SB^{3}C2020
Summer Biomechanics, Bioengineering and Biotransport Conference
June 17-20, Vail, CO, USA

USE OF VIRTUAL REALITY FOR ASSESSING GROSS HAND DEXTERITY IN YOUNG HEALTHY INDIVIDUALS

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INTRODUCTION

Functional tasks, such as reaching and grasping, are an important aspect to quality of life that can be greatly impacted when motor deficits occur [1]. Stroke is a leading cause of adult disability with approximately two-thirds of stroke survivors experiencing motor deficits [1]. Early post-stroke neuro-rehabilitation can improve functional outcomes as indicated by improved Fugl-Myer Assessment scores [2]. However, transportation and access to rehabilitation clinics can be a limiting factor for individuals in early post-stroke rehabilitation. Previous literature has studied the effects of Virtual Reality (VR) as a neuro-rehabilitation tool for stroke survivors and has reported increases in functional task performances [2, 4, 5, 6]. However, it is still not known whether VR systems provide the same level of care as conventional manual therapy

Many conventional rehabilitation protocols include a focus on improving gross hand dexterity. We can measure rehabilitation improvements in different domains through the use of Box and Blocks test and Functional Near Infrared Spectroscopy (fNIRS). The Box and Block test is a common measure of gross hand dexterity. In this test a participant is asked to move as many one-inch blocks as possible over a partition in a one-minute time limit. Improvements in functional tasks can also be assessed through brain imaging techniques such as fNIRS. fNIRS measures the changes in cortical blood oxygenation by detecting differences in the absorption of near-infrared light between oxygenated and deoxygenated blood [3]. fNIRS has emerged as a practical neuroimaging technique to assess hemodynamic cortical responses and cortical reorganization. By delivering near-infrared lights via fiber optic cables, fNIRS is less sensitive to noise and movement artifacts than resonance imaging (fMRI) and electroencephalography (EEG). This makes fNIRS, easier for individuals to tolerate and providing excellent spatial resolution [3].

The purpose of this pilot study is to assess the use of VR as a modality for testing gross hand dexterity in young healthy individuals while performing the Box and Block test under observation with fNIRS. We hypothesize that there will be no difference in the magnitude of brain activation between the manual and VR conditions of the Box and Block test for both the dominant and non-dominant hands.

METHODS

Three young healthy right-hand dominant participants were included in this study (2F, 1M, 23.67±0.57 years old). Exclusion criteria included a diagnosis of a neurological disorder and/or upper extremity injury and self-reported left dominant handedness. Informed consent was obtained from the University of Nebraska Medicine IRB.

Participants were asked to perform three trials of the Box and Block test in two conditions: manual and VR (Oculus Rift, Oculus, Irvine CA, USA) with their dominant and non-dominant hands. A total of twelve trials were collected per participant. The Box and Block test was set to a standardized height of 1 m for both conditions. Manual and VR conditions were randomized to control for possible learning effects. fNIRS (NIRS Sport2, Nirx, Morrisville NC, USA) was used to measure motor cortex (M1) activity during both conditions. The adjustable headgear was positioned on the head following the 10-20 international system so that the center of the headgear is aligned with the vertex (Cz) and the 8x8 sensor-detector montage covered the area around the C3 and C4 landmarks, which have been shown to detect motor activity that drives hand and arm movement.

The fNIRS signals were truncated to 30 seconds before and after the trials. To correct for detector saturation, the signals were interpolated at every 4 frames. Changes in optical density were converted to changes in oxygenated hemoglobin (HbO) and deoxygenated hemoglobin (HbR) using the Modified Beer-Lambert

Law. A 0.02 Hz high-pass filter and a 0.5 Hz low-pass filter were used to remove any slow drifting signal components. Hemodynamic states were calculated using standard nirsLab2019.04 parameters. A wavelet filter was then applied with a 5 standard deviation threshold to remove motion artifacts. HbO was used as the signal of interest, which was averaged for each detector on the contralateral M1 for the dominant and non-dominant hands. Detector signals were then averaged together to get the change in HbO magnitude for both dominant and non-dominant hand for both conditions. Data analysis was performed in both nirsLAB2019.04 and Matlab2018a. Two paired t-test analyses were performed comparing the manual and VR conditions for both averaged dominant and non-dominant hands. Statistical analysis was performed in SPSS with significance set as an alpha value $p \leq 0.05$.

RESULTS

There is no difference in M1 HbO saturation between the manual and VR Box and Block test for both the dominant (p=0.984) and non-dominant (p=0.885) hand (Table 1). In both manual and virtual tasks, the dominant hand exhibited a trend towards increased brain activity compared to the non-dominant hand.

The non-dominant hand trended towards an increased number of blocks moved during both the manual and VR Box and Block tasks (Table 2). There was also a trend for greater variability in the number of blocks moved during the VR task compared to the manual task (Table 2).

Table 1: Mean Brain Activation during Box and Block tests with paired ttest results

	Manual (µmol/l)	VR (µmol/l)	P value
Dominant Hand	0.0203±0.0222	0.0204±0.0254	0.984
Non-Dominant Hand	0.0147±0.0253	0.0167±0.0452	0.885

Table 2: Mean Number of Blocks moved during the Box and Block test

	Manual			VR		
	Trial 1	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
Dominant Hand	63±8.2	67.3±4.0	71±2.6	61.3±18.5	58.3±22.9	60.7±18.5
Non-Dominant Hand	68.7±8.5	71.7±7.6	72.3±4.5	61.7±14.6	61±10.4	68.7±11.2

DISCUSSION

The purpose of this pilot study was to determine the use of VR as a modality for testing gross hand dexterity through the use of the Box and Block test. Our results indicate that there is no difference in motor cortex activity when performing the Box and Block task manually and in VR.

The use of VR as a neuro-rehabilitation tool has been studied in previous literature. Holper L et al. [7] have investigated the use of a VR system during the performance of observation, imagery, and imitation of a ball grasping task in healthy young participants. The study found significant changes in HbO with lower HbO magnitudes during observation compared to motor imitation [7]. While Holper L et al. used a virtual arm on a computer screen as their VR system and we used an immersive VR system, both the results from the Holper L et al. study and our study indicate that VR systems can elicit brain activation that may be beneficial in neuro-rehabilitation. Previous literature has investigated the neuro-rehabilitative effects of VR systems within a stroke population. Many of these studies have reported increases in functional task performances from finger extension, upper extremity function, and Fugl-Meyer Assessments within clinical environments [2, 4, 5, 6].

The use of VR as a neuro-rehabilitation tool can have an impact on clinical areas like stroke. VR systems are highly portable which can be easily implemented outside of rehabilitation clinics. This can benefit patients by reducing the number of clinic visits while still being able to maintain their rehabilitation programs with engaging games and progress that can be monitored by their clinician.

The limitations of this ongoing study include a small sample size. There may be differences in brain activation between manual and VR tasks that our study has not seen due to the small sample size. Another limitation of this study includes a potential learning effect as dominant and non-dominant hand order was not randomized. This effect can potentially be seen in our results where the non-dominant hand, which was always performed second, had increased Box and Block results compared to the dominant hand. A final limitation to this pilot study includes a lack of upper extremity muscle activation data. While there is no difference in the brain activation between the manual and VR tasks, there could be a difference in the motor strategies used during the two tasks.

Future studies could include the use of upper extremity electromyography data to assess the differences or similarities in motor strategies used during both manual and VR Box and Block tests with a larger participant sample size.

ACKNOWLEDGEMENTS

Funding: NIH R15 094194, R01 NS114282

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