heightened risk perception. Also, these physical objects are not actually inside the play area. Further investigations are needed to test if actual physical objects inside the play area could induce similar effects as the current experiment.

Overall Implications and Contribution

The result of this current study helped provide evidence that physical objects within/or near VR use environments may introduce higher perceived risk to the using of VR devices hence reduce people's willingness and enjoyment of the VR experience. While lacking power, the trend of people getting less involved in the VR experience could be used as a foundation of research on how to reduce the real-world distractions on the VR experiences. The overall lack of literature in this regard makes this research valuable in understanding people's use of VR devices.

Conclusion

This study intended to provide evidence of how real-world distractions such as physical objects might have an impact on VR experiences. The difference of two groups between less ideal play environment and ideal play environment filled the gap within the literature of how real-world distractions as a physical form could have affected virtual experience.

This study also provided evidence to the existence of Break In Presence (Slater, 2000). While most researchers focus on using VR as a distraction tool, current literatures paid less attention to how a VR experience could get distracted by other factors such as real-world objects. Such studies are needed for a better understanding on how to improve VR experiences with current VR technology. The reduction of break in presence induced by a real-world environment could be beneficial for a much more immersed VR experience.

Last but not least, while VR is generally safe to use, the fear of falling existed in VR experiences and could have a negative impact on them. The reduction of fear of falling could lead to a more immersed VR experience as well.

Appendices

Questionnaire

Pre-experiment Survey

What is your age? _______

What is your gender?

Male B. Female C. Other D. Don't want to tell

What best describes your race ethnicity?

White

Hispanic, Latino, or Spanish

Black or African American

Asian or Asian Indian

American Indian or Alaska Native

Middle Eastern or North African

Native Hawaiian or Other Pacific Islander

Other

On a scale from 1 to 7, how well do you know about virtual reality technology?

Not at all 1 2 3 4 5 6 7 Very much

On a scale from 1 to 7, how much experience do you have with virtual reality?

Not at all 1 2 3 4 5 6 7 Very much

On a scale from 1 to 7, how much experience do you have with computer games?

Not at all 1 2 3 4 5 6 7 Very much

On a scale from 1 to 7, how much experience do you have with VR games?

Not at all 1 2 3 4 5 6 7 Very much

On a scale from 1 to 7, how much experience do you have with Puzzle games?

Not at all 1 2 3 4 5 6 7 Very much

On a scale from 1 to 7, how much experience do you have with Escape Room games?

Not at all 1 2 3 4 5 6 7 Very much

Have you played VR: The Puzzle Room before?

A.Yes B. No

I think it is safe to play VR games in general.

Not at all 1 2 3 4 5 6 7 Very much

I think it is safe to play VR games in this area.

Not at all 1 2 3 4 5 6 7 Very much

I think I might fall.

Not at all 1 2 3 4 5 6 7 Very much

I think I might trip into something.

Not at all 1 2 3 4 5 6 7 Very much

I am likely to bump into something.

Not at all 1 2 3 4 5 6 7 Very much

Post-experiment Survey

Attention

I was keenly aware of everything in the virtual environment.

Not at all 1 2 3 4 5 6 7 Very much

I was conscious of what was going on in the virtual world.

Not at all 1 2 3 4 5 6 7 Very much

I was conscious of all objects around me in the virtual environment.

Not at all 1 2 3 4 5 6 7 Very much

I paid attention to everything in the virtual environment.

Not at all 1 2 3 4 5 6 7 Very much

I was not focused during the experience.

Not at all 1 2 3 4 5 6 7 Very much

Information Recall

Please briefly describe the room you were in

Please list the items you have seen in the room

Enjoyment

I enjoyed it.

Not at all 1 2 3 4 5 6 7 Very much

I felt bored.

Not at all 1 2 3 4 5 6 7 Very much

I disliked it.

Not at all 1 2 3 4 5 6 7 Very much

I found it pleasurable.

Not at all 1 2 3 4 5 6 7 Very much

It was no fun at all.

Not at all 1 2 3 4 5 6 7 Very much

It gave me energy.

Not at all 1 2 3 4 5 6 7 Very much

It made me sad.

Not at all 1 2 3 4 5 6 7 Very much

It was very pleasant.

Not at all 1 2 3 4 5 6 7 Very much

My body felt good.

Not at all 1 2 3 4 5 6 7 Very much

I got something out of it.

Not at all 1 2 3 4 5 6 7 Very much

It was very exciting.

Not at all 1 2 3 4 5 6 7 Very much

It frustrated me.

Not at all 1 2 3 4 5 6 7 Very much

It was not at all interesting.

Not at all 1 2 3 4 5 6 7 Very much

It gave me a strong feeling of success.

Not at all 1 2 3 4 5 6 7 Very much

It felt good.

Not at all 1 2 3 4 5 6 7 Very much

I felt as though I would rather be doing something else.

Not at all 1 2 3 4 5 6 7 Very much

Presence

In the VR experience, how much did it seem as if you could reach out and touch the objects?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, how often when an object seemed to be headed toward you did you want to move to get out of its way?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, to what extent did you experience a sense of being there inside the virtual environment you saw/heard?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, to what extent did it seem that sounds came from specific different locations?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, how often did you want to or try to touch something you saw/heard?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, did the experience seem more like looking at the events/people on a movie screen or more like looking at the events/people through a window?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, to what extent did you feel mentally immersed in the experience?

Not at all 1 2 3 4 5 6 7 Very much

How involving was the experience?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, how completely were your senses engaged?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, to what extent did you experience a sensation of reality?

Not at all 1 2 3 4 5 6 7 Very much

How relaxing or exciting was the experience?

Not at all 1 2 3 4 5 6 7 Very much

How engaging was the story?

Not at all 1 2 3 4 5 6 7 Very much

How much did touching the things and people in the environment you saw/heard feel like it would if you had experienced them directly?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, how much did the heat or coolness (temperature) of the environment you saw/heard feel like it would if you had experienced it directly?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, overall, how much did the things and people in the environment you saw/heard smell like they would had you experienced them directly?

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, overall, how much did the things and people in the environment you saw/heard look they would if you had experience them directly

Not at all 1 2 3 4 5 6 7 Very much

In the VR experience, overall, how much did the things and people in the environment you saw/heard sound like they would if you had experienced them directly?

Not at all 1 2 3 4 5 6 7 Very much

Awareness of the VR content

While you were in the virtual experience, how aware were you of the temperature of the virtual environment?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the smell of the virtual environment?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the surface that you stand on of the virtual environment?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the sound of the virtual environment?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the overall environment of the virtual environment?

Not at all 1 2 3 4 5 6 7 Very much

Awareness of the Lab space

How much did you feel the lab space in general?

Not at all 1 2 3 4 5 6 7 Very much

How much did you feel the objects in the lab space (not in the virtual environment)?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the temperature of the Lab space?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the smell of the lab space?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the surface that you stood on in the lab space?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the sound of the lab space?

Not at all 1 2 3 4 5 6 7 Very much

While you were in the virtual experience, how aware were you of the overall environment of the lab space?

Not at all 1 2 3 4 5 6 7 Very much

Real-world affect VR experience

How much did the feeling of the lab space affect your enjoyment in playing the VR game?

Not at all 1 2 3 4 5 6 7 Very much

How much did the feeling of the lab space affect your feeling of immersion in playing the VR game?

Not at all 1 2 3 4 5 6 7 Very much

How much did the feeling of the lab space affect the amount of attention you paid to the content of the VR game?

Not at all 1 2 3 4 5 6 7 Very much

Post-test risk perception

After playing the game, I thought it is safe to play VR games in general.

Not at all 1 2 3 4 5 6 7 Very much

After playing the game, I thought it is safe to play VR games in this area.

Not at all 1 2 3 4 5 6 7 Very much

I thought I might fall.

Not at all 1 2 3 4 5 6 7 Very much

I thought I might trip into something.

Not at all 1 2 3 4 5 6 7 Very much

I thought I might bump into something.

Not at all 1 2 3 4 5 6 7 Very much

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Publications and Papers

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