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# Toward a Unified Definition of Virtual Reality

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**Highlights**

Virtual Reality is moving into a phase of further innovations and new uses for the technology.
Use of the term Virtual Reality encompasses a plethora of modalities which can be confusing to many.
Virtual Reality definitions could include levels of immersion which consider characteristics of presence according to the senses of the user(s) they are designed to purposefully deceive.

**Key Points**

Precise definitions of Virtual Reality are needed as the application of the term engenders confusion.
The adoption of a standardized classification of Virtual Reality levels will provide greater clarity for authors, readers, and developers.
Manuscript authors should provide clear descriptions for their method(s) of Virtual Reality delivery.

**Key Words**

Virtual reality, augmented reality, immersive technologies, simulation

**Abstract**

Virtual reality will be widely adopted by nursing within the next five years as simulation method. The confusion generated by the various emerging definitions of VR led to the authors to review various definitions and to make a recommendation for the use of the concepts immersion and presence as a way to define VR.

# A Call to Unify Definitions of Virtual Reality

## Introduction

The adoption, application, and maturity of novel technologies often evolves according to a similar pattern which can be graphically represented. The Gartner Hype Curve depicts the trajectory of new and developing technologies that are created and come to market (Panetta, 2017). The commonly described phases of a new technology include: the trigger; the peak of inflated expectations, the trough of disillusionment, the slope of enlightenment, and the plateau of productivity. Virtual reality (VR) is now emerging from the Trough of Disillusionment, whereby the first blush of excitement is over and the initial interest has dissipated in favor of what is possible with immersive technologies. VR is now moving into the Slope of Enlightenment, a secondary wave of innovation begins and new uses for the technology are realized. In fact, according to a 2016 survey conducted on nursing schools in the USA by the National League for Nursing and the publisher Wolters Kluwer, within the next five years there will be substantial adoption of VR as a method of simulation (Tiffany & Forneris, 2018). According to Tiffany and Forneris (2018), the forecast for technology usage depicts that over the next 5 years VR will experience the greatest increase in adoption, pushing it from the current 10% use to 45%. VR articles are ubiquitous in online social platforms such as such LinkedIn, and Twitter and reputable professional blogs and websites; many VR articles are being published in healthcare and education journals. This article was prompted by various emerging definitions of VR with the healthcare literature. The confusion generated from the various definitions of VR terms led the authors to report on the definitions of VR over time, to review the examples of VR types in healthcare literature, and to discuss immersion and presence as a way of defining VR.

**Definitions of VR**

The range of relatively varied and heterogeneous definitions of VR that can be found in the literature (Table 1) highlight the lack of standardization or coherence. Historically, a call for precise definitions of VR is increasingly urgent as the number of related terms continues to grow and evolve (Cant, Cooper, Sussex,& Bogossian, 2019; Steuer,1992). Standardized clarity of terms is a high priority so that development and research can move forward through more informed user input. Adding to the complexity of defining VR, is the rapidly expanding field of augmented reality (AR) which is often considered a variant of VR by some, but is also viewed as a unique form of simulation (Tiffany & Forneris, 2018). It is thus also important to consider the range of definitions available regarding AR (Table 2).

**Exemplars of VR studies in literature**

A multitude of varying types and methods of VR were found using the search words "virtual reality simulation". VR studies which include "2D" methods have been used in rehabilitation (Atkins et al, 2018; Chen, Fanchiang, & Howard, 2018; Fasilis et al, 2018; O'Sullivan & Kearney, 2018). Hou, Shi, Lin, Chen, and Yuan (2018) completed a VR study using a monitor and haptic interface for surgical training. Studies using "3D" methods for virtual environments include those with head mounted displays (HMD's) and cave automated virtual environments (CAVE). Examples include a study evaluating a cranial tumor simulator as a means of planning for surgery (Mazur, Mansour, Mugge, & Medhkour, 2018). Deng et al. (2018) applied VR to learners' study of gross anatomy; Wiebrands et al. (2018) used VR to immerse users into virtual environments for studying biomolecular structures.

**Presence and Immersion**

Steuer (1992) suggested "the definition of virtual reality is based on concepts of "presence" and "telepresence," which refer to the sense of being in an environment, generated by natural or mediated means, respectively" (p.72). Telepresence is defined as a "medium induced presence" which is accomplished through vividness (sensory richness) and interactivity (ability to influence) of the environment (Steuer). Another important notion in relation to VR is that of immersion. Slater (2009) defined immersion as the sensorimotor contingencies (SCs) available within a virtual environment (Slater, 2009). SCs are the physical actions required within a specific environment to perceive and interact with a given environment, for example, bending and shifting to see something underneath an object or reaching and grasping an object. These are learned, for example, by wearing a HMD. "Valid actions" cause a change in the immersive environment while other actions do not. Valid sensorimotor actions vary by game or environment. Higher levels of immersion would result in higher levels of presence (Witmer & Singer, 1998).

Witmer and Singer (1998) developed a questionnaire to measure presence in virtual environments that has since been cited over 3,500 times in the literature. The researchers assert that presence is dependent on the participant’s ability to shift attention from their physical environment into the virtual environment, including the ability to exclude or ignore unrelated stimuli originating from the user’s physical environment. Presence in VR refers to experiencing the computer-generated environment rather than the actual physical locale. These authors describe immersion as the psychological reaction or response to the virtual environment (VE) which causes the participant to be enveloped by and interact with an environment that provides a continuous stream of virtual and haptic stimuli and experiences. “A VE that produces a greater sense of immersion will produce higher levels of presence” (Witmer & Singer, p.227). The critical aspects of VR include immersiveness *and* presence and can be used to describe its taxonomy.

Slater and Wilbur (1997) describe the Framework for Immersive Virtual Environments (FIVE framework) as a method for objectively assessing the characteristics of immersiveness and presence within a virtual simulation. Building on the work of Slater and Wilbur (1997), Miller and Bugnariu (2016) further developed the concept, as seen in Table 3. They link the degree of immersion to the participant’s subjective experience of the VE. The degree of immersion is linked to the participant’s sensory modalities that are triggered or purposefully deceived by the VR technology and environment. The more senses of the participants are accommodated in a non-perceptive manner as part of the VR experience, the higher the level of immersion achieved.

**Discussion**

VR is attractive in healthcare training because it can be used almost anywhere and anytime for learning or honing skills. As is generally the case with screen-based simulators, the feedback and scoring of participants’ achievement of learning objectives is computer-generated and consistent, decreasing the cognitive load of the learner while both educators and equipment manufacturers are trying to establish safer habit patterns (Schrader & Bastiaens, 2012). Equipment requirements are minimal as no medical equipment or consumables are needed.

The quality of the participant's experience is enhanced by computational power, wearable displays, interactivity, and sensor technologies. Participants (users) can practice at home, at work or at an educational facility, as long as the equipment is available. Although much progress has occurred, from a development and affordability point of view, the widespread adoption and use of virtual technology has been slower than predicted or hoped at the start of this century when various industries and users believed that by 2020 most simulation activities would be virtual as opposed to real (Panetta, 2017.)

**Recommendation**

Misuse of simulation terminology has previously been highlighted in the literature as it can raise false expectations and lead to confusion (Alinier, 2007). A lack of clarity continues with the terminology used to describe or differentiate both VR and AR (Cant, et al., 2019). These issues have led to a plethora of modalities understood to be VR. Shneider (2009) describes this as an expected stage in any new discipline. New scientific language and terms will be developed first. However, the lack of clarity creates problems when reviewing literature and comparing findings. Clarity will emerge as definitions for "VR" are standardized and further developed across the many modalities and disciplines. Cant et al. (2019) suggest a 3-step conceptual definition for VR including level of fidelity, immersion and patient depiction. We concur and suggest that the term VR be further delineated to include levels of immersion which consider characteristics of presence. The adoption of a standardized classification of VR levels are described as: *VR:Low*, *VR:Medium* or *VR:High* (Table 3). These general levels are based on the criteria developed by Slater and Wilbur (1997) and provide greater clarity for authors, readers, and developers. In addition, manuscripts accepted for publication should be asked to include clear descriptions of the method(s) of VR delivery.

The authors of this article recognize that AR does not typically rely on the concept of presence. However, if the physical environment has been virtually altered to change an otherwise generic physical room to resemble a fully equipped OR, complete with a mix of virtual and real equipment with virtual patient, then the augmentation has resulted in providing further immersion, and likely will produce an adequate sense of presence. This could be lead to some AR applications being considered a true VE. As AR continues to advance, physical elements will be enhanced to allow improved tactile capabilities. The success of any VR or AR depends on appropriate immersion and the creation of an environment that is conducive to the user's/learner's sense of presence and the ability for learners/users to meet learning objectives.

**Conclusions**

VR remains a relatively new technology and is being tested in a variety of contexts. Hybrid forms of AR/VR platforms *and* mannequin-based simulation are already present within the literature. To assist with the development of this emerging discipline—developers, authors, and reviewers are encouraged to clearly define terms and definitions when publishing; definitions should include specifications for the various levels of immersion *and* presence. This is critical in evaluating and comparing learner/participant outcomes of either VR or AR. The quality of the virtual system (including virtual environment and other enhancements) will determine how well presence is achieved by users. All end users should be careful not to fall into the same misuse of designations for "fidelity" of mannequins, where simulators were defined as either low, medium/intermediate and high fidelity. Such terms alone are now recognized as deficient when discussing realism. Nevertheless, the use of previously established definitions, when possible, and a clear paper-trail of new definitions, concepts and terms will help with standardization and provide clarity of the provenance of emerging terminology.

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**Table 1: Definitions of Virtual Reality**

| Definition | Source |
|---|---|
| **Virtual reality simulation**- "Simulations that use a variety of immersive, highly visual, 3D characteristics to replicate real-life situations and/or healthcare procedures; virtual reality simulation is distinguished from computer-based simulation in that it generally incorporates physical or other interfaces such as a computer keyboard, a mouse, speech and voice recognition, motion sensors, or haptic devices" (p. 40). | Lopreiato, et al. (2016). |
| **Virtual simulation**- (in Lopreiato, et al., 2016, P.42).<br>The recreation of reality depicted on a computer screen (McGovern, 1994).<br>A simulation involving real people operating simulated systems. Virtual simulations may include surgical simulators that are used for on-screen procedural training and are usually integrated with haptic device(s) (McGovern, 1994; Robles de la Torre, 2006).<br>A type of simulation that injects humans in a central role by exercising motor control skills (for example, flying an airplane), decision skills (committing fire control resources to action), or communication skills (as members of an air traffic control team) (p. 41) | Lopreiato,.,et al. (2016).<br>McGovern, K. T. (1994).<br>Robles de la Torre, G. (2006).<br>Hancock, et al., (2008). |
| **Virtual reality environment**- "A wide variety of computer-based applications commonly associated with immersive, highly visual, 3D characteristics that allow the participant to look about and navigate within a seemingly real or physical world. It is generally defined based on the type of technology being used, such as head-mounted displays, stereoscopic capability, input devices, and the number of sensory systems stimulated" (p. 40) | Lopreiato, et al. (2016). |

| | |
|---|---|
| **Virtual reality-**<br>• "The use of computer technology to create an interactive three-dimensional world in which the objects have a sense of spatial presence; virtual environment and virtual world are synonyms for virtual reality" (Department of Defense, 2018).<br>"A computer-generated three-dimensional environment that gives an immersion effect" (p. 40)<br><br>• (also known as "computer-assisted simulation, computer-based simulation). "A computer-generated reality, which allows a learner or group of learners to experience various auditory and visual stimuli. This reality can be experienced through the use of specialized ear and eyewear." (p. 47). | Department of Defense (2018).<br><br>Lopreiato, et al. (2016).<br><br>INACSL Standards Committee: INACSL standards of best practice: Simulation^SM Glossary. (2016). |
| • "an artificial environment which is experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment; also: the technology used to create or access a virtual reality."<br><br>• "Virtual reality is best described as a collection of technologies that allow people to interact efficiently with 3D computerised databases in real time using their natural senses and skills…. It is an immersive technology" (McCloy & Stone, 2001, 912). | Merriam-Webster.com.<br><br>McCloy & Stone, 2001. |
| • "computer-generated simulation of a three dimensional environment the user is able to view and manipulate or interact with" (p. 315).<br>• Identify that key features of the VR environment include: a) three-dimensional imaging, b) the ability to actively interact with the virtual environment, and c) visual and auditory feedback and further points out that it should prevent users from perceiving any elements of the real world by being completely immersed into the virtual environment. The best example are the flight simulators where the users are part of the simulated experience. (p.392). | Kilmon, et al. 2010.<br><br>Mantovani et al., 2003. |

| | |
|---|---|
| • "a collection of technologies that allow people to interact efficiently with 3D computerized databases in real time using their natural senses and skills" and is described by behaviorists as, "an advanced form of human–computer interface that allows the user to interact with and become immersed in a computer-generated environment in a naturalistic fashion" (p.230). | Riva 2002. |
| • "A real or simulated environment in which a perceiver experiences telepresence" (p.75) | Steuer 2003. |
| • "a computer generated display that allows or compels the user (or users) to have a sense of being present in an environment other than the one they are actually in, and to interact with that environment" (, p.25). | Schroeder, 1996. |

**Table 2: Definitions of Augmented Reality**

| | |
|---|---|
| **Augmented reality is:**<br>• **"**A type of virtual reality in which synthetic stimuli are superimposed on real world objects usually to make information that is otherwise imperceptible to human senses perceptible"<br><br>• A technology that overlays digital computer-generated information on objects or places in the real world for the purpose of enhancing the user experience (DoD, 2018).<br><br>• The combination of reality and overlay of digital information designed to enhance the learning process.<br><br>• A spectrum of mixed reality simulation that is part way between the real world and the virtual world (p. 206).<br><br>• "A form of virtual reality that includes head mounted displays, overlays of computer screens, wearable computers or displays projected onto humans and manikins" (p.4).<br>• "[a technology which] supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world. While many researchers broaden the definition of AR beyond this vision, we define an AR system to have the following properties: combines real and virtual objects in a real environment; runs interactively, and in real time; and registers (aligns) real and virtual objects with each other." ( p.34**).** | From Lopreiato et al., 2016.<br><br>Department of Defense (2018) DoD Modeling and Simulation Glossary.<br><br>Berryman, 2012.<br><br>Bajura, Fuchs, Ohbuchi, 1992.<br><br>Fuchs et al., 1996.<br><br>Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001. |

**Table 3. Aspects of Immersion:** Examples of virtual environment characteristics by level and aspect of immersion

| ***Aspects of Immersion*** | | | | | |
|---|---|---|---|---|---|
| ***Level of immersion*** | ***Inclusiveness*** | ***Extensiveness*** | ***Surrounding /Plot*** | ***Vividness*** | ***Prop. Matching*** |

| | | | | | |
|---|---|---|---|---|---|
| Low | Numerous signals indicating the presence of device(s) in the physical world (e.g., use of a joystick or mouse to control the VE, direct instruction from an experimenter during the task) | Only accommodates 1 sensory modality (e.g., auditory, visual, motor/proprioceptive); stimuli are not spatially oriented | Computer monitor presentation with limited field of view | Low fidelity and visual/color resolution; display may replicate features of the simulated environment, but not in a detailed or specific manner | No motion capture; visual experience does not match proprioceptive feedback |
| Moderate | Some signals indicating the presence of device(s) in the physical world (e.g., noise from a computer fan, weight and movement restriction from wearing a safety harness) | Accommodates 1–2 sensory modalities (e.g., auditory, visual, motor/proprioceptive); stimuli may or may not be spatially oriented | Large-screen projection with extended field of view | Moderate fidelity and visual/color resolution; display replicates some features of the simulated environment, but some detail may be missing | Body segment motion capture (e.g., head, hand); visual experience somewhat altered to match proprioceptive feedback based on head or body segment movement |
| High | Limited signals indicating the presence of device(s) in the physical world (e.g., the weight of an HMD or an eye-tracking device) | Accommodates >2 sensory modalities (e.g., auditory, visual, motor/proprioceptive); stimuli are spatially oriented | Head-mounted device or surround projection | High fidelity and visual/color resolution; display closely replicates multiple features of the simulated environment in great detail (e.g., correctly placed, dynamic shadows) | Full-body motion capture; visual experience altered to closely match proprioceptive feedback based on whole body movement |

Source of table: Miller, H.L., Bugnariu, N.L. (2016). Level of immersion in virtual environments impacts the ability to assess and teach social skills in autism spectrum disorder. *Cyberpsychology, Behavior and Social Networking*, *19*(4), 246-256. doi:10.1089/cyber.2014.0682. 