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# Human Factors in the Design of Virtual Reality Instruction

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Human Factors in the Design of
Virtual Reality Instruction

by
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## Abstract

The objective of this project was to identify measurable factors that contribute to the quality and effectiveness of training and education in a virtual reality environment. The second objective was to develop a VR application using the Oculus Rift head mounted display and hand controllers to present high resolution 360° video with cumulative multi-choice challenges to create a mental state of flow, immersion, and a suspension of disbelief. Finally, this document represents a guideline on how to produce virtual reality education and training content with a real-world example of the process from research, design, production and use.



**Keywords:** Virtual Reality, Mixed Reality, Augmented Reality, Training, Education, Flow, Immersion, Suspension of Disbelief, Instructional Technology, Instruction, Learning, Skill Development, Curriculum Development, Simulation Based Instruction

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## Glossary of Terms

| | |
|---|---|
| Virtual Reality (VR) | A medium that surrounds the user in an interactive environment. |
| Head Mounted Display (HMD) | A high-resolution screen worn over the eyes with head tracking sensors allowing the user to look around in a virtual environment. |
| 360° Video | A video format that uses panoramic imagery played in a sphere around the user's perspective. |
| Flow | A mental state of focus on a task that is characterized by heightened attention and increased retention of information. |
| Suspension of Disbelief | The act of not questioning the validity of an experience. |
| Immersion | The feeling of being in an experience fully as if it is reality. |
| Computer-aided Education | Any instructional content presented using a computer. |
| Computer Generated Imagery (CGI) | A 3D modeling technique that allows animation of virtual elements. |
| Optimal Experience | A measurable event and that internal and external factors influence it. |

# 1. Virtual Reality as a Medium

We shape our tools and thereafter our tools shape us. This phrase has been used by many people to describe how the communication tools we create and use affect our concepts about reality and even our ideas of what is possible. The latest evolution of interactive media is demonstrating this in a profound way that promises to shape how people communicate, learn, and play.

Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) devices are now readily available at a consumer level price point. Currently, VR, AR, and MR are presented through computer-generated simulations allowing users to experience virtual environments with user interfaces that provide visual, auditory, and sensory experiences, transporting users into a different reality. Head Mounted Displays (HMDs) are worn over a user's eyes, as they move their head, the perspective changes with their movements. Hand controllers with haptic feedback are used to interact with the environment further. These user interfaces create a remarkably realistic sense of immersion in a virtual environment.

Using virtual environments to communicate is an ancient concept that has fascinated people throughout history. Ancient temples and cathedrals were versions of some of the first virtual environments, as they were created to evoke emotions and present narratives that allowed the audience to experience a different reality. Staged plays with elaborate sets, actors in costumes, and special effects such as smoke and lights have been used for centuries to immerse the audience into a virtual reality. In modern history, Walt Disney created narrative environments with extensive spatial interfaces and virtual realities when he built Disneyland's "Pirates of the Caribbean" and other theatrical experiences that created fully immersive virtual environments (Pearce, 1997).

Now, most computer-generated virtual environments are created with low fidelity, 3D models, and 3D rendered environments using Computer Aided Graphics (CGI). The CGI method to create virtual environments was first used in the 1980s and became the primary tool for video game development and experimental simulation training by NASA and the US Military. Creating virtual environments using CGI is a time-consuming process requiring a high degree of skill, expensive software, and powerful computers. Even with state-of-the-art technology life-like realism has remained elusive for CGI virtual environments.

Advances in digital video cameras and software that stitches and renders 360° imagery and video have steadily brought increased resolution, frame rate, and ease of production are making it easier and quicker to create photorealistic, virtual environments. This rapidly changing technology is making the production of 360° imagery and video drastically quicker and cheaper than creating the rendered CGI virtual environments.

In recent years, massive strides have been made in technology increasing computing power, improving screen resolutions, and enhancing graphics. These advancements in technology allow immersive VR, AR, and MR to come center stage as a practical method to present photorealistic virtual environments to the masses.

Like all evolutions in communication technology, the emergence of VR provides new opportunities to create and deliver more sensory rich information. To create effective content in VR requires a next level approach compared to other mediums. With other mediums like print and video, the user's attention is intuitively focused on the nature of the medium, such as the text on the page, the framing of the video, or the duration and pace of the audio. With VR, the user can look away from the intended subject and disregard the pace and timeline of the content, but still be immersed in the experience. This dynamic makes the creation of VR content more complex than the creation of other media content, but it also makes the experience more realistic.

## 2. VR's Application in Learning

Training is generally characterized as the development of specific skills while education is the accumulation of theoretical knowledge about a subject. The use of VR shows promise in both training with simulations that provide instruction and practice of skills, and academic education that explains complex topics in interactive and visually compelling ways. In both cases, VR instruction has been shown to be effective at fostering intrinsic motivation, reflective thinking, and perceived learning effectiveness, three key elements of effective learning content (Zhang, Jiang, Ordóñez de Pablos, Lytras, & Sun, 2017).

Today, workforce training and academic instruction is still delivered much how it has been for decades. The gold standard is in-person instruction, though computers have been used to educate and train people for decades. Computer-aided instruction provides ease of access from anywhere as it fits in the user's schedule, it maintains consistent standards, and reduces the need for travel. Computer-aided instruction takes a variety of forms such as text, illustrations, videos, video conferencing, interactive presentations, and story driven games. While computer-aided instruction is effective for some applications it is generally unsuccessful in maintaining users' interest (Monahan, McArdle, and Bertolotto 2008).

My project investigated overlapping topics in e-learning, psychology, and VR technology that provide meaningful and timely knowledge about how to best use VR to communicate and learn. Three key factors leading to improved memory and skill retention of instructional content in VR were identified.

First, to create the optimal state of mind for learning, the VR training content needs to create a *psychological state of flow* for the user during the training experience. Second, is to produce training content that encourages a *suspension of disbelief.* Third, is to develop a *sense of immersion* within the training experience, an element that is essential in order to create flow and the suspension of disbelief.

**Flow** is a psychological condition characterized by a heightened state of focus, a decrease in distraction, and an increase in the short and long-term retention of information experienced during that state. Being ''in flow'' is the subjective experience of engaging just-manageable challenges by tackling a series of goals, continuously processing feedback about progress, and adjusting action based on this feedback (Csikszentmihalyi, 2014a).

**Suspension of D isbelief** allows users to believe the unbelievable and resist judgement of authenticity; it's the cognitive act of accepting information as fact. Suspension of disbelief allows the user to accept the virtual experience as real, even with its constraints of movement or lack of visual or audio realism (Muckler, 2016).

**Immersion** is a satisfying psychological state of perceiving to be in an environment that meets expectations. A sense of immersion is achieved when the user's experience feels like the real world with scenarios and interactions they would expect in the real world, allowing them to relax their focus on what is different than reality (Douglas, 2000).

## 3. VR Instruction as a Technical Communication Challenge

My primary objective was to identify measurable factors that contribute to the quality and effectiveness of instructional content in virtual reality. Then, build a proof of concept that incorporates these factors in a virtual reality instructional experience. Finally, to create this document to represent the experience, the knowledge gained and lessons learned, developing an instructional virtual reality experience.

The project applied the Technical Communication core competencies learned during the coursework and mentoring I received at Montana Tech. The project encompassed the User Experience (UX) design process with a discovery phase, a product definition, ideation, testing, prototype, and build & deployment phases (Lauer & Brumberger, 2016).

## 3.1. Project Planning

The goal of this project, to create effective learning experiences in VR, began with a plan that outlined manageable tasks and divided them into phases. The project planning phase outlined a research timeline, estimated a budget, and identified the skills needed to execute the project. This plan grew and adapted as my research unveiled new best practices and the technology changed.

## 3.2. Solution Design

After researching what makes an effective learning experience in VR, I began identifying criterion for the proof-of-concept. This stage of the project included a forward-looking survey of VR hardware and software available, the business trends that were expected to reveal new hardware and software, and how those tools can sustainably provide development options to effectively deliver learning experience in VR.

## 3.3. Visual Communication

A key element in the production of a VR learning proof-of-concept module was determining how to best communicate visually compelling learning content in the VR medium. This project required a great deal of research and skill development in 360° video production, VR development methods, and information communication techniques. Best practices in VR communication evolved quickly as the technology matured.

## 3.4. Content Development

Real world educational content was needed for the application because the focus of this project is to develop a VR learning application encompassing factors of optimal learning experiences. I contacted industry experts to develop training curriculums that could be presented in VR, then, I produced 360° videos in real world settings to present these training curriculums.

### 3.5. Final Production

The final production of the VR learning application was the culmination of years of planning, research, and coordination. I worked with training experts, programmers, business analysts, and marketing professionals performing thousands of hours of work to accomplish this goal. The product is a functioning proof-of-concept that represents the principles of UX, content development, visual communication, solution design, and project management I learned throughout my graduate education in Technical Communication.

## 4. Literature Review

This literature review investigates sources shedding light on factors that influence instructional effectiveness within virtual environments. This review focuses on concepts detailing the application of 360° video, 360° imagery, and other sensory modes as tools to tell stories, share emotions, and communicate perspectives.

In addition, this review connects concepts about *flow psychology* and *instructional theory* within *virtual environments* and *simulation based instruction*. Finally, the review compares those concepts with research and theory to measure factors of *presence* and *immersion* in *virtual environments*, thus, identifying how these similar fields of study relate to *learning outcomes* using *360° video* based learning.

### 4.1. 360° Imagery and Video

In a fascinating series of academic work, Karol Kwiatek and Martin Woolner documented their research and real-world applications using 360° imagery and video to educate and increase awareness of cultural and historical stories (2012). They created “choose your own adventure” style narratives using innovative applications of web technology and 360° video and imagery.

These dynamic views allow the locational experiences of art, culture, and poetry to be shared around the world asynchronously, transporting the audience to the virtual environments.

*Cultural memory* can be described as a form of collective memory that conveys an identity with a location dimension. *Loco-descriptive narrative* is defined as an interactive narrative, which is designed to allow the audience to experience the location and to navigate between decision locations within the narrative (Kwiatek, 2012).

In one example, Kwiatek created a web-based 360° image and video experience of a location that inspired a poet. The audience visited the virtual environment and experienced the factors that inspired the poet. The experience allowed the audience to understand what motivated the poet by virtually walking a day in his shoes. The 360° loco-descriptive narrative allowed the audience to read poetry in the same environment that inspired the poet to create his poetry (Kwiatek, 2012). Another Kwiatek example of a 360° video project was of a church that was destroyed in World War II, with nothing but ruins left. Before the church was destroyed, photographers took film panoramas of the inside of the church. After the church was destroyed, this project created a 3D model of the church using the historic photos stretched over the 3D model. The project rendered 360° video from the 3D model and displayed the 360° video on a web-based interactive viewer. The users could see the church as it was before World War II.

Kwiatek is critical of simple hotspot-linked still panoramas like Google Street View because of the awkward transition. Instead, she describes how to create interactive storytelling with a mixture of 360° still imagery and 360° video. The goal of this imagery/video combination is to bring a photorealistic representation of the space into the story environment; mixing with video shows actions and transitions that call on people’s reflections and emotions about a place and an experience (Kwiatek, Woolner, 2009).

In another project, Kwiatek documented the use of 360° video to investigate learning. Through her research, she found that students were more motivated to learn about a given topic if the they were immersed in a 360° virtual environment. She found that these students were doing more self-learning and were not simply memorizing information for short periods of time.

Kwiatek found that immersive environments motivated learners to move at their own pace through a series of events and a “choose your own adventure” style narrative. In addition, to keep learners even more engaged, users could further explore topics of great interest including historical trivia and geographical spaces (Kwiatek, 2012).

Ramalho and Chambel are another research team that has investigated 360° video in similar ways. They use the term hyper video to describe 360° video and imagery with links between each other. Their research seeks to identify properties and parameters that leverage a multisensory approach to increase immersion and user satisfaction in different conditions. Ramalho and Chambel define immersion as “the subjective experience of being fully involved in an environment or virtual world.” They go on to say that immersion may be increased by a 360° surround imagery that includes additional sensory modalities in the experience such as locational audio and increased vividness through photorealism. Ramalho proposes that the feelings of immersion are strongly related with the perception of presence inside the virtual environment (Ramalho, Chambel, 2013).

In one project, they augmented a 360° video experience with a directional wind generator and a 3D sound stereo system. An emotional recognition system was used to track and log the user’s facial expressions. The emotional recognition system categorized eight emotions (neutral, anger, contempt, disgust, fear, happiness, sadness, surprise) throughout the experience. Using a task-based contextual inquiry process identifying errors, hesitations, and performance of the tasks, the results of emotional states were compared throughout the process. After the evaluation, users answered a series of questions. The research found that increasing the sensory realism with multisensory layers increased users’ perceptions of immersion (Ramalho, Chambel, 2013).

## 1.3. Suspension of Disbelief

Muckler researched how the suspension of disbelief during simulation based learning facilitated the retention of information. Her research determined that learners in a simulation environment must accept the unrealistic aspects of the experience to fully engage in the experience. (Muckler, 2017)

| Factors Necessary for Suspension of Disbelief (Muckler, 2017 ) | |
|---|---|
| 1. | Fidelity (realism and believability) |
| 2. | The Fictional Contract (users ability to feel immersed) |
| 3. | Psychological Safety (feeling that consequences of failure are not harmful) |
| 4. | Emotional Buy-in (how relevant and applicable the experience is) |
| 5. | Assigned Meaning (the message the experience holds) |

**Figure 1: Factors Necessary for Suspension of Disbelief**

Fidelity is the degree of realism and believability of the simulation. This is a result of the learner's familiarity with the simulated environment, the degree to which they can interact with the simulated environment, and the realistic nature of the scenario. Emotional buy-in is based on how relevant and applicable the simulation is to the learner's understanding of the tasks and the learner's goals for experience. The simulation must invoke the emotions of the real-life event and the learner must experience an emotional attachment to the experience. The fictional contract is based on the learner's ability to feel immersed in the simulation, how easily they get into character as the star of the simulation, and their ability to play along with the simulation. (Muckler, 2017)

Psychological safety is built by creating a simulation that is conducive to learning. The learner must feel confident enough to take risks and feel like consequences of failure are not overly harmful. The learner must feel free from humiliation or serious penalties if they make poor decisions or fail the training. Assigned meaning depends on how the learner assigns meaning to the experience. The assigned meaning incorporates elements of fidelity, emotional buy-in, and psychological safety. (Muckler, 2017)

## 1.4. Instructional Design in Virtual Environments

Cook performed research on applications of technology to enhance simulation as an educational tool. His research team identified advantages and disadvantages of instructional simulations depending on the mechanisms, instructional objectives, and context. Based on a review of simulation instruction studies in the healthcare industry, Cook identified instructional design features that led to effective simulation and measured them across several case studies.

| | Key Factors of Effective Instructional Simulations (Cook, et al, 2013) |
|---|---|
| 1. | Context Variation (multiple scenarios) |
| 2. | Cognitive Interactivity (repetition, feedback, task variation, task sequencing) |
| 3. | Curricular Integration (required as a formal element of training program) |
| 4. | Distributed Practices (training spread over time) |
| 5. | Feedback to Learning (telling them what they did right and wrong) |
| 6. | Group Practice (two or more learners interacting) |
| 7. | Individualized Learning (responsive to individual learners needs) |
| 8. | Mastery Learning (learners must attain standard of performance before advancing to next task) |
| 9. | Multiple Learning Strategies (mixing work example, discussion, feedback sequencing, task variation) |
| 10. | Range of Task Difficulty |
| 11. | Repetitive Practice |

Figure 2: Key Factors of Effective Instructional Simulations

Other research on instructional design with e-learning technology has laid a clear framework on how to measure instructional effectiveness of technology-based learning. Liaw, Huang and Chen each have a large body of work in e-learning and evaluation of effectiveness in online education. Liaw describes how surveying personal attitudes about educator's perceived experience with the e-learning technology can determine how effective the education experience is. Instructor attitudes can be determined with questions that measure perceived usefulness of the technology and the user's feelings of self-efficacy with the e-learning technology (Liaw, Huang, & Chen, 2005; Liaw, 2007).

Identifying educator and student anxiety and comfort with the technology is a key factor in educational effectiveness of an e-learning tool.  Comfort with the technology can be measured with questions about the difficulty they have using the tool to accomplish their tasks. Anxiety with the use of the technology can be measured with questions that identify the educator's perceived usefulness of the tool and perception of their ability to accomplish their tasks within the with the technology (Liaw, Huang, & Chen, 2006).

Zhanga, Jianga, Ordóñez de Pablosb , Lytrasc and Sun contributed greatly to the body of knowledge of VR by researching what factors influence perceived effectiveness of VR instruction in users. Their research found that Task Technology Fit while using VR as a learning tool was a basic requirement. While VR learning content may offer a high-fidelity experience, a great degree of user control, and accurately represents the real-world, it will not necessarily facilitate the development of conceptual understanding. Appropriate learning goals and UX that utilize the hardware is essential for learners to feel the experiences useful and easy to use.

They found perceived learning effectiveness in users requires the technology to be accessibility and have a high quality. The curriculum and learning goals must be a good fit for the technology and the information presentation. Finally, the experience must stimulate a process of reflective thinking in the user. If these factors exist, the user is likely to have a high degree of perceived learning effectiveness which is a core element of effective instruction. (Zhanga, et al., 2017)

## 4.2. Presence, Immersion, and Flow in Virtual Environments

The investigation in factors that make 360° video and imagery effective for instruction highlighted the importance of Presence and Flow in the discussion. Mihaly Csikszentmihalyi's earlier research makes the case that an **Optimal Experience** is a measurable event and that internal and external factors influence it. Optimal Experiences are an ordered state of consciousness, depending on factors of information flow, too much or little, predictability, and usability of the information all affect the experience.

Within an Optimal Experience, the person is challenged to the edge of their skills. While the challenges in the experience do not exceed what the person can accomplish. The Optimal Experience is the state in which a person does not feel anxiety because they cannot accomplish the task, but they are not bored from lack of tasks or tasks below their skill level. An optimal experience is a state in which thought is ordered in response to continual challenge, without internal conflicts of worry or other distractions. The person is focused on the challenge at hand without thinking about other things. The person is in a state of **Flow** within a stream of information with complete concentration on achieving successful reactions to the challenges. (Csikszentmihalyi, 2014a)

In *Flow*, Mihaly Csikszentmihalyi's outlines his research on the characteristics of a heightened psychological state that is measurable and can be created with a reliably repeatable process.

| Conditions That Allow Flow (Csikszentmihalyi, 2014a) | |
|---|---|
| **1.** | Opportunities for action that are challenging and appropriate at the current skill level |
| **2.** | Clear and achievable goals |
| **3.** | Immediate feedback about progress |

Figure 3: Conditions That Allow Flow

Flow is identified as the psychological state of the optimal experience, one in which, “experience seamlessly unfolds from moment to moment”. As Flow is achieved, the individual thinks less about the past and the future, focusing on the moment with few internal distractions. When in a state of Flow, memories, future plans, anxieties, and self-consciousness are put out of the mind.

| Characteristics of Flow (Csikszentmihalyi, 2014a) | |
|---|---|
| 1. | Intense focus on tasks in the present moment |
| 2. | Action and awareness are closely connected |
| 3. | Loss of self-consciousness |
| 4. | A sense of control and self-efficacy |
| 5. | Distortion of temporal experience, time passes faster |

**Figure 4: Characteristics of Flow**

Csikszentmihalyi, reports about his experimental research that measure how the state of Flow compares to motivational aspects of learners and learning outcomes of a game-based learning experience. The game Csikszentmihalyi used was a locational history game using mobile devices, learners were asked to play the game while observers watched for excitement and engagement, key indicators of flow. The learners were then given questionnaires to measure self-efficacy and flow, then given an exam to test learning outcomes.

A chief conclusion of this research was that technology that disrupted game play also interrupted the state of Flow and negatively impacted learning outcomes. Sense of learner’s self-efficacy within the game also impacted Flow and learning outcomes. The game play was tailored to high school and college learners who found it challenging and engaging, while learners younger than that found it too difficult to achieve Flow while playing. (Csikszentmihalyi, 2014b)

In other research by Douglas, the pleasure principle is identified as a concept that affects engagement and the perception of favorable experiences. The idea comes from an analysis of the affective dimensions of an audience as they experience a story, and the factors that make it a pleasurable experience for them. The factors include all elements of how the story is experienced: audience's assumptions about the continuity of the characters, narrative twists, timeline, plot resolutions and setting. All these factors influence the affective dimensions: the mood, feelings, and attitudes of the audience.

Designers of interactive experiences are faced with challenge of creating stories and interfaces that lead the audience through the experience while carefully managing their affective dimensions. The research analyzed interactive narratives with scheme theory.

Schema theory charts how information shapes the audience's perception and the choices the audience make by breaking the experience down to its fundamental blocks of comprehension. Schema's are connected groups of contents that represents concepts and knowledge about the world that the audience uses to perceive, understand and act. The audience's expectations, perceptions and actions are based on the schema, setting up their affective dimensions as the experience unfolds.

The Pleasure Principle is that we can trace the pleasures we enjoy from an experience directly from how well the schemas interact with the audience's expectations. Comfort and pleasure is greatly influenced by how the schemas fit within the audience's expectations. Immersion is a result of being swept away by the expected flow of schemas.

> *"The pleasures of immersion stem from our being completely absorbed within the ebb and flow of familiar narrative schema. The pleasures of engagement tend to come from our ability to recognize a work's overturning of conjoining conflicting schemas from a perspective outside the text, our perspective removed from any single schema."*

Shifting expected schemas in the narrative create engagement through suspense and tension, because the changing schema keep the audience focused. While meeting expectations creates immersion in the experience by relaxing the audiences focus on the schemas because they are predictably delivering what is expected.

> *"Just as immersion is satisfying as long as local details infuse the schema with unique or unpredictable elements, so engagement remains pleasurable only when it displaces or subverts one schema while offering readers suitable alternatives."*

The pleasure in an interactive narrative comes from the way the audience's meaningful choices navigate the story. Immersion and engagement are not mutually exclusive or polar opposites. (Douglas, 2000)

In earlier research from Dinh in 1998, his research team experimented with 322 participants to investigate effects of multisensory layers on the audience's sense of presence and their memory recall after a virtual environment. The reported results suggest that increasing the sensory modalities directly increase the sense of presence and memory retention of experiences within the virtual environment. The research used a very simple 3D rendered space with an office layout. The experiments requested users to familiarize themselves with the virtual environment software under a cover story that it is to be used for real estate sales. After the experience, the audience was given questionnaires to test their memory of key landmarks within the virtual environment. The sensory modes were adjusted and the resulting changes in memory retention and sense of presence were recorded. (Dinh, et al, 1999)

The authors found a strong connection with tactile, olfactory and auditory cues and the increase in the sense of presence and memory of the virtual environment. While, this study did not see an increase in presence and memory retention with the increase of visual detail.

Dinh acknowledges that other research showed an impact on presence from changes in visual detail, and images of the test virtual environment included in the paper show a static, 3D rendered environment with very little physical variety or landmarks so in increase visual detail in this case will not change the experience much. Dinh’s research supports the idea that the more immersive the virtual environment is in each of the sensory modalities the more intense the sense of presence will be for the audience. (Dinh, et al, 1999)

The late 90s was a hot time to research presence, immersion and flow in virtual environments, Witmer wrote a seminal paper laying out a method to measure the extent a person feels presence while in a virtual environment. The authors describe presence in the case of virtual environments as the subjective experience of being in the virtual environment while physically situated in another. Witmer’s research is based on the belief that presence is a normal awareness phenomenon, requiring directed attention and is based on sensory stimulation, involvement leading to immersion, and internal tendencies to become involved. Degrees of presence depend partly on the allocation of the attention resources of the audience and the individual factors of sensory stimulation and immersion.

Presence is a matter of focus, the more a person’s attention is directed at something, on the other hand, when a person is in a novel, immediate, or arousing environment, their focus is broadly applied to the overall experience. Selective attention is the allocation of attention resources towards information that is meaningful and interesting to the audience. The author’s argument is that presence requires the ability to focus on one meaningfully coherent set of stimuli.

Involvement is the psychological state of focusing attention on a coherent set of stimuli, activities, or events. The amount of involvement depends on how well the activities and stimuli keep the observer’s attention. Immersion is the psychological state of perceiving to be in an environment providing a stream of stimuli and experiences. Involvement and immersion are both requirements for presence.

Witmer grouped the factors of presence into four categories affecting involvement and immersion: control factors, sensory factors, distraction factors, and realism factors. Witmer constructed a Likert style survey that tested each factor. After experiments on 152 subjects, the score of eleven of the twelve control factors, five of the seven realism factors, eight of the nine sensory factors and four of the six distraction factors correlate significantly with the total score of the Presence Questionnaire. (Witmer,1998)

| Factors of Presence (Witmer,1998) | |
|---|---|
| **Degree of Control** | More control over the environment provides the use with a greater sense of presence. |
| **Immediacy of Control** | Appropriate and apparent consequences of actions add to a sense of presence. |
| **Anticipation** | The ability to anticipate or predict the environment increases sense presence. |
| **Mode of Control** | The more closely the manner of interaction relates to what is expected for the environment the greater the sense of presence. |
| **Physical Environment Modifiability** | The ability to modify the environment increases presence |

Figure 5: Factors of Presence

| Sensory Factors Affecting Immersion (Witmer,1998) | |
|---|---|
| **Sensory Modality** | Visual senses have the highest impact on the feeling of presence with other senses like sound, and touch contributing. |
| **Environmental Richness** | The greater the sensory information in each modality, the more a sense of presences is achieved. |
| **Multimodal Presentation** | The more completely all senses are engaged the greater the sense of presence. |
| **Consistency of Multimodal Information** | If the experience of each sense agrees with others it increases the sense of presence. |

| | |
|---|---|
| **Degree of Movement Perception** | The perception of movement increases the sense of presence. |
| **Active Search** | Control of focus within the environment can increase sense of presence. |

Figure 6: Sensory Factors Affecting Immersion

| Distraction Factors Affecting Immersion (Witmer,1998) | |
|---|---|
| **Isolation** | Isolation from reality as in a head mounted display, leads to a greater sense of presence. |
| **Selective Attention** | The audience's ability to focus or ignore distraction impacts the sense of presence. |
| **Interface Awareness** | The less the interface is noticeable, the greater the sense of presence. |

Figure 7: Distraction Factors Affecting Immersion

| Realism Factors Affecting Immersion (Witmer,1998) | |
|---|---|
| **Scene realism** | presence increases as realism increases |
| **Consistency of information** | with the objective world, the more consistent the environment is to the real world the easier presence is |
| **Meaningfulness of experience** | the more the experience becomes meaningful to the audience, the more presence increases |
| **Separation anxiety / disorientation** | the more present the audience feels in the environment the more they should experience disorientation upon returning to reality |

Figure 8: Realism Factors Affecting Immersion

Another chief investigator in presence and immersion is Slater has influenced many researchers in immersive virtual environments. Written at a time when virtual environments were just becoming a possibility, the authors identify "presence" as being the central goal and defining feature of virtual reality.

Slater analyzed the concepts of immersion and presence in virtual environments, proposing that the degree of immersion in a virtual environment can be objectively assessed and measured as a characteristic of the technology.

Slater contrasts immersion vs presence, identifying immersion as an objective and quantifiable description of what a virtual environment system is capable of, presence being heavily influenced by the factors of immersion.

> *"Immersion is a description of a technology and describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant. Inclusive (I) indicates the extent to which physical reality is shut out. Extensive (E) indicates the range of sensory modalities accommodated. Surrounding (S) indicates the extent to which this virtual reality is panoramic rather than limited to a narrow field. Vivid (V) indicates the resolution, fidelity, and variety of energy simulated within a modality (for example, the visual and color resolution). Vividness is concerned with the richness, information content, resolution and quality of the displays." (Slater, 1997)*

Slater described another factor of immersion as the ability of the virtual environment to match the user's real-world body movements inside the virtual environment. A self-representation of the user body as part of and the center of the virtual environment.

> *"Matching requires that there is match between the participant's proprioceptive feedback about body movements, and the information generated on the displays. A turn of the head should result in a corresponding change to the visual display, and, for example, to the auditory displays so that sound direction is invariant to the orientation of the head. Matching requires body*

*tracking, at least head tracking, but generally the greater the degree of body mapping, the greater the extent to which the movements of the body can be accurately reproduced." (Slater, 1997)*

Slater categorizes each dimensions of immersion with an associated scale, indicating the extent of its realization. The measure of matching includes the latency between action by the user and the response by the virtual environment. The final dimension of immersion described by the paper is plot, the degree that the virtual environment presents a self-contained storyline that is self-contained, has its own dynamic unfolding of events.

Presence is contrasted with immersion as being the perfect state of consciousness where the mind believes it is there within the virtual environment.

*"Immersion can be an objective and quantifiable description of what any particular system does provide. Presence is a state of consciousness, the (psychological) sense of being in the virtual environment." (Slater, 1997)*

These factors of immersion and their role in presence within a virtual environment have been frequently used and cited by researchers, making them a sort of standard measurement tool to analyze presence in virtual environment technology. (Slater, 1997)

## 5. Developing a VR Instruction Environment

My research and practice throughout this project revolved around understanding the psychology of learning, the production of the 360° video, and the development of interactive VR experiences for education and entertainment purposes. This accumulation of knowledge, technical skills in a variety of software, and development methods culminated in this project with the design and production of a functioning platform to present VR instructional content.

My literature review identified a list of core factors that contribute to effective instructional content. Because when I started this project in 2015, very little research had been published, testing the factors for effective instruction specifically in VR, I had to apply research form online learning, simulation learning, and human factors that affect memory retention and focus.

Creating a VR instructional environment that evokes Flow, Suspension of Disbelief and Immersion became the primary requirements during the development phase of the project. Using these criterion, choices were made to create a choose your adventure style software to curate and play 360° videos in a VR headset with interactive interactions.

1. The application should cultivate focus and memory retention by presenting the instructional content in a way that stimulates a Flow like psychological state in the user.
2. To promote buy in and encourage a psychologically safe learning environment the instructional content should build suspension of disbelief in the user.
3. To increase retention and interest in learning skills and processes the instructional content and VR equipment should facilitate a quality sense of immersion in the user.

## 4.3. The VR Hardware

The beginning of this project started with an analysis of available VR hardware. Based on past experiences and best practices in iterative design principles, I determined it was essential that the VR equipment had to be accessible to consumers, and reliably supported by the manufacture for the foreseeable future. The quality of the user experience and its ability to deliver a sense of immersion, suspension of disbelief and the functionality to create a state of

**Figure 9.** Student Wearing VR Headset

flow was another primary criterion. Another consideration was the ease and cost of development of the VR experience with the functionality determined from the research. Finally, the platform had to be capable of the quality needed to produce a high degree of immersion.

| My Hardware Selection Analysis | |
|---|---|
| **Consumer Access** | How easily will consumers access the equipment and instructional content. This includes the cost, operating system, and how easily it can be purchased? |
| **Manufacturer Support** | How well will the VR equipment manufacturer provide replacement parts, software updates, application development utility? |
| **Ecosystem Longevity** | How long after purchase will the manufacturer improve and maintain the development environment, hardware, and how long will applications developed for the system be useable before deprecation? |
| **Quality of user Experience** | How well will the head mounted display, audio systems, controls, menus, and ease of use provide a quality experience? |
| **Ability to deliver factors of effective Instruction** | How well will the system deliver Immersion, Suspension of Disbelief, and Flow? |

**Figure 10: My Hardware Selection Analysis**

There were three main VR ecosystems that promised to have the longevity and quality needed as this project started; the Oculus Rift, the HTC Vive, and Google Cardboard that became Google Dream. Each VR platform has advantages and disadvantages from a development standpoint.

Google Cardboard became Google Dream since 2015 when this project was started, it may eventually have the quality of Oculus and Vive but as this project started, the user experience was poor, limited to Android mobile devices requiring large video assets to be downloaded or streamed, making it difficult to deliver high resolution video to the application.

Google products come with a lot of risk for developers because of Google's philosophy of constant change and their track record of experimenting with products only to cancel the platform or change the direction of the technology quickly with no warning as they did with Google Glass.

HTC Vive was developed by the Valve video game company in collaboration with HTC. The Vive was a great option with only slightly lower quality as the Oculus but represented a similar risk because it was initially presented as an experiment but has since evolved into a stable platform with even more current development than Oculus.

The Oculus Rift was selected as the platform because of the massive investment being done by Facebook in its development. Facebook indicated clearly that Oculus was a platform that they intend to promote and improve for many years to come. The Oculus also had the highest HMD quality and offered extensive support for several development environments such as Unity and Unreal Engine. The features that made it clearly a better choice was the Facebook's early signals of building in social media capability and full, documented developer support. This made Oculus a platform that appeared to have longevity in a quickly changing technology landscape.

## 4.4. The software

After determining that the Oculus Rift was to be used, two development environments that supported the Oculus were analyzed, the Unity Game Engine and the Unreal Engine. Both have similar capabilities but Unity appeared to be more widely supported, a favorite for developers with an active developer community and a low barrier of entry with a free version and a wide range of tutorials and extensive documentation. Unity supports several programming languages, but C# was determined to be ideal because it is a favored by game developers for it is designed to be scalable and flexible for object oriented programming projects.

### 4.4.1. Application Development

After the delayed release of the Oculus Consumer Version 1 in June 2016 pushed the start of the project back a few months, the application development started in July of 2016. Software developers were given a series of goals for the application development and a budget of $5,000 to accomplish the programming. Two different software developers were hired during development because the first left the project for a job before it was completed.

The application is designed to deliver information rich, multi-sensory 360° video with a quick succession of questions about the content and instant feedback on the user's response, the sense of control, and quick pace of user challenges was designed to create a state of flow with a heightened state of focus in the user.

**The goals of the software development were as follows:**

- Build a Windows native application using the Unity Game Engine and C# programming language to deliver 360° video educational scenarios with formative and summative challenges.
- The trainings will be delivered through the Oculus Rift VR platform, using an Xbox one controller.
- The video assets and application will be stored on the PC and launch independent of the Oculus Home dashboard.
- The 360° video will be delivered in an equirectangular projection in an mp4 video format of the highest resolution and frame rate possible.
- The application allows the video assets and challenge questions to be easily changed in through by placing new video files in an assets folder and changing a text document pointing to the videos and editing the formative and summative challenges.

### 4.4.2. Elements of the application design:

1. An introduction to the training in the form of a starting screen will appear when the app loads giving the user an introduction and short description of how to use the app and the training content that the user is about to experience.
2. A training process menu in the form of a screen that allows the user to choose the training module with a title and a thumbnail for each scenario. The process menu appears after completion of each training module allowing the user to progress to the next module or go back to any of the previously completed modules.
3. Tutorial timeline control in the form of a menu of and start buttons for the user to control their progress through the tutorials. The tutorial plays a 360° video clip that goes through each step of the instruction modules. After each step is played the video pauses and triggers a formative question. If the user chooses the correct answer the training progresses to the next step. If the user selects the wrong answer the training replays the last step of the training module.
4. Identify the object challenge type in the form of a 360° panoramic image shown with a prompt for the user to identify a hotspot area in the panorama. The headset is used to look at the object and the Xbox controller is used to select it.
5. Multiple Choice Challenge Question in the form of a heads-up style multiple choice question is displayed at the end of each video clip. The Xbox controller is used to select the choices. The challenge question is relative easy and the user interaction is quick promoting a state of flow throughout the training experience.

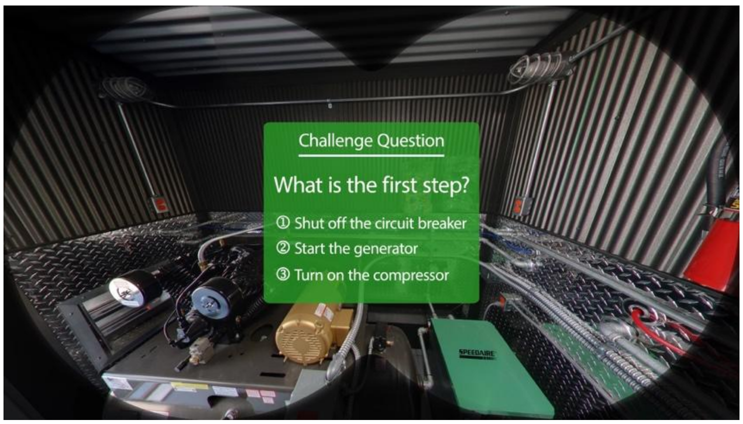

Figure 11: Multiple Choice Questions in VR

6. Success Screen and Progression in the form of a popup style message, "Correct" then progressing the instruction to the next 360° video clip.
7. Summative Questions in the form of a series of questions presented at the end of each module to review the information presented in the module. The Xbox One controller is used to select the answers.
8. Data Collection in the form of the results of the summative and cumulative questions collected and written to a text file.

### 4.4.3. The 360° Video Production

The instructional content is recorded in 360° video based on a curriculum designed by an expert in the topic. The videos are produced with the goal of immersing the user into a first-person point of view during instructional scenarios with real people demonstrating the skills and knowledge. The 360° videos are recorded and edited in short clips to facilitate quick user interactions between the cumulative challenge interactions.

## 6. Conclusion

This investigation has value for a wide variety of training, educational, and entertainment applications. The obvious is in academic education, industrial, medical, and business training scenarios where the skill or knowledge fits with the technology. By establishing a set of design criteria that lead to better focus and information retention through 360° video training has implications for marketing, psychotherapy, addiction treatment, cultural preservation, as well as almost any other communication purpose.

This project produced a stable training tool that can be easily customized depending on the purpose. The training tool incorporates the research in what an effective VR training experience requires. It uses quick, challenges and immersive 360° video and an easy to use user interface to create a state of flow and encourage a suspension of disbelief in the learner.

The low cost to capture 360° video of environments presents a great opportunity to build what feels like real world experience, with improved situational awareness for demanding situations. Trainings captured with 360° video and delivered with consumer level head mounted displays will be easy to access, low risk solutions to practice complicated maintenance tasks, emergency responses, skill development in complex situations.

This vein of research is very deep with massive potential because it is a relatively new field of research with the new lower cost capture and delivery technologies. In the future, capturing the 360° video in multiple perspectives including first and third person perspectives with a more dramatic storyline will encourage more immersion and suspension of disbelief. A script that drove the action in the video with quicker, more bite sized chunks of information allowing a faster pace for challenges would better encourage the state flow. A more polished user interface and a tutorial about how to use the application would improve the user experience.

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