An Immersive Virtual Reality: The Effect of Haptics on Agency in a Virtual Environment

Abhi Kamboj

Wayzata High School

12th Grade

ABSTRACT

With an increasing number of virtual reality applications, more research must be conducted regarding human interaction with virtual environments. Various studies have researched agency over a virtual avatar and others have researched haptics in virtual reality (VR). This experiment combines these two sects of VR studies to determine if haptics in a virtual environment alters the perception of agency a user feels over their virtual hands. Unreal Engine 4 and an Oculus Rift with an attached Leap Motion sensor were used to create an immersive virtual environment with hand tracking capability. Human subjects were individually tested in 2 tasks. First, they were to touch and lift a block with their virtual hands, then they did the same with an identical block in front of them so they would be interacting with a real and virtual block simultaneously. A questionnaire was given afterwards to measure the user's agency over the virtual hands during each task. The results show that haptic feedback decreases one's agency over virtual hands. This suggests that the proprioceptive response related to feeling an object with a person's actual hands decreases the effectiveness of the illusion that the hands on the screen actually belong to the user, meaning a more immersive virtual environment could be created with less haptic feedback. More research should be conducted verifying the impact tangible virtual objects have on a user's virtual experience, but overall this research could have far-reaching implications. Instead of augmenting virtual environments with real ones, an environment with less interaction with reality could allow for better VR applications.

INTRODUCTION

Background/Rationale:

Much research has been conducted regarding the ownership illusion over an alien appendage. The rubber hand illusion is a well-known example. In this experiment a rubber replica of a test subjects hand was placed in front of the subject in a life-like position while the subject's real hand was hidden. Researchers measured how the subject responded to simultaneously tactile stimulation of their hand and the rubber hand. The results showed that the users created a sense of agency over the rubber hand and reacted as if it was their own hand when the hand was threatened (Botvinick & Cohen, 1998). This is significant because it leads the way to a whole new psychophysical area of study concerning the basis of bodily self-identification.

Since the advent of immersive virtual reality, the inquiry into this agency illusion has gained much more traction. It is now possible to model a person or their body part in a virtual environment and determine how they respond. Studies have been conducted detailing how various feats of virtual reality can be manipulated to further create an illusion. For example, Argelaguet et al. (2016) researched how the realistic look of a user's hand in virtual reality can affect that user's ownership and agency in a virtual setting. Further studies have altered the skin color (Kilteni et al, 2013), shape of a person's body (Priyankova et al., 2014), or even number of fingers on a hand (Hoyet et al. 2016) in virtual reality and measured the user's response to such alterations.

In addition to self-perceptual studies in virtual reality, haptics is becoming a larger research area. After it was discovered that hands could be modeled in virtual reality, researchers started conducting experiments to determine how the user responds to a virtual environment that is haptically different from the physical environment. This sort of study in psuedohaptics manipulates what the user is feeling in real life and what it looks like they are feeling in virtual reality to determine how much the virtual environment can be altered until the user does not think they are in a virtual environment. An example is Lecuyer et al. (2000) experiment using a Spaceball device to simulate the compression of the spring, while the user was shown a differing view of how much the spring was being compressed. It was determined that the visual feedback given to the user created an illusion that the spring took a different amount of force to compress than it actually did. This haptic disconnect hints at the potential to which virtual reality can manipulate proprioception.

The research conducted in this experiment combines the advances in ownership illusion with haptic feedback to determine if a user’s agency over a virtual hand can vary depending on the haptic feedback they receive.

Hypothesis and Support:

How does haptic feedback effect one’s sense of agency in virtual reality? It was hypothesized that the more one feels with their hands in the real world while immersed in virtual environment, the less they will associate the virtual representation of hands to actually being theirs.

Many researchers have shown some counterintuitive results in regards to agency and virtual representation. Argelaguet et al. (2016) determined that the more like a real hand the virtual representation looks, the less agency a person feels because the hand has a larger chance of acting imprecisely.

In addition, many haptics studies observed psuedohaptic feedback to effectively being able to cause a false impression, indicating that a visual stimulus usually outweighs haptic feedback. Ban et al. using a viseo-haptic system, determined when a user touches an object that has horizontal edges different from the angled edges shown on the screen displaying their hands, most of the users believed that the actual object's edges had some angles like the one shown on the screen.

A combination of the idea that the realism decreases agency and haptics can be illusory support a hypothesis for this experiment that if the user can feel an object that they are seeing on the screen with their own hands in real life as well, their agency of the hands on the screen would be less.

MATERIALS AND METHODS

Setup and Preparation

A simple virtual environment was created using Unreal Engine 4 in which the user is placed in a first-person perspective in front of three blocks. An Oculus Rift with an attached Leap Motion sensor was used to provide an immersive virtual environment in which the users can see and use their hands in virtual reality. In order for the experiment to work, the virtual environment must be able to create the illusion that the virtual hands are part of the person using them. The setup described is almost guaranteed to be effective enough to create this illusion as per the research of Maselli & Slater in 2013. They tested different variations of a virtual environment outlining a sufficient threshold at which the illusion of ownership or agency can take place with virtual hands. They concluded that the virtual environment must be in first person perspective to create and sustain the illusion and that when using hands the fake hand does not necessarily need to be realistic for the illusion to take place. The experiment conducted uses a first-person perspective and the Leap Motion Floating Hands character that has a consistent appearance between the tasks, meaning the agency illusion should be possible and the effects on one's agency over his/her hands can only be attributed to the haptic difference between the tasks.

Experimentation

This experiment consisted of two separate tasks. In the first task, the user was told to lift any of the virtual blocks present in front of them. In the second task, the user was told to lift a virtual block while a replica in size and shape was in its position in the real world. Before each the test subject went through the tasks, they were initially given time to move their hands around in virtual reality and look around to experience how the leap motion hand tracking works. This control run, allowed the user to feel what an immersive virtual environment with their hands being tracked felt like, before assessing the agency of their hands while doing tasks.

In this experiment 3 random test subjects at an age of 19, with no previous experience in virtual reality were used. Each test subject was guided individually through each task. Afterwards, they were given a short questionnaire (Figure 1). The questionnaire consisted of 6 questions rated on a 7-point Likert scale (Figure 2). The questions were made as specific as possible to the situation the participants were immersed in, and was used to determine the agency each user felt over the virtual hands.

It felt like I was actually holding something when I was holding the virtual block.
I expected the virtual representation of my hand to act in the same was as my actual hand.
When rotating the virtual block did It felt like I was rotating a real block.
Using the virtual representation of my hands to move blocks in virtual reality felt comfortable.
The size of the virtual block felt similar to a real one.
The shape of the virtual block felt similar to a real one.

Figure 1: Six questions give to the user. A questionnaire is a common and effective way to measure agency or embodiment in virtual reality, also used by Argelaguet et al. (2016), Kilteni et al. (2012) and many others.

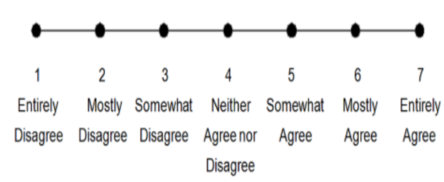


Figure 2: 7-Point Likert Scale. A common method to measure one's attitude or opinion from one's cognitive or affective components of attitude (McLeod, 2008).

Risk and Safety

Virtual Reality has developed far enough to the point where practically anyone can use a Head Mount Display (HMD) safely. None of the equipment that the subjects used or tasks that they were asked to do posed a risk to their safety or health. Most researchers conclude that Virtual Reality-Induced Symptoms and Effects (VRISE) are short lived and minor (Cobbs et al., 1999) (Nichols & Patel, 2002). Many researchers believe that that virtual reality can even be beneficial to health in psychological therapy (Schuemie, 2001).

In this research experiment, the risk of any VRISE was minimized. The users were allowed to take a break or stop using the headset altogether if they felt discomfort in anyway. Before beginning the users, comfort was assured and during the experiment it was verbally reassured. If the user did need a break, it would not affect the collection of data in the experiment because there was no ongoing measurement of agency nor were the subjects' tasks timed, only a questionnaire was given afterwards. In addition, the Oculus Rift HMD was used, which Chessa et al. in 2016 determined to have a strong effect on immersing a user into a virtual environment while avoiding negative VRISEs, such as simulator sickness, in comparison to other HMDs. The research done by Chessa et al. explicitly suggests that the Oculus rift is a safe and powerful tool to use in research and in clinical applications.

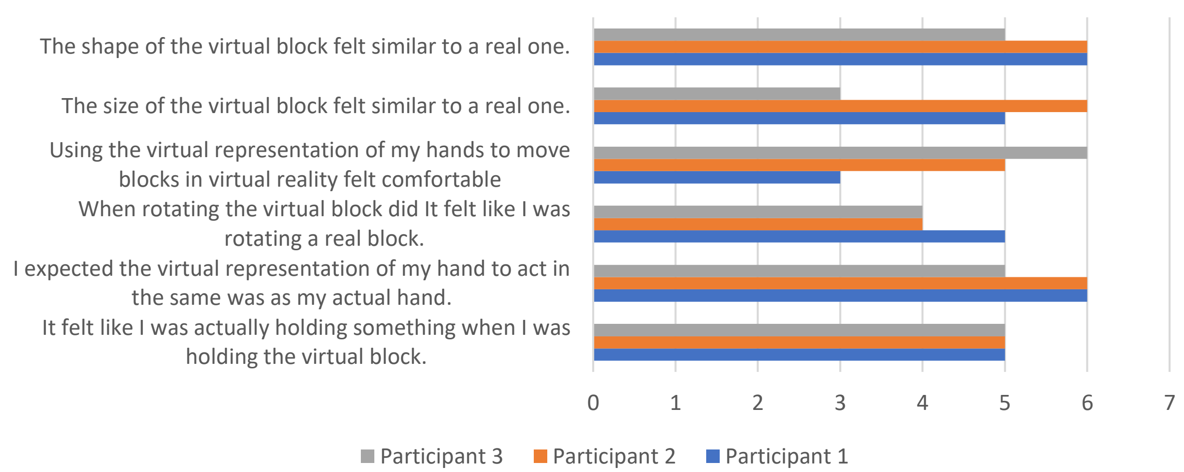
RESULTS

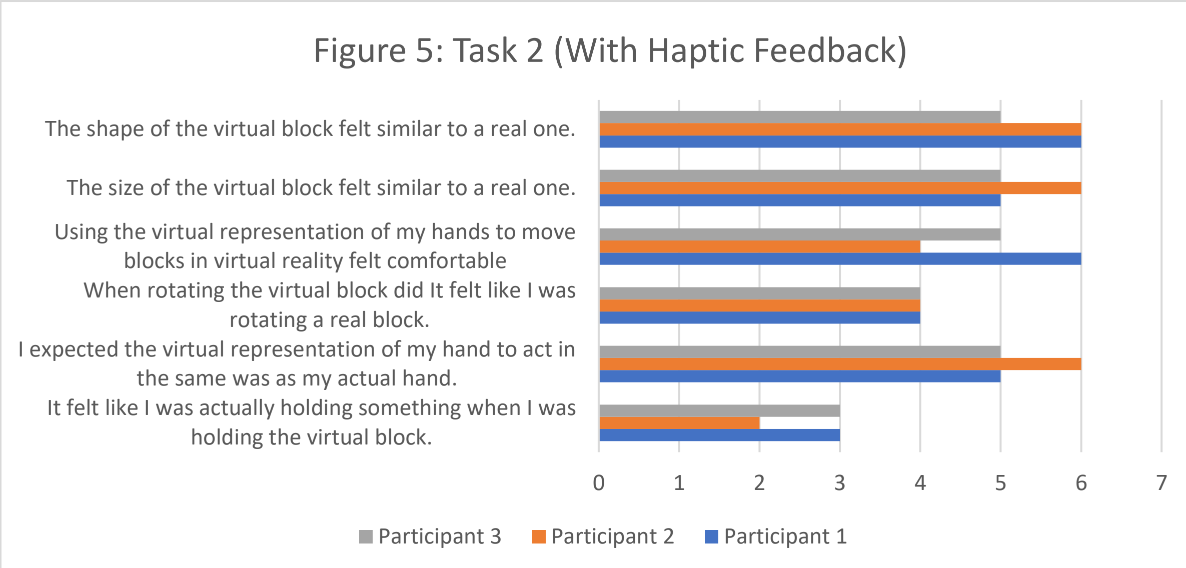
Data

Figure 3: Average Agency for Each Participant				Average Agency per task
Task	**Participant 1**	**Participant 2**	**Participant 3**	
1	5	5.33	4.67	5
2	4.83	4.67	4.5	4.67

The data was collected plotted and the mean of the responses was determined as shown in Figure 3. The questions were worded so that a higher numbered response would indicate a larger sense of agency, making it easy to compare the mean values for the agency each participant felt in each task. The results show that for each task individually and when averaging the tasks together, task one involving the users touching blocks without a real one in front of them most strongly caused the illusion of agency. In addition to this statistical analysis, each participant's response to each question will be graphed on 2 different cluster bar charts (Figures 4-5) and visually analyzed to determine the overall trend in agency between the two tasks. As shown, Task 2 had more lower scores of 2s 3s and 4s, and fewer higher scores of 5s and 6s.

Figure 4: Task 1 (Absent Haptic Feedback)





Analysis

The results support the original hypothesis that the second task involving haptic feedback would result in the user feeling less agency than during the first task. This correlation could be attributed to the idea that proprioception triggered a cognitive response that ascribed the action of lifting a box to the real world instead of virtual reality. Therefore, the illusion of agency a user feels over a virtual hand is lessened when they touch something with their real hands.

DISCUSSION

Comparisons to Past Research

The results of this research compliment and add to past research. Ownership and agency illusions often ignore haptic or even motor conditions. Kilteni et al. (2012) discovered that a user can feel ownership over arms that are longer than normal length, but this research did not account for the fact that if this virtual arm was to be used in a virtual application, the user would be moving their arm and using it complete tasks. The ownership illusion, therefore, may be broken by haptic feedback when completing virtual tasks. In addition, Pusch et al. (2011)

describes how a higher fidelity from the hand is desirable over a more realistic hand in creating an effective immersive environment. This implies that lifting a virtual block and real block simultaneously might have a lessened feeling of agency because the hand may have less fidelity, being constrained to holding a block in real life which may have affected the hand tracking.

Other experiments however have come out with slightly different results regarding agency over a user's hand. Kokkinara & Slater (2014) experiment with a stimuli in between visual representation and haptic feedback, such as visuotactile and visuomotor stimulation. They correlated a larger ownership illusion to synchronous visuotactile and visuomotor stimulation, indicating that the more virtual interaction is combined with real interaction, the more likely the user will feel ownership over their hands. However, it is important to note a distinction between ownership and agency that Argelaguet et al. (2016) makes. Agency describes motor control and awareness of one's actions whereas ownership describes the feeling that one's body is the source where sensations are being felt. This means, even if Kokkinara & Slater determined an increase sense of ownership, that doesn't necessarily contradict this experiments increased sense of agency.

Applications

Finding an effective way to immerse and interact with a user in a virtual environment has many futuristic applications. Being able to effectively use hands in virtual reality without losing a sense of agency means that people could expand virtual reality to many more areas. For example, in globalization, people could use virtual reality to play games or communicate with each other across the world. In education, human computer interaction in virtual environments could be used to train doctors to give surgery or train astronauts for foreign environments (Rautaray & Agrawal, 2015). In health, virtual reality could be used to enhance therapy treatments (Schuemie, 2001), like for treating PTSD by creating controllable situations and enhancing emotional engagement (Botella et al., 2015). Overall, more research needs to be conducted with interaction in virtual environments, but once completed the applications are endless.

CONCLUSION

The extent to which haptics play into the illusion of agency over a virtual pair of hands, is a specific topic in virtual reality that has not previously been explored. In this study, it was determined that haptics negatively affect the agency one feels over a virtual pair of hands they use, indicating that more immersive virtual environments should exclude more realistic haptics. Since this is a relatively unexplored relationship in virtual reality, more research can be done based of this study to determine whether perspective, location, avatar representation, or other factors may alter the negative effect haptics has on agency. Nevertheless, the discoveries of this research mark a step forwards in creating a fully immersive virtual environment.

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