INTRODUCTION

The sense of touch plays a crucial role in our everyday lives. Touch allows us fine motor control, adds to our sense of self, and helps with our perception of the world around us [3]. Without it, accomplishing simple everyday tasks would become overwhelmingly difficult. Such is the life of approximately two million amputees in the United States today [2].

In order to improve the lives of amputees, advancements have been made allowing the prosthetics to interface with the subject’s brain. This neural link allows the subject to move the prosthetic device through the sheer power of their mind [3]. As a result the prosthetic begins to feel more natural to the amputee. But without sensory feedback, the subject still experiences difficulties in fine motor control and pain which appears to emanate from the missing limb [3].

During recent experiments at the Human Rehabilitation and Neural Engineering Laboratory (hRNEL), we have demonstrated it is possible to generate sensations which appear to emanate from a missing limb. In order to create these sensations, a subject must be implanted with an array of electrodes along their cervical spinal nerves. By electrically stimulating these electrodes, the subject begins to feel sensations originating from the location of their missing limb. Ideally if these sensations are incorporated with the prosthetic, the amputee’s will see improvements in fine motor control, and a reduction in pain. But these sensation are not ideal. In fact more often than not, they are accompanied by an unnatural buzzing feeling known as paresthesia [3]. Another issue is that the location of the produced sensations is not always exactly where it was intended to be. Combining both problems causes an unnatural feel which takes away from the benefits of sensory feedback restoration. Therefore in order to help amputees, we need to discover a way to improve the naturalness of the sensations generated through electrical stimulation.

OBJECTIVE

The main goal of this project was to build a Virtual Reality environment which can be integrated with electrical stimulation equipment. This environment then will be used to determine if it can assist in altering the modality, naturalness, and referred location of the sensations generated.

HYPOTHESIS/SUCCESS CRITERIA

To reach this objective, there was three main criteria of success. The first criterion was to create a virtual environment for a Rubber Hand Illusion (RHI) Test. The goal of this test is to trick a subject’s brain into believing a fake hand (or in this case a virtual one) is in fact their own hand [1]. This test will verify that the system works and if the VR environment might have an effect on the sensation generated through electrical stimulation. The next criterion was to create a virtual environment for electrical stimulation testing. Here, electrical stimulation will be applied to the subject to mimic the touching of the virtual hand in the VR environment. With both environment created the final criterion was to conduct the actual testing.

METHODS

Creating a VR environment required the use of both hardware and software. The hardware consisted of an Oculus Rift, and the Phantom Omni Haptic Device. The Oculus allows the user to see a VR environment and the Haptic Device makes it possible to touch a virtual object. The Phantom Omni Haptic Device does this by using three motors to generate forces in the xyz planes. As the device’s stylus is moved, a corresponding virtual stylus moves in the VR environment. Once the virtual stylus comes into contact with a “touchable” object, the three motors of the device generate forces to simulate the normal force of the virtual object.

In order to integrate the Haptic Device with the Oculus and also to create the environment itself, a software package called Unity Game Development Software was used. Unity allows the user to place objects into a virtual scene and use C# programming to manipulate those objects. In this case, the objects being manipulated are virtual representations of hands downloaded from the Unity Asset Store.

Using the virtual hands, a virtual reality environment was created which allows an experimenter to conduct a RHI test. During this test, the subject will use the haptic device to touch the virtual hand. While doing so, an experimenter will brush the subject’s real hand in the same exact manner at the same exact time. This stimulation will hopefully convince the subject’s brain that the sensation they are feeling is coming from them touching the virtual hand. As a result, they may begin to believe the virtual hand is in fact their own real hand. Therefore the VR environment must be able to accommodate this testing. To do so, a virtual hand was added to the environment along with a table and a virtual stylus as shown in Figure 1. The table was added to replicate the table they will be sitting at in real life during the test. Hopefully by keeping the environment as close as possible to real life will result in a higher chance of inducing the illusion. The virtual stylus, as mentioned earlier, represents the stylus of the Haptic Device and will resemble the object used to touch the subject real hand during the test. Typically a paint brush will be used.
After completing the RHI VR environment, functionality with electrical stimulation was added. This involved segmenting the virtual hand into sixty eight different regions shown in Figure 2.

These regions represent areas in which sensations can be generated through electrical stimulation. Unity Colliders, which are invisible outlines of spheres shown in Figure 3, were used to create these regions. When the virtual stylus comes into contact with both the Collider and the virtual hand, the force applied by the user and the region of contact are recorded by the VR environment.

The force and region are then used to create a message which is sent to an outside program called a Producer. This program accepts the message and relies it to another program called the Consumer. Once the message is at the Consumer, the information is then used to generate the appropriate electrical stimulation and the corresponding sensation.

The last step was in making the VR environment dynamic. There were two reasons for doing so. First, since the effectiveness of the VR environment on changing the quality of sensations relies heavily on the RHI, the environment and everything in it has to look as realistic as possible. This means the size of the hand, the placement of the hand, whether it’s a male or female hand, all have to resemble the test subject’s actual hands. The second reason is to make it easier for future experiments which do not include the ones mentioned earlier. In order to make the VR dynamic, it only required one thing, user input. By accepting keystrokes from a keyboard, an experimenter can easily change certain objects in the VR environment to their need. For example, pressing the arrow keys move the virtual hand in the corresponding direction and the greater than and less than symbols scale the hand appropriately.

DISCUSSION

Although a VR environment was created which supports both a RHI test and electrical stimulation, the overall objective was not met. We are currently in the pilot testing stage of the RHI test and will not begin testing with electrical stimulation until after the RHI tests are completed. Therefore it is impossible to say if this VR environment will have any effect on the modality, naturalness, and referred location of sensations generated through electrical stimulation.

The reason for not meeting the overall objective, is simply time. I underestimated how long it would take to develop these environments. This was mainly due to my lack of knowledge in using Unity Game Development Software. It took significant engineering time to understand how to use Unity and how to integrate it with the Phantom Omni Haptic Device.

Moving forward, the first step will be conducting the RHI test. As stated earlier, this test verifies that the system will work. If the RHI test fails to produce the illusion then conducting tests with electrical stimulation will be useless. But if the illusion is induced, we will then conduct tests with electrical stimulation. Lastly, since not all amputees are upper limb amputees, lower limb functionality will be added to the environment. This will allows us to conduct the same tests with a virtual foot as opposed to the virtual hands which are currently in use.

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REFERENCES
