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ABSTRACT

Originally designed for video gaming purposes and media consumption, virtual reality (VR) has recently garnered interest as a research and therapeutic tool. Previous studies have investigated the use of virtual reality as psychological therapy to treat issues including, but not limited to, phobias, anxiety, and post-traumatic stress disorder. Use has expanded into the optometric field, where it has shown promising results in the last few years. In VR, the subject looks through a headset displaying a simulated environment with which they can interact. Navigating in the virtual environment and manipulating objects are usually done via controllers/keyboard or body motion tracking. There are many commercially available VR systems that can run the same software; however, there is no industry standard in VR research. This literature review summarizes the findings of three studies that use VR as a means to improve visual function outcomes in amblyopes and identify vision-related disabilities in patients with glaucoma.

Use of Virtual Reality Simulation to Identify Vision-Related Disability in Patients With Glaucoma

Lam AKN, To E, Weinreb RN, et al. JAMA Ophthalmol 2020;138(5):490. doi:10.1001/jamaophthalmol.2020.0392

Glaucoma continues to be the leading cause of irreversible blindness. The current gold standard of functionally assessing the optic nerve in glaucoma involves visual field (VF) testing. These tests provide clinicians with baseline information regarding their patients' visual disabilities. However, it does not assess their vision in real-life situations. Although there are several methods that a clinician uses to evaluate vision-related disabilities, these tests are currently either too difficult to set up or too costly to be used clinically. VR headsets provide an affordable alternative to measuring glaucoma-related visual disabilities. This paper evaluated the clinical applications of VR technology and measured vision-related disabilities through simulations of real-world daily tasks. In this study, 148 subjects were observed; ninety-eight were glaucoma patients, while the remaining 50 were healthy patients. These subjects were given HTC Vive headsets to use. The authors noted that the VR environments and objects programmed on Unity (Version 5.3.3p1) could be adapted to all available VR headsets. Orientation and positional tracking were programmed into the HTC Vive using the SteamVR SDK plugin. Before the experimental simulations, each subject completed a training simulation to familiarize themselves with each experimental condition. Participants interacted with a three-dimensional environment in a binocular stereoscopic view. Each participant was then asked to complete five different VR simulations: 1. Identify ten shopping items from a supermarket rack; 2. Walk up and down two flights of stairs during the day; 3. Walk up and down the stairs at night; 4. Navigate a city area over a virtual distance of 90 m in a simulated day; 5. Navigate the city in the simulated night. In the simulations, the following parameters were recorded: time elapsed to complete the simulation, the number of incorrectly identified objects, and the number of object collisions both on the stairs and in city navigation. Fifty of the participants with glaucoma were tested in both the VR shopping simulation and a similar real-life shopping simulation, and the results were compared. The test-retest variability was found to be relatively low by calculating intraclass correlation coefficients (ICC). The overall VR performance score was defined as "good" since the ICC was 0.70 and fell between the predefined range of 0.60 and 0.75. Comparisons were made between the glaucoma and healthy groups. In all tests performed, glaucoma negatively impacted the patient's performance in several daily tasks. Subjects with glaucoma were found to require 15.2 seconds (34.1%) more time than healthy

subjects when identifying items in the shopping simulation. Nighttime stair navigation required 72.8 seconds (33.8%) more time compared to the healthy group. Daytime navigation simulations were found to be similar between the glaucoma and healthy groups. It should be noted that although the results seem similar, the significance (p=0.52) reveals that there is a high probability that it may be due to chance. Subjects with glaucoma were also found to have more collisions in both night and daytime (2.9) than healthy individuals (1.2). Experimental results from the shopping identification simulation revealed that glaucoma subjects performed worse on the VR simulation compared to the same task in a real-life simulation. This study, in my opinion, contains several design flaws. The authors did not specify the duration of the training period prior to the experimental simulations. They did not specify how they determined that the subjects were adequately trained with the equipment. This could impact the replicability of this study and could account for the slower identification time in glaucoma patients when tested in the simulation compared to the real-life simulation. Furthermore, the participants observed were not representative of the entire human population since all participants in this study were Chinese. Future studies could replicate the experiments conducted by these authors using a more diverse experimental group so that the results could be more generalizable. All visual function tests were also subject to the learning effect and mastering of VR devices, which was minimized by changing the types and locations of VR objects in the simulation. The HTC Vive headset used in this experiment costs roughly $500, which is much cheaper and can be easily set up compared to conventional glaucoma visual assessment equipment. As technology advances, VR equipment will continue to improve to produce better representations of real life in the VR headset. These VR simulations can be used by all commercial VR headsets, which prevents the formation of monopolies in VR, thereby incentivizing cost reductions through competition. The authors of this paper suggest that virtual reality simulations present a clinically viable platform to access vision-related disabilities in patients with glaucoma. Self-reported poor night vision is a typical response from a glaucoma patient, but clinicians often underestimate the degree to which the patient has visual disabilities. .

Amblyopia Treatment of Adults with Dichoptic Training Using the Virtual Reality Oculus Rift Head Mounted Display: Preliminary Results

Žiak P, Holm A, Halička J, Mojžiš P, Piñero DP. BMC Ophthalmol 2017;17(1). doi:10.1186/s12886-017-0501-8

When it comes to amblyopia, patching and pharmacological treatments force the use of the amblyopic eye. This paper seeks to evaluate therapeutic dioptic training using VR as a treatment option for amblyopia. This paper was intended to be a preliminary study; it has a small sample size. Seventeen amblyopic subjects were observed, 10 men and 7 women. Subjects had to be 17 or older with anisometropic amblyopia. Subject ages ranged from 17-69 years old, with a mean age of 31.2 years. Candidates with strabismus, corneal irregularities, opacification of the ocular media, previous ocular surgery, and active ocular disease were excluded. Each of the subjects underwent eight training sessions. Two training sessions were conducted per week. Each session lasted 40 minutes, and subjects played two games per session, 20 minutes each. BCVA was determined before and after each training session. In this experiment, subjects wore an Oculus Rift OC DK2 virtual reality headset, which ran the beta version of a dichoptic visual training game called Diplopia game. The Oculus Rift was equipped with an AMOLED display (5,7" diagonal, resolution of 960 × 1080 pixels per eye), with 100° field of view, mounted with an accelerometer, gyroscope, and magnetometer sensor for positional tracking system. Two games were available, a spaceship piloting game and a block breaker game. Both games had a dichoptic setting, which displayed different images to both eyes. After the eight dichoptic training sessions, the BCVA was improved significantly from a logMAR value of 0.58 ± 0.35 before training to a mean post-training value of 0.43 ± 0.38 ($p<0.01$, Student t-test). The authors noted that 3 of their older subjects did not improve in BCVA upon the completion of the eight training sessions, suggesting that decreased plasticity with increased age was at fault. Stereoacuity was also found to improve from a mean value of 263.3 ± 135.1 arc seconds before dichoptic training to 176.7 ± 152.4 post-training. Several notable limitations were present in this study. The small sample size could result in the overestimation of the VR's clinical outcomes and low statistical power. The study also did not include a control group using patching treatments to quantify

and to compare the treatment outcomes. Almost half of the pre-training stereoacuity results were untestable using Stereo Randot tests. Future studies should include more comprehensive stereoacuity tests to quantify the improvements in stereo acuity. Despite the limitations, these findings seem promising and are consistent with the literature regarding VR treatments. Future experiments can be conducted on a larger scale to confirm these preliminary results.

A Dichoptic Custom-Made Action Video Game as a Treatment for Adult Amblyopia

Vedamurthy I, Nahum M, Huang SJ, et al. Vis Res 2015;114:173-87. doi:10.1016/j.visres.2015.04.008

The authors of this paper evaluated a novel approach to enhancing vision in amblyopic patients. Previous studies explored the potential of perceptual learning, monocular video gameplay, and dichoptic training, but none combined the three and observed the outcomes. It also compared these outcomes to more traditional approaches to amblyopia treatment, such as patching. Subjects needed the following requirements to be included in the study: (1) Subjects were all 18 years or older; (2) Subjects had either anisometropic, strabismic, or mixed amblyopia; (3) Interocular visual acuity difference of 0.2 LogMAR; and (4) No history of eye surgery except strabismic correction, when needed. Subjects who were non-comitant, had large-angle strabismus (>30 prism diopters), had ocular pathologies, or had nystagmus were excluded from the study. Two groups were set up: a gaming cohort that consisted of 23 subjects and a movie group that consisted of 15 subjects, who used the traditional patching treatment. Subjects in each group were required to complete a total of 40 hours of each intervention (1.5- to 2-hour sessions for 2-5 sessions a week). The authors of this study designed a VR stereoscope headset that ran a custom-made version of the Unreal Tournament video game. This dichoptic version of the game had 5 main innovations: (1) A split-screen view presented different images to each eye; (2) Alpha blending was used to balance the perceived image strength between the eyes at the start of each session to reduce the effect of suppression; (3) Easy tutorial levels prevented mastery of the game; (4) An orientation discrimination perceptual learning task was presented to the amblyopic eye (AE) only via a Gabor patch. Failure to respond/incorrect responses resulted in the appearance of a strong enemy in the game; (5) Suppression checks were integrated into the game to ensure the AE was being used. The experimental group viewed through the stereoscope and played the game using a gamma-corrected monitor with a refresh rate of 60Hz, 68cm away. Subjects in the traditional treatment/movie group wore a patch on the non-amblyopic eye (NAE) and watched action-intensive movies for a total of 40 hours. Visual tests were performed on all subjects before, upon completion, and two months after the 40-hour intervention, including visual acuity, stereoacuity, contrast sensitivity function, and reading speed. Visual acuity was measured using either Bailey-Lovie logMAR letter charts or high contrast ETDRS Sloan optotypes. Stereoacuity was measured using the Randot stereo test. The contrast sensitivity function was determined using the quick Contrast Sensitivity Function (qCSF), and the contrast sensitivity was determined using the area under the log CSF curve (AULCSF). Two hundred fifty contrast sensitivity measurements were made for each eye. Reading speed (words per minute) was measured using the MNRead Acuity Chart for each eye and then binocularly. The average VA improved by 0.14 ± 0.01 logMAR (28 ± 2% improvement) and 0.07 ± 0.03 logMAR (15 ± 6.4%) for the game and movie groups, respectively ($p<0.05$). VA improvements were retained after follow up, more so in the game group (0.12 ± 0.02 logMAR; 24 ± 4%) compared with the movies group (0.05 ± 0.03 logMAR; 11 ± 6.5%). Strabismic amblyopia only improved following the game intervention but not following the movie intervention. Stereoacuity improved most in the game group, with an average improvement of 0.18 ± 0.05 log arcsec (34 ± 9.4%) and 0.08 ± 0.04 log arcsec (17 ± 8.4%) for the game and movie groups, respectively. Contrast sensitivity was also found to increase in both groups, with an average increase of 0.3 (from 2 ± 0.19) and 0.1 log units (from 1.8 ± 0.15) for the game and movie groups. Post-intervention reading speeds of subjects in the game group improved more (26.2 ± 8.5 wpm) than the movie group (–5.8 ± 9.7 wpm). It should be noted that the reading speed results were not found to be statistically significant ($p=0.22$). Following the 40 hours of gameplay, the subjects in the game group improved in all of the visual function tests performed. The patching group did not show any significant improvements, with the exception of the VA test in anisometropic amblyopes. The authors of this paper initially hypothesized that there would be an additive effect by combining the three benefits;

however, this was not the case upon completion of the experiment. The VA improvement made by the gaming cohort was roughly 1.4 lines and, therefore, did not result in an additive effect. The authors noted that a 1- to 2-line improvement is consistent with the literature and may be the maximum VA improvement possible for adult amblyopia using these methods. They also hypothesized that the game's fast-paced nature could be a possible explanation for the increased reading speed in both strabismic and anisometropic amblyopes. This is due to the game's reaction time and eye movement demands. This novel study was the first to display the retention of improvement gains two months after gameplay completion, without any additional training. Future studies could explore the improvement retention beyond the two-month period in this study and optimize the training schedule to produce long-lasting visual function outcomes. Several limitations were present in this study, mainly from the total interventional hours to complete the study. Low sample sizes resulted due to a large drop-out rate of 38% in the gaming cohort. To prevent similar dropout rates in the movie group, subjects were permitted to view the movies at home while on a video call with the observer. The differing viewing locations could be seen as a potential confounding variable and result in a different training outcome. The present study supports the notion that amblyopic patients' visual systems might be more plastic than previously thought. The significant visual improvement outcomes demonstrate the treatment potential of dichoptic images on adult amblyopic patients beyond the critical period. This study's custom hardware and software designs can be implemented in commercial VR headsets for therapeutic use in the general population. When treating pediatric patients after a concussion, any challenges facing the child's family must be considered when recommending treatment plans. Many of the financial burdens voiced by participants in this study align with previous literature regarding the impact of other childhood injuries and illnesses such as asthma and influenza. It is important that the discussion of concussion and its financial impact be included with these statistics due to the fact that the incidence of concussion within pediatric populations is on the rise. Ultimately, reducing financial stress on a family should be focused on the prevention of concussion so that these burdens do not end up affecting the well-being of families.

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