Virtual Buzzwire: Assessment of a Prototype VR Game for Stroke Rehabilitation

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ABSTRACT

We created a VR version of the Buzzwire children's toy as part of a project to develop tools for assessment and rehabilitation of upper-body motor skills for people with dexterity impairment after stroke. In two pilot studies, participants wearing a HMD used a hand-held wand with precision tracking to traverse virtual 'wires'. In the first study, we compared able-bodied participant's performance with and without binocular viewing to establish a connection with previous experiments using physical versions of the game. Furthermore, we show that our extended measures were could also discern differences between subjects' dominant versus non-dominant hand. In a second study, we assessed the usability of the system on a small sample of subjects with post-stroke hemiparesis. There was positive acceptance of the technology with no fatigue or nausea and measurements highlighted the differences between the hemiparetic and unaffected hand.

1 INTRODUCTION

The process of recovering fine motor skills requiring eye-hand coordination after brain injury is a long and arduous process. Many hours of therapy involving simple movement tasks are required. Patients must visit clinics regularly and require trained therapists, posing a massive burden on every health system. Furthermore, adherence to rehabilitation programs is low. Factors including fatigue, lack of motivation, and musculoskeletal issues prevent people from initiating or maintaining therapy programs [2]. There is therefore justification, with current advances in VR technology, to investigate means of motor rehabilitation which are more enjoyable, can be used at home, and with which precise measurements and assessments of improvements can be made. Here we report on the evaluation of a VR system that requires eye-hand coordination in a simple game that allows us to determine if current VR technology can aide the rehabilitation process.

The VR game we developed (see Figure 1) is based on the well-known children's toy called the loop and wire test, or Buzzwire, physical versions of which have been used in several empirical studies. For example, Budini et al. [1] used it to evaluate the effect of a short-term dexterity-training on muscle tremor and Read et al. [4] used it to study binocular advantage in fine motor skills.

All previous studies utilizing Buzzwire to assess motor skills have used the number of contacts made with the physical wires as their dependent variable. Some also timed the task to completion. We believe that these measures are rudimentary and much more useful data may be available by using VR. For example, we can track the user's 3D movements with accuracy and so adopt performance measures such as orientation of the loop, distance to the wire and average speed of movement.

We devised two experiments to test the feasibility of a VR version of the game. The first experiment determined if previous results could be replicated and extended, and the second evaluated the usability of the game on a small number of stroke patients.

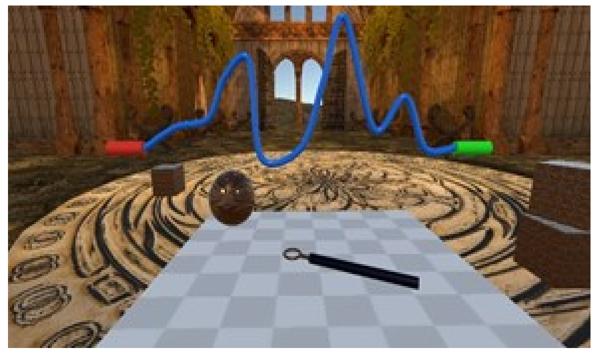

Figure 1: The blue wire assumed different shapes between trials but always started and ended at the same place, indicated by cylinders. Green cylinder indicates the start position.

2 EXPERIMENT 1

The first experiment investigated the advantage of binocular stereopsis to establish a connection between physical and virtual versions of the game [4]. We also tested whether we could measure an effect of handedness (dominant versus non-dominant hand) using extended dependent variables not readily available in the physical version. Handedness means better performance, or individual preference, for the use of the dominant hand over the non-dominant hand.

A within-subjects design assessed players ability to maneuver across 5 differently shaped wires. We compared players dominant versus non-dominant hand control across the same wire by having them traverse each wire with both their dominant and non-dominant hand. Presentation of each wire and the use of left and right hand was randomized. In the first part of the test participants performed the task with binocular vision. In the second part, the screen for their non-dominant eye was turned off producing a monocular display. The same set of wires (in randomized order) was used for both binocular and monocular tests. The dependent variables were: The **time** to complete each wire, the number of **collisions** between loop and the wire, the mean **deviation** from the center of the wand loop and the wire, the total **distance** covered from start to end points, and the average **speed**.

Participants were indicated which hand to use by changing the colour of the start position to green (see Figure 1). Thus, if the start cylinder was green on the right, they used their right hand to perform the task.

Eighteen able-bodied subjects participated in the experiment (9F,9M). Mean age was 33.2 (Median 34). Each of them completed the Edinburgh Handedness Questionnaire prior to the experiment to determine their dominant hand [3]. A minimum

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2018 IEEE Conference on Virtual Reality and 3D User Interfaces
18-22 March, Reutlingen, Germany
978-1-5386-3365-6/18/$31.00 ©2018 IEEE

measured level of stereopsis ability was set at 200 arcsec to participate.

The Unity3D game engine was used to create the simulation with lighting, particle systems (sparks on collision with the wire), audio on collision, etc. The SteamVR SDK was used to handle display of the scene as well as handling the tracking data from the sensors and user interaction from the hand-held HTC Vive tracker. The 5 'wire' curves were generated using cubic Hermite interpolation across 12 3D control points set (prior to the test) in a 2D plane perpendicular to the table in the scene.

2.1 Results

Results for deviation from the wire showed that the best performance was with stereo vision using the dominant hand (mean deviation=0.4cm, s.e.=0.02cm). The fastest time was similarly with stereo vision and dominant hand (mean=18.4sec, s.e.= 1.35). This pattern was observed for all our other measures demonstrating that the most effective way to play the game was with stereo vision using the dominant hand. Separate repeated-measures analysis of variance (ANOVA) were performed on the individual scores for time taken, number of collisions with the wire, average deviation of the center of the wand loop to the wire, total distance covered in traversing the wire and average speed. There were three main factors STEREO (2 levels, Binocular and Monocular), HAND (2 levels, Dominant and Non-Dominant and WIRE (5 levels for the 5 wires). The results confirmed that stereo was in all measures significantly better with binocular vision than with monocular vision. Furthermore, we found that with the dominant hand the total time taken, average deviation and average speed were significantly better with the dominant hand.

We therefore believe that the VR version of the game could make a useful assessment of fine motor hand-eye coordination if there is stereo vision provided to the player. We next proceeded to test the motor skills of several subjects with known motor skill deficits to see if such methods are at least feasible in terms of usage and whether they could potentially be used as an entertaining form of motor skill exercise with the added ability to measure progress and improvement over time.

3 Experiment 2

The second experiment took place at a rehabilitation clinic and involved the same task except that only stereoscopic viewing was used. Six participants with upper body hemiparesis took part. Four had suffered right hemispheric ischemic stroke, and two left hemispheric stroke (one ischemic stroke, and one hemorrhagic stroke). Mean age was 55.5 years (median 56). Participants were seated in a chair or wheel-chair.

3.1 Results

Most of the difficulties in accurately following the wire arose from lack of rotation (pronation and supination) in arm and hand movements. This could be easily seen in visualizations of the participant movements recorded during the experiment (Figure 2). These show an inability to rotate the wand so that the ring was centered around the wire as it changed curvature. Translational movements (right to left, left to right) were slow and staggered, but nevertheless participants managed to traverse the distances from start to end points with both hands.

The average speed was found to be higher for the hemiparetic hand although this probably reflects that participants did not follow the curve exactly with their weakened hand, as shown by the elevated number of collisions. To explore this further we performed separate ANOVAs as in the previous experiment although this time the main factor was Hand only (2 levels, Hemiparetic, Unaffected). This showed that the difference in the number of collisions was significant between the two hands. The total distance covered was also significantly different. The mean deviation from the wire, mean speed and average time taken using the weak and normal hand was not significant.

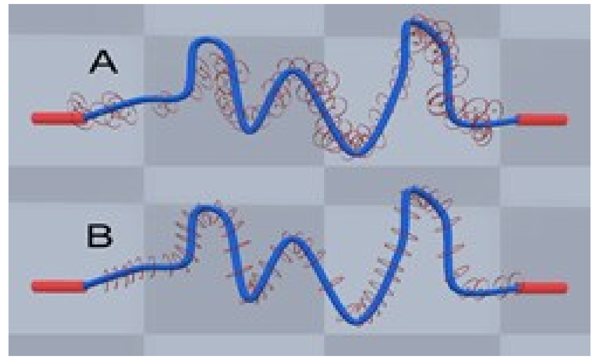

Figure 2: Comparison of weakened hand (A) and unaffected hand (B) in one trial from a patient with right-side hemiparesis.

A questionnaire was administered after the test to assess usability. The results showed generally that the HMD did not produce much discomfort and there were no reports of nausea (often associated with large movements in virtual environments). Some patients did however report difficulty in focusing on the scene.

4 Conclusion

Experiment 1 showed that the VR version of the game provides useful data that is not easily obtainable using the physical version. This data demonstrated that, as in the physical version, stereopsis is highly desirable, for accurate hand-eye coordination. Furthermore, we were also able to demonstrate an effect of handedness which has not been reported in previous studies.

The second experiment tested the feasibility of this technology on a small sample of stroke sufferers. Head-mounted displays, although improving continuously, are still relatively heavy and cut off the outside world entirely. This could cause fatigue and other difficulties, such as nausea. In terms of comfort and ease-of-use our participants easily adapted to the technology. These results are encouraging, and further studies will involve longer term monitoring with control groups to determine whether VR can provide a better alternative in stroke rehabilitation.

Acknowledgments

Authors acknowledge travel funding from the European Union's Horizon 2020 Framework Program through project NOTRE (H2020-TWINN-2015, Grant Agreement Number: 692058).

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