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**Critical Literature Review
(ANTA602)**

***Measuring the impact of 360° Videography in
Antarctica for Educational Purposes***

Robert W. Lindeman

Student ID: 89241433

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Abstract

This report surveys the main issues and approaches to measuring *presence* as they relate to user experience design in virtual reality. The main focus is on how to evaluate the impact of using 360° video to capture and replay subject matter experts talking about specific topics *in situ* in Antarctica. Presence is typically defined simply as the sense of 'being there' in a virtual environment. Research over the past 20+ years, however, has shown that there are several important aspects of overall presence, and that each one requires careful evaluation. The three main aspects are Place Illusion (the feeling of being in the environment), Copresence Illusion (the feeling of being with others in the environment) and Plausibility Illusion (the coherence and believability of the environment itself).

Three complimentary methods for measuring all aspects of presence are discussed, including questionnaires, physiological measures and behavioural observations. Each has its own strengths and weaknesses, and it is advised that combining them should lead to the most robust measures of the impact of 360° video for Antarctic content and beyond.

Measuring the impact of 360° Videography in Antarctica for Educational Purposes

Rob Lindeman
Student ID: 89241433

Introduction

Capturing visual content in the harsh environment of Antarctica can be challenging, due to technical as well as environmental reasons. The potential impact that effective use of visual media can have on telling the important scientific and personal stories from Antarctica is massive. One major draw for going to the trouble of producing such *in situ* material is the idea that we can virtually transport people to 'The Ice' who could not otherwise get there. People who have been there, such as scientists, often exude a passion when talking with others about their Antarctic expertise. The current exercise provides a literature survey of methods of measuring the impact on viewers of using immersive media (360° video displayed using a virtual reality headset) of experts describing their field of study in Antarctica. The goal is to survey methods of assessing the effectiveness of presenting Antarctic content in 360° video format, as opposed to traditional (flat-screen) formats.

The results of this work will inform those wishing to use immersive 360° video as an effective media delivery mechanism, in the hopes of capturing the "Antarctic experience" in such a way that viewers feel present.

The Meaning of Experience

Through the course of preparation for my first visit to Antarctica, the one constant I have heard from people who have been to 'The Ice' is that it changes you, that you cannot really know what it is like until you have been there. Of course, I will not actually know how accurate these statements are, or how deep an impact Antarctica will have on me, until I get to The Ice.

Still, these recurring statements reminded me somewhat of how people talk about their first exposure to virtual reality (VR). Like any new experience, there is some element of a "Wow!" factor at play in both of these experiences. The question is, once this initial effect has subsided, is there something that leaves an indelible mark on people, such that they remember and retain the essence of the experience? Can some of the impact made by actually visiting Antarctica be conveyed using VR technologies, so that virtual visitors can experience some of the essence of the physical experience? These are the questions I will explore here.

The Perception and the Brain of Being There

Driver (2001) tells us that when we experience something, we perceive with our senses and filter with our brains. From my 20+ years of research into different aspects of VR, in most cases, our senses of sight, sound, touch, and smell all combine to help define the sensory experience. Each of our senses has evolved to provide different aspects of our

understanding of our surroundings, and each has strengths and weaknesses. In general, people are visually dominant, in that our vision system can capture a wide range of features (*e.g.*, colour, shape, movement, parallax, *etc.*), can process stimuli quickly, and can work across a wide range of environmental conditions (*e.g.*, low light). However, vision requires the stimuli to be within the user's field of view in order to be perceived. Audio is also an important sense, and expands the reach of the senses, in that (unlike the eyes) the ears hear even when they are not pointing directly towards a sound source. Sound is defined by the frequency, amplitude and location of a given sound source, and these values can change over time. The other senses (touch, smell, and taste) are also used in experiencing places, but do so in a more intrusive way, requiring stimuli to touch the body in much more complex ways. The VR technology for delivering stimuli to these "secondary senses" is much less defined, and will not be covered more here.

The fact that we have two eyes and two ears allows us to better perceive the space around us, either how far away things are, or how large they are, and in the case of audio, to get an idea of the direction and even elevation of sounds around us. Also, since we sense things over time, we can better sense the movement of objects because of these "stereo" cues. Visuals and sound also work in concert to give us a better overall understanding of the scene than either one could do by itself. Being able to hear an object approach while seeing it approach helps us to estimate its movement. If an object approaches from behind us, we will almost certainly hear it first, then turn to attend to it visually. To make sense of the vast amount and type of stimuli we perceive, we need to filter and process it with our brains.

While the exact nature of the filtering done by the brain is not known, it is a hot topic within both the perception and neuroscience literatures (see Driver, 2001 for a thorough review). In short, even in simple situations, there are far too many details for us to process everything, so filtering mechanisms help us choose what we actually notice. Current thinking (Driver, 2001) is that this is a combination of our previous experience and current expectations (or *priming*), constrained by our limited short-term memory. If someone is instructed to focus on one aspect of a scene (count the number of people moving around), they tend to miss other aspects (which shirt colour was most popular amongst the people). Some aspects of this are also referred to as change blindness (Chabris & Simons, 2010). A precise neuroscience formulation of the *nature of experience* is beyond the scope of this review. However, since we know that both sensing and priming play major roles, we will look at how to define and measure the feeling people have of visiting a place, which is called *presence*.

Defining Presence

Intuitively, to feel *present* is to feel like you are in a place, and the VR literature colloquially describes the notion of presence almost uniformly as the 'sense of being there' (Heeter, 1992; Slater, 2009). Heeter (1992) gives one of the earliest sets of definitions of presence, dividing it along three different axes: Personal Presence, Social Presence and Environmental Presence. Roughly, these can be respectively thought of as "I feel present," "I feel like we are present" and "I feel like the space reacts to my presence." These different aspects of the general term presence have subsequently been refined, expanded and debated.

A very recent historical review of the presence literature gives the clearest and broadest coverage of the aspects of presence (Skarbez, Brooks, Jr., & Whitton, 2017). The term *immersion* has generally been used to describe an *objective* measure of how much of the real world the system replaces with the virtual world (Slater & Usoh, 1994), as opposed to *presence* which exists in the head of the user, and is a *subjective* measure of the feeling of being there. As a simple example, a larger screen would be more immersive than a smaller one viewed at the same distance, since it covers more of the viewer's field of view. The relationship between immersion and presence is that more immersion (*e.g.*, a wider field of view) should be able to allow the user to more easily (and more deeply) achieve a sense of presence. Skarbez *et al.* (2017) formalise this, making the connection between *Immersion* leading to *Place Illusion*, *Consistency* leading to *Plausibility Illusion*, and *Company* leading to *Copresence Illusion*. The three Illusions can clearly be mapped to Heeter's axes described above. Skarbez *et al.*'s (2017) contribution lies in the connecting of the three factors (Immersion, Consistency and Company) to the three types of illusions. In Skarbez *et al.*'s (2017) model, they also mediate each of the factors with individual differences between viewers. So, in their model, they attribute to individual differences in the viewers the fact that not all stimuli lead to the same results for all users. One could see these as guidelines for how to best support users achieving a sense of presence: provide good immersion, be consistent and provide companions, while also considering the individual traits of the users.

VR technologies are designed to immerse the user in (mainly visual) stimuli. In general, there are two approaches for completely surrounding the user's view with virtual content. One involves the use of a head-mounted display (HMD), commonly referred to today as a "VR helmet" in the mass media (Figure 1). HMDs place a small display in front of each eye, track the rotation (and usually position) of the user's head, and update each display with the view of the virtual world according to these head movements. This means that if the user wants to see something to the left, she simply turns her head to the left, and the displays will show her that part of the virtual world. This is designed to mimic how we look around in the real world.



Figure 1: User wearing a commercial Head-Mounted Display (HMD)
(Photo: By Maurizio Pesce - <https://www.flickr.com/photos/pestoverde/17136177965>, CC BY 2.0, <https://commons.wikimedia.org/w/index.php?curid=39894108>)

The other main technology for visually immersing the user is to surround him within a large cube, with images displayed on each wall of the cube, and often the ceiling and floor (Figure 2). As with the HMD, the user's head is tracked, and the images on each wall are updated to match the correct point of view. The advantages of HMDs are their portability, small relative

cost for hardware, space and maintenance, and simplicity of design. The main advantages of CAVEs are the freedom of movement of the user, a reduced need to wear a heavy display on the head, and the ability to have multiple people be physically present in the same space, and using the same hardware. VR audio displays come in similar forms, but instead of an HMD or a CAVE, the user either wears headphones or is surrounded by a set of speakers. Since the user's head is tracked, the audio signals are processed to make them sound like they are coming from a given location in space, which is called *sound spatialisation*.



Figure 2: Cave Automatic Virtual Environment (CAVE) (By User:Davepape - own work (self-photograph using timer), Public Domain, <https://commons.wikimedia.org/w/index.php?curid=868395>)

Theoretically, if we can generate and combine visual and audio cues in such a way as to mimic what one would see and hear in an analogous physical space, then a person should feel present in the virtual space¹. Clearly, the sense of presence involves more than just sensory stimuli, as it is a feeling that exists in the brain. But since it is formed and is shaped to a large extent by what we sense, providing correct stimuli is crucial. But *which* stimuli, and *how much* is enough to elicit a sense of presence? This is what VR researchers have tried to answer using measures of presence. By varying the stimuli, and collecting data on the depth of presence felt by users, VR researchers have been able to form some overall guidelines about how systems should be designed to promote presence. Actually creating validated measures of presence has proven to be elusive, though some progress has been made.

Measuring Presence

Several approaches have been proposed for measuring presence in VR, including questionnaires, physiological measures and behavioural approaches.

Presence Questionnaires

There has been very active debate about how to define, quantify and measure presence in VR for more than 20 years. Witmer & Singer (1998) linked presence to *attention*, as well as to a particular user's *predisposition* to being engrossed by media, and developed two

¹It should be noted that VR is not limited to mimicking reality, but can also be used to create fantastical worlds. In this case, the world should behave as expected or at least in a believable, consistent way.

instruments, the Presence Questionnaire (PQ), and the Immersive Tendencies Questionnaire (ITQ). Sample questions from the PQ include: "5. How much did the visual aspects of the environment involve you?" (Witmer & Singer, 1998, p. 232) and "18. How compelling was your sense of moving around inside the virtual environment?" (Witmer & Singer, 1998, p. 232). Examples from the ITQ include: "5. Do you easily become deeply involved in movies or TV dramas?" (Witmer & Singer, 1998, p. 234) and "9. How frequently do you find yourself closely identifying with the characters in a story line?" (Witmer & Singer, 1998, p. 234). Using these two questionnaires together gives a sense of both the environment and the tendencies of the user.

The Slater-Usoh-Steed Presence Questionnaire (SUS-PQ), which the authors developed over several years and many studies (Slater, McCarthy, Maringelli, & Maringelli, 1998; Slater, Usoh, & Steed, 1995; Slater & Usoh, 1993, 1994; Usoh *et al.*, 1999) uses several questions, all variations on one of three themes: the sense of being in the virtual environment (VE), the extent to which the VE becomes the dominant reality, and the extent to which the VE is recalled as a "place" (Usoh, Catena, Arman, & Slater, 2000) . Sample questions include: "To what extent did you experience a sense of being 'really there' inside the virtual environment?" (Slater & Usoh, 1993, p. 93), and "3. When you think back about your experience, do you think of the office space more as *images that you saw*, or more as *somewhere that you visited*?" (Usoh et al., 2000, p. 499).

In a slight back and forth between these two groups, Slater (1999) presents a critique of the Witmer & Singer (1998) questionnaire, claiming while it is interesting to use in evaluating VR systems, it should not be used to measure and compare presence *per se*. Possibly in support of this argument, Usoh *et al.* (2000) present one of the most interesting studies exploring the fundamental effectiveness of questionnaires for measuring presence. They forward the notion that any instrument that purports to measure how present someone is in an environment that mimics a real-world scene should pass a "real-world test." They go on to describe an experiment in which they compare one group of subjects who performed a task (find a red box) in a real physical office space, and another group who performed the same task in a high-fidelity virtual replica of the same office space. They then compare the results from two different questionnaires, Witmer & Singer (1998) and their own. The interesting finding is that some participants actually felt *more present* in the VR version than the real version, and that their own questionnaire performed better than the one by Witmer & Singer (1998). Some of the feedback they received from participants about why they scored the real environment so low had to do with how the questions were interpreted. For example, on a question asking how realistic the experience was, some participants said that the real environment seemed a bit artificial, because there were no people in the real space (they had been removed for the study), and that the same question for the VR experience was interpreted as how realistic the graphics were. Since the fidelity of the graphics was high compared to other computer-generated experiences, they rated the *technology* high. The authors claim that the variations in the interpretations of the questions made the responses suspect, and that care should be taken when relying too heavily on questionnaire responses.

Physiological Presence Measures

To mitigate the subjective interpretation inherent in questionnaires, some researchers advocate measuring physiological changes in the user's body (Meehan, Insko, Whitton, &

Brooks, 2002; Skarbez *et al.*, 2017). The idea is that exposure to some types of scenes (*e.g.*, high platforms) induces involuntary changes in measures such as heart rate, sweating and skin temperature (Meehan *et al.*, 2002). If the measures collected while experiencing the virtual world align with those when experiencing similar environments in the real world, we can say that the person is feeling similar things, and so has some level of presence. The most cogent reporting of this comes from a study by Meehan *et al.* (2002). This paper describes three separate studies using the same virtual environment (Figure 3), consisting of a Training Room and a Pit Room with a 6m deep pit in the middle, and a 0.6m wide walkway around the edge. In some conditions, on the opposite side from the entrance to the Pit Room was a chair. Users were asked to perform several tasks in the environment (depending on the study), including walking over to sit on the chair. The SUS-PQ was administered in addition to collecting the physiological measures. The general findings are that heart rate correlates best with reported presence measures, and that there was some support for skin conductance (sweating) as a measure. Since the goal of this study was to identify reliable, valid, sensitive and objective measures of presence over multiple exposure conditions (Meehan *et al.*, 2002), they found support for physiological measures as a good instrument.



Figure 3: The Pit (Figure 1 from Meehan *et al.*, 2002, p. 645))

Behavioural Measures of Presence

As early as 1992, researchers have conjectured that how one behaves while immersed in VR could be used to assess how "real" they feel the experience is (Sheridan, 1992). Similar to the approach of physiological measures, if there is a match between actions in VR and actions in a similar real-world experience, we should be able to say the person feels present in the VR experience. For example, if a person feels some sense of fear, as evidenced by triggering of responses to known phobias (Regenbrecht, Schubert, & Friedmann, 1998), within VR, we can say their behaviour mimics what they might exhibit when exposed in the real world. In two studies into behavioural measures of Copresence Illusion, Bailenson *et al.* (2004) showed that subjects maintained a greater personal-space distance to virtual agents they held in high esteem (teachers), compared to unknown virtual agents (strangers). The authors report that these findings were consistent with studies done in the real world, where people of high esteem were given a wider berth than strangers when people walked around. Anecdotally in my own work, it is not uncommon for people attacked by virtual zombies to scream, duck and otherwise try to escape. I have seen similar results when VR participants ride virtual roller coasters, where it is not uncommon for people to laugh,

scream, hold on to the chair, and the like. We can therefore say that user behaviour can be used to note the effects of exposure to virtual experiences.

Discussion and Conclusions

This survey has explored options for assessing how present someone feels in a virtual representation of a physical space. In general, three main instruments have been widely tested. Self-report questionnaires ask the user to provide feedback on various aspects of the experience following exposure. These tools have evolved over time and use, as researchers continually uncovered various "new" aspects of the complex puzzle that is the sense of presence. At first being defined and measured simply as a sense of "being there," later work found the need to subdivide the concept into solitary (Place Illusion) and group (Coproence Illusion) aspects, in addition to the believability of the VR world itself (Plausibility Illusion). The main limitations of questionnaires are that there can be ambiguity of interpretation of the questions, and that they are administered after exposure, making it hard to use the results in real time to alter the experience.

In search of more-objective measures, researchers have compared users' physiological changes in VR to changes evident in the real world, and have found some support for measures such as heart rate and skin conductance (sweating) as they relate to user experience. There is a large body of (non-VR related) literature on physiological measurements that could be leveraged in further studies. Though the measures are objective and hard to fake, the main limitations of physiological measures are that the infrastructure for collecting the data can be both expensive and cumbersome to wear.

The resemblance of behaviours exhibited in VR to real-world experiences has also been used to measure how present a person feels in a given environment. Since this is also a relatively objective measure, it can be used with some confidence. However, behaviour can be controlled (faked) in many cases, so this needs to be taken into consideration. The main limitations of behaviour as a measure have to do with the fact that many experiences (*e.g.*, listening to an academic lecture) are mainly devoid of recognisable behaviours, requiring some artificial manipulation of the VR experience in order to test behaviour. While this is not a major limitation, it needs to be considered.

Like many applications of technology, rather than selecting a single approach, it would be better to combine aspects of all three of these approaches to balance their strengths and weaknesses. In the Antarctic case, if we imagine a viewer (student) immersed in a 360° VR capture of a scientist describing lichen on a rock formation in the dry valleys, we could watch them listening to the scientist, and watch their head movements as the scientist points to a rock in front of them. If the student turns their head to follow the scientist's gesture, we could say they are exhibiting a behaviour that would support them feeling a sense of presence, and even claim this feeling spans all three types of Illusion, Place, Plausibility and Coproence. We could also measure the heart rate of the student, and see if it changes from their rest-state rate while they experience the session. In addition, we could ask them some presence questions following exposure, and try to correlate these with the other measures.

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