

## Effects of Virtual Reality Immersion in Individuals with Central Nervous System Injury

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### Abstract

*The use of Virtual Reality (VR) based therapeutic interventions as an adjunct to traditional physical therapy is innovative, yet many questions remain regarding its efficacy and safety. The purpose of this exploratory study is to assess the level of presence, amount of simulator sickness and level of perceived exertion when individuals with central nervous system (CNS) injury exercised with the Sony PlayStation 2 EyeToy, an off-the-shelf, VR-based. A convenience sample of ten participants, 4 with stroke and 6 with spinal cord injury, were recruited from the local community. Participants exercised for 1-2 hours/day for 20 sessions. Assessments used included the Simulator Sickness Questionnaire (SSQ), Presence Questionnaire (PQ) and BORG Rate of Perceived Exertion Scale (RPE). Data were collected after each session (SSQ and BORG RPE) and weekly (PQ). In general the results suggest that, as with individuals with intact nervous systems, these participants reported a decrease in presence with an increase in simulator sickness. They also reported a decrease in RPE earlier in training, suggestive of a training effect. In conclusion, while much more research is needed, we have begun to explore the relationship between presence and simulator sickness in individuals with CNS injuries.*

**Keywords---** stroke, spinal cord injury, virtual reality games, presence, simulator sickness, rate of perceived exertion

### 1. Introduction

Virtual Reality (VR) as an adjunct to current rehabilitative interventions, while novel, shows promise in individuals with central nervous system (CNS) injury [1-11]. What is currently unknown, however, is the occurrence of simulator sickness, level of presence, or rate of perceived exertion when individuals with CNS injury interact with virtual environments (VEs). VEs are unique in that they simulate real life experiences in a computerized 3-dimensional space that can be manipulated, interacted with or navigated through. Some VEs are deeply immersive, using head mounted displays that don't allow the user to see his/her natural surroundings, while others are non-immersive and the user simply interacts with objects on a computer or television screen.

Being that they simulate real-life situations and tasks, VEs are suitable for rehabilitating individuals post stroke [2, 4, 5, 7, 9, 12-15] and spinal cord injury (SCI) [16-18] because they utilize many of the established principles that promote motor learning and recovery of function after CNS injury [19, 20]. In fact VR based upper extremity rehabilitation post stroke increases force production [7], improves hand function [2, 7], increases finger strength, reduces movement time, and transfers to functional tasks [11]. While the benefits of VR-based rehabilitation in stroke motor recovery is beginning to emerge, an understanding of simulator sickness, presence, and the level of perceived exertion while in the VE is still uncharted territory.

Simulator sickness, similar to motion-sickness, is expressed as headaches, vertigo, nausea or other visceral symptoms often associated with an inconsistency between input from the visual and vestibular system [5]. The incidence of simulator sickness is associated with the depth of immersion, with reports of deeper immersion also resulting in increased reports of simulator sickness. In fact, non-immersive VEs have shown to have few side effects [5]. Simulator induced symptoms often reported in individuals with intact nervous systems include disorientation, balance disturbances, headache, and nausea during or after exposure to an immersive VE. While a number of studies have investigated the use of VR post stroke to our knowledge, only a few have studied the incidence of simulator sickness after being immersed in VE [21, 22].

Presence, the subjective experience of being in one environment even when one is physically situated in another [23], is linked with level of enjoyment experienced while performing a VR task [16, 24]. While low levels of presence are associated with high levels of simulator sickness, this relationship is unknown in individuals with CNS injury. The "presence" experienced in VEs may be advantageous when rehabilitating people following CNS injuries because the individual feels more immersed in the "simulated" task and thus the task becomes more motivating [2, 5, 7].

Lastly, reports of the "level of perceived exertion" while performing activities in a VE is unknown in individuals with CNS damage. Perceived exertion is the overall effort or distress of the body that is felt during exercise. The gold standard method used to measure rate of perceived exertion (RPE) is the Borg Scale. The Borg Scale of Perceived Exertion is used to assess an individual's perception of

physical exertion and has been used in investigations involving individuals post stroke [5]

The purpose of this preliminary study was to begin to explore if individuals with CNS injury (stroke or SCI) experience 1) simulator sickness, 2) presence when involved in an off the shelf VR game, and 3) explore the relationship between RPE and training. Understanding the relationship between presence and simulator sickness will assist in developing effective VR based training protocols, with least side effects, while maintaining a selected level of exertion.

## 2. Methods

### 2.1. Participants

Twelve participants with central nervous system injury (n=7 with SCI, n=5 with Stroke) began the study. Data from 4 subjects were incomplete and one subject changed medications and thus were not used in the final analysis. Both subjects with stroke were female with left hemisphere damage. The subjects with SCI were male and had injuries ranging from C6 to T5. The participants' age was 35.2+/- 16 years old with a range of 8-156 months since injury. The inclusion criteria were: 1) greater than 18 years old, 2) not receiving physical therapy services, 3) willing to maintain their physical exercise and medication regimen for the duration of the study. Methods were approved by the Institutional Review Board at Georgia State University.

### 2.2. Instruments

**2.2.1. Hardware** We used the Sony Playstation®2 as the VR tool for this intervention. The Sony EyeToy™ is a game designed for the Sony Playstation®2. A USB camera for the EyeToy™ interfaces with the Playstation®2 so that it captures and superimposes the player's image and therefore, movements onto the screen of the television. This places the player into the VE of the game. The software design enables the player to interact with the images in the VE using any part of their body.

**2.2.2. Software** The EyeToy™ gaming device requires that the player move their body in a multitude of challenging ways that require accurate, target based movements of the arms and legs. These movements require planning, balance and coordination in multiple planes and multiple directions. Examples of the games include drumming, air-guitar, soccer, baseball, boxing, and karate to name a few.

### 2.3. Outcome measures

We used the Presence Questionnaire (PQ), the Simulator Sickness Questionnaire (SSQ) [25, 26], and the BORG RPE scale [27, 28], as well as a daily log to determine level of presence and effects of the VE.

### 2.4. Procedure

Researchers set up the Sony Playstation®2 in each participants' home. Training consisted of 1-2 hours per day/ 3-5 days per week for a total of 20 sessions. The participants were instructed to play each game twice to familiarize themselves with all of the games, but then they played the games of their choice. After each training session, the participants rated their RPE using the Borg RPE scale, intensity of simulator sickness using the SSQ and documented the games played and time spent playing each game. Weekly, they measured presence using the PQ.

### 2.5. Data analysis

Due to the heterogeneity of the group, the Kruskal Wallis test was used to determine differences across weekly summed data. A level of significance was set at  $\alpha < 0.05$  for all analyses.

## 3. Results

### 3.1. Games played

All participants played a multitude of games, however, the most frequently played game was "Knock-Out", a simulated boxing game.

### 3.2. Outcomes

The participants reported a statistically significant decrease in simulator sickness from session 6-10 compared with session 16-20 ( $p < 0.01$ ) (Table 1.). The greatest amount of presence was reported during sessions 11-15 and was statistically greater than sessions 6-10 ( $p < 0.01$ ). In general when reports of simulator increased, presence decreased. RPE was significantly lower at session 11-15 and 16-20 compared with 6-10.

| Session | SSQ  | PQ    | Borg RPE |
|---------|------|-------|----------|
| 1--5    | 0.17 | 120   | 13.06    |
| 6--10   | 0.22 | 137.4 | 12.83    |
| 11--15  | 0.12 | 150.2 | 11.94    |
| 16--20  | 0.15 | 120.2 | 11.86    |

Table.1. Mean Scores of the Simulator Sickness Questionnaire (SSQ), Presence Questionnaire (PQ), and Borg Rate of Perceived Exertion Scale.

## Conclusions

This study only begins to scratch the surface of how individuals with CNS injuries may behave in VEs. Although these results are quite preliminary, we found that individuals with SCI and stroke behave similarly to those with intact

nervous systems. This lack of VE- induced cyber sickness may be explained by the minimal level of immersion with this type of VR device. Furthermore, the reporting of a decrease in RPE over time with training is important because these participants were permitted to completely self regulate. They consistently played with more intensity over time, yet reported a slight drop in RPE. This is noteworthy because this type of training has the potential to tap into an individual's intrinsic motivational strategies that will potentially result in more practice time and eventually further recovery of function following injury. Future studies are planned to further determine the threshold for immersion that is safe and efficacious for individuals with CNS injuries.

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