# A Mini Review of Presence and Immersion in Virtual Reality

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Virtual reality technology is constantly improving such that a virtual environment is more like a physical one. However, some research evidence suggest that certain virtual reality scenarios are less real than others to human observers (e.g., experience of falling from a high place) leading to potential limitations of using virtual reality as a research tool for certain tasks. Moreover, since the inception of VR research the terms presence and immersion have been somewhat convoluted and at times, even used interchangeably. Using a thematic content analysis based on seventeen articles, a theme for each term emerged. Presence is an experiential quality in virtual environments and immersion is associated with the technical aspects of a virtual system that aide the user in feeling a sense of presence. Several new technologies, as well as more traditional approaches are discussed as potential methods to improve of immersion, and therefore presence, in virtual reality.



## INTRODUCTION

Virtual reality (VR) is a computer-generated environment (Biocca, 1992) with a user-interface (UI) that displays a real-time simulation by which an individual(s) can interact through one or more sensory channels (Burdea & Coiffet, 1994; Lee & Wong, 2014). The current and continuously evolving technology allows for an impressive experience using virtual reality with head-mounted displays (VR-HMDs), especially with regard to height-related events.

In recent years, the use of this technology has become more widespread due to cheaper buy-in options. VR has found a home in gaming (Oculus, HVT Vive, PlayStation, Google Cardboard, etc.), clinical and more generalized research, and in training.

VR-HMDs tend to have a more palpable sense of presence compared to traditional two-dimensional (2D) displays. For example, Pallavicini et al. (2019) found that while there were no differences in performance with regards to usability between VR and traditional 2D desktop displays, participants elicited stronger emotional responses as well as a stronger sense of presence in VR while playing a video game. In particular, height-related events in VR makes the interactive experience evocative and realistic and are frequently studied in VR as well as other fear-inducing stimuli. While research concerning presence and realism between VR and 2D displays is reasonably strong, that evidence notwithstanding, it is unclear whether there are any presence-related limitations to VR and whether is it possible to mitigate those limitations.

There have been a wide range of studies that examine the efficacy of VR associated with presence which is generally measured by objective arousal such as heart rate and skin conductance, and subjective arousal using a multitude of rating scales. Some research points to the equivalency of VR to physical reality. Notably, Simeonov et al. (2005) compared a real-world situation of leaning over a rail from a 9m high balcony to a similar surround screen virtual reality (SSVR) simulation. Their results indicated comparable levels of anxiety and risk in both situations; however, SSVR achieved lower heart rate and skin conductance responses, as well as a lower sense of danger. One of the limitations of this study is the use of SSVR which tends to have a less immersive quality compared to VR-HMDs because participants are able to see the edges of the screens. In contrast, other evidence seems to suggest notable limitations of VR related to presence. Peterson et al. (2018) used a beam walk for their VR study to test physiological stress and cognitive load. They also used a physical wooden beam for participants to walk across as a way to provide tactile feedback. By recording beam step-offs (errors), heart rate, electrodermal activity, response time and electroencephalography (EEG), they found that their high height condition elicited increased heart rate variability compared to the low height condition. Further, participants' performance (balance) decreased. While these findings do suggest that VR may provide an experience which is comparable to reality, VR does seem to be associated with poorer physical and cognitive performance such as increased RT as compared to performance when participants walked on a physical wooden beam.

Recently, Wilkinson et al. (2019) conducted a study to explore subjective experience of slow-motion using VR which consisted of various height-related events (three events for arousal manipulations: walking on a sidewalk, plank-walking from 100m height, falling from the plank from top of a building) coupled with a perceptual encoding task. Heart rate was used as an objective measure of arousal. Although it was hypothesized that the condition involving falling would be the most arousal eliciting, the study found the two conditions involving planks had comparable heart rates and were both significantly higher than that of the condition that involved walking on a sidewalk. A potential explanation is a ceiling effect such that the conditions of presence and/or immersion in VR are not sufficient enough to elicit a higher arousal response while falling. If this is the case, is it possible to break through this ceiling? But what is *presence* and what is *immersion*? Given the inconsistencies in the findings as well as how the two constructs are defined, a mini review was conducted. In particular, attention was given to the operationalization of presence and immersion as well as how they were manipulated in research.

Many studies examining presence and immersion in VR generally compare this [VR] technology to another medium or the real world. Although some research suggests the effectiveness of VR-HMDs in supporting participants' feelings of being in the world just like in the physical one, Wilkinson et al. (2019) discovered that there may be a ceiling effect that certain scenarios may not lead to optimal presence (i.e., the experience of falling was not realistic enough to make participants believe they were actually falling).

VR technology has been used for a few decades now and the terms of presence and immersion have, at times, become convoluted, and even used interchangeably in some cases. Therefore, an exploration of how they are defined is necessary. Furthermore, few studies have explored ways to increase presence. Thus, the purpose of this paper is two-fold: (1) to explore how presence and immersion are defined and distinguished (if so) in the literature and (2) explore possible methods that may increase presence in VR.

## METHOD

A mini review was conducted with a literature search involving two databases (PsycINFO and ProQuest) of peer-reviewed articles from 2016 to 2021 using key terms and AND/OR logics (Figure 1). The most recent five years were chosen as a way to clarify the most findings. Some literature was also identified via checking publications cited in those articles' reference lists, which were not restricted by date. Articles were initially screened based on title and abstract to determine whether an article was specifically exploring presence and/or immersion in VR. Additional inclusion/exclusion criteria are described in Figure 1. A thematic content analysis was conducted to explore the key words/phrases used to define presence and immersion and also the share terms between presence and immersion.

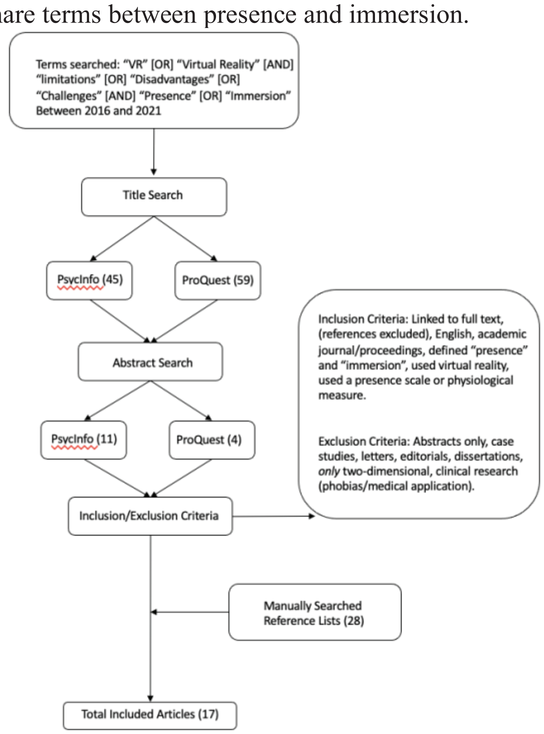


Figure 1. Literature search and screening procedure.

An initial search revealed 132 matches for keywords and terms which were narrowed down to 17 articles at the end of the process. We plan to extract various information such the definition of presence and immersion, how they were manipulated (and any limitations), a well as the findings on subjective and objective behavioral measures. This present paper analyzes how each study defined presence and immersion related to VR and provides a brief summary of how to improve presence and immersion.

## RESULTS

### Definitions of Presence and Immersion

First, each term's [total discovered] definitions (presence = 11; immersion = 6) were input into *MonkeyLearn,* a word cloud generator. Word clouds are visual representations of words used in text. The more often a word is used within a given text, the larger that word is in the cloud. The visualization for presence revealed four meaningful words/phrases: environment, illusion, experience, and subjective feeling (Figure 2). The phrase, "virtual environment" was excluded due to its contextual similarity to "environment". The visualization for immersion revealed three meaningful words: experience, system, and environment (Figure 3). The word "extent" is used frequently; however, in the absence of context it provides no value itself with regard to VR.


Figure 2. Word cloud for the term, "presence".


Figure 3. Word cloud for the term, "immersion".

In addition to the preliminary analysis using word cloud visualization, we also examined how each included article operationalized the terms presence and immersion. In its context within the definition, presence is generally associated with the *experience* of being in another place or situation – a detachment from *normal* reality and a perceptual attachment to a different reality (Table 1). On the other hand, immersion is associated with the more *technical* aspect related to the illusion. It is a more objective quality of VR insofar as the technology is capable of providing realistic feedback, general interaction, and its ability to allow the user to move and behave as they would normally (Table 2). The thematic content analysis revealed two themes: presence is experiential, immersion is the technical qualities of a system that aide the feeling of presence. This seems to fall in line with the Presence Questionnaire (PQ) by Witmer et al., (2005) suggesting that presence and immersion are related, but not completely identical, as the questions related to the abilities of the system loaded onto the *immersion/adaptation* factor of their scale, which accounted for 5.7% of the variance.

**Table 1.**
Definitions of presence related to virtual reality.

| Study | Definition |
|---|---|
| Roettl & Terlutter (2018) | Sense of being in a virtually mediated location instead of being in a real location. |
| Triberti & Riva (2016) | Cognitive process with the purpose to locate the Self in a physical space or situation, based on the perceived possibility to act in it. |
| Zahorik & Jenison (1998) | Tantamount to successfully supported action in the environment. |
| Lombard & Ditton (1997) | Perceptual illusion of non-mediation. |
| Slater (2018) | Illusion of being there, notwithstanding that you know for sure that you are not. It is a perceptual but not a cognitive illusion. |
| Pan & Hamiliton (2018)<br>Cooper et al. (2018) | Making you feel like you are somewhere else.<br>Subjective feeling of being present in the virtual environment, rather than the real space. |
| Makransky & Lilleholt (2018) | A psychological state in which the virtuality of the experience goes unnoticed. |
| Kisker et al. (2019). | The subjective feeling of being there in a virtual environment while the awareness of the physical environment and technical equipment diminishes. |
| Slater (2003) | The extent to which the unification of simulated sensory data and perceptual processing produces a coherent place that you are in and where there may be a potential for you to act. |
| Diemer (2015) | The perceptual distance between the actual experience and the simulated experience. |

**Table 2.**
Definitions of immersion related to virtual reality.

| Study | Definition |
|---|---|
| Slater (2018) | Objective property of the system, to the extent to which a VR system can support natural sensorimotor contingencies for perception including the response to a perceptual action. |
| Witmer & Singer (1998, 2005) | A subjective experience: the psychological state where one perceives oneself as being included in and interacting with an environment that provides a continuous stream of stimuli and experience. |
| Kisker et al. (2019)<br>Slater & Wilbur (1997) | The degree to which a technical system generates an inclusive, extensive, surrounding, and vivid illusion of reality. |
| Slater et al. (1996) | A quantifiable description of technology, which includes the extent to which the computer displays are extensive, surrounding, inclusive, vivid, and matching. |
| Shu et al. (2019) | The result of a good gaming experience that includes disconnection from the real world and real time, and involvement in the task environment. |
| Slater & Wilbur (1997) | To be shut out of physical reality, offering high fidelity simulations through multiple sensory modalities, finely maps a user's virtual bodily actions to the physical counterparts, and removes the participant from the external world through self-contained plots and narratives. |

## Improving Presence and Immersion in VR

Based on the findings of the reviewed articles and authors' understanding of other relevant domains and technology, the section summarizes methods that may be effective in improving presence and/or immersion in VR.

One way to enhance presence is to increase immersion. Older graphics cards render three-dimensional (3D) images through a series of polygons that can be shaded. New graphics cards, such as the NVIDIA RTX 2080 Super simulate the behavior of light by tracing the path it would take if it were traveling from the human eye through the environment, allowing it to create shadows and refractions (NVIDIA Developer, n.d.).

Multi-sensory feedback is also another way to increase immersion. Hecht et al. (2008) found that RT for trimodal signals were faster than RT for bimodal signals. The use of haptic feedback is now commercially viable and may serve as another sensory feedback system to supplement traditional visual and auditory stimuli (Figure 4). It is also possible to create haptic feedback outside of the VR environment. For instance, Simeonov et al. (2005) built a physical railing for participants to lean over when comparing height effects in real life and virtual environments using SSVR. Additionally, many studies such as Kisker et al. (2019) have employed the use of wooden planks or beams as a means for haptic feedback outside the virtual world, providing participants the sensation of having to balance while seeing a plank in VR.

Auditory stimuli in the environment could also play a role in presence and immersion. While conducting research, we often attempt to mute ambient sound for more experimental control. Although, this may not necessarily be beneficial for research conducted in VR. The cinema industry has led the way in terms of sound design to create a more intense sense of presence in movies and games (Serafin & Serafin, 2004). This may also be an overlooked but important aspect of developing relevant research design in VR if one were to attempt more realism for their study.

Emotion has often been linked to presence (Roettl & Terlutter, 2018), especially in regard to physiological or subjective arousal. Gromer et al. (2019) found that not only more detailed sound and visual stimuli led to higher ratings of presence within participants, but emotional responses also led to stronger feelings of presence during height exposure in VR. This is also related to Slater and Wilbur's (1997) definition that immersion encompasses the removal of a participant from the real world through self-contained plots and narratives.

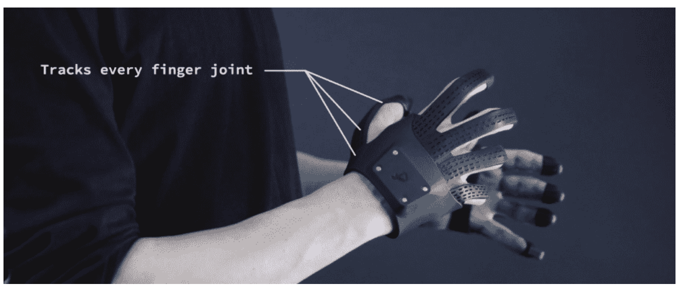


Figure 4. Plexus haptic feedback gloves for virtual reality systems, (Nadyrshin, 2019)

Lastly, newer technology such as commercially available LiDAR has been increasingly useful for 3D model rendering. It may now be possible to create more realistic avatars and other environmental features (such as furniture) via LiDAR scanning (Figure 5). With this in mind, we propose a new method of a slow integration into a virtual environment for research. A researcher can take a 360-degree video of a real room, where a participant is able to look around in all directions. Over the course of several minutes, 3D rendered models can fade into the environment, similar to that if one were transitioning from one scene to another in a movie. More realistic figures and objects afford the user a smaller leap into a virtual world and may provide a stronger sense of presence given more familiarity with their interaction in an environment (Figure 6).

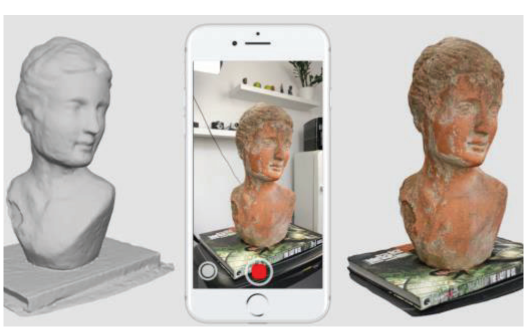

Figure 5. 3D rendering of a bust using a mobile application, (Sculpteo, 2021).

Figure 6. Transition of a real human from video to avatar in VR.

## DISCUSSION

The purpose of this paper was to examine and distinguish definitions of presence and immersion in an attempt to more accurately define them, as well as to provide a synopsis about how they may be improved in VR. Further, presence has been more often used in VR research when comparing two or more mediums to ascertain which is more practical or useful for a given purpose. Moreover, many studies relate to presence in the sense that it exists or does not exist under context-specific conditions in VR.

There are newer, commercially available options for enhancing immersion in VR, which can subsequently improve presence, such as haptic feedback gloves and vests and ray-tracing graphics cards. A more traditional method is sound design for auditory feedback taken from the entertainment industry. These newer technologies and re-visited methods may be instrumental in raising the ceiling effect for increasing presence. Lastly, we propose a LiDAR as a way to easily (and affordably) render 3D models to be used in VR which can be slowly transitioned into an environment to mitigate the uncanny valley.

There are a few limitations of the current study that could be addressed in future research. First, this mini review was based on article searches from only two databases, PsycINFO and ProQuest. A more comprehensive and exhaustive search with more databases could widen the coverage. Another limitation of this paper was the methodology. Thematic content analyses are subject to biases by the researcher(s). In addition, the preliminary analysis used word clouds for easier theme searchability; however, word clouds on their own as a sole means to a thematic content analysis tend to lack context. Despite this limitation, word clouds provide some unique values by visualizations which distinguished the terms while also showing that presence and immersion had been a point of contention in the past.

There is no question that involving new technological aspects for better immersion (ray-tracing graphics cards, haptic feedback apparel) is likely to be a more costly option as well suffering from usability issues both for researchers and participants. Moreover, Cummings and Bailenson (2015) found that immersion itself has a medium-sized effect on presence, although individual immersive features varied in their effect size. However, the advent of newer technology coupled with the ability to slowly transition a participant into a virtual world may prove to be worthwhile. Cummings and

Bailenson (2015) concur that the limitation of their meta-analysis is that it compares technologies that change and improve with time.

One potential future research is to explore commercially available LiDAR technology as a viable option to realistically render models in virtual reality. This technology has the potential to work along with ray-tracing graphics cards, better sound design, and haptic feedback, all of which may contribute to presence and immersion in VR, enhancing the VR experience as well as its value in research.

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