Virtual Eye Rotation Vision Exercises (VERVE): A Virtual Reality Vision Therapy Platform with Eye Tracking

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1 Abstract

Binocular vision disorders such as convergence insufficiency (CI) impact the quality of life in patients across the entire age spectrum. While office-based vision therapy has been found to be effective, home-based vision therapy has been found to be no more effective than placebo therapy. It is hypothesized that this may be due to poor patient compliance and the "boring" nature of therapy. This pilot study tested VERVE (Virtual Eye Rotation Vision Exercises), a virtual reality video game that incorporates effective elements of office-based vision therapy, on nine CI patients. A masked, licensed clinician diagnosed and re-examined patients. Near point of convergence, positive fusional vergence, symptom surveys and vergence responses to 4 deg symmetrical step stimuli were compared pre- and post-VERVE. After 12 one-hour sessions with VERVE, seven subjects were shown to be remediated, while the remaining subjects showed symptomatic and clinical improvement.

2. Introduction

Convergence insufficiency (CI) is a prevalent binocular vision disorder which significantly impacts the quality of life in adults and children[1]. Symptoms include double/blurred vision, eyestrain, headaches, and re-reading of words for comprehension, so performing near work (for example, reading from a book or smart-device) interferes with a subject's day to day activities. CI is present in 4.2% to 17.6% of the general population[2–5]. CI has also been observed in 50% of civilian [6] and 46% of military/veteran populations following a traumatic brain injury (TBI), including concussions [7].

Traditional Office-Based Vergence and Accommodative Therapy (OBVAT) is 73% effective in remediating patient symptoms[1]; yet, home therapy has been reported to be no more effective then sham therapy. It may be that the repetitive nature of the therapy protocols and lack of engagement by a vision therapist in a home environment may in part be the reasons for the low success rates for home-based therapy. Therefore, there is a need for a vision therapy tool that is fun, interactive, automated, and can produce quantitative metrics for the clinician and patient, in both office- and home-based settings.

VERVE (Virtual Eye Rotation Vision Exercises) is an interactive virtual reality experience, which incorporates eye tracking monitoring and engages patients like a traditionally fun video game. VERVE has been designed with elements of vision therapy; specifically, VERVE modifies the vergence demand, or amount of eye rotation, required to complete each exercise. VERVE alters the vergence demand within each gaming session and increases the total vergence demand every session that the subject plays the vision therapy game.

3 Methods

Nine subjects (5M, 22.6 + 4.7 years) were recruited for this pilot study. All signed informed consent documentation prior to the experiments, which were approved by the New Jersey Institute of Technology's (NJIT) Institutional Review Board (IRB) in accordance with the Declaration of Helsinki. Clinical and oculomotor quantitative assessments were performed before and after VERVE vision therapy outside the therapeutic environment. Clinical exams were performed by an optometrist who was simultaneously examining subjects from another study involving the same patient demographics, participating in both active and placebo therapies. Hence, the clinician was masked, leading to a virtually unbiased clinical exam.

VERVE is played on a FOVE 0 head mounded display (HMD), a commercially available headset with integrated eye tracking. VERVE displays specific stimuli in the FOVE 0 that controls the amount of time a patient converges (inward eye rotation) in the near or far space on their visual midline. The magnitude of convergence is varied within a single session. The total magnitude of convergence demand in each session is systematically increased from session 1 to session 12. All subjects participated in 12 one-hour sessions (1 – 2 sessions per week) of VERVE.

The following clinical measures were measured from each subject pre- and post-therapy: 1) Near Point of Convergence (NPC), 2) Positive Fusional Vergence (PFV), 3) near / far dissociated phoria, and 4) Convergence Insufficiency Symptom Survey (CISS). The CISS is 15 questions using a 5-point Likert scale to assess vision symptoms where the greater the score the more symptomatic the subject.

These methods were chosen because CI is diagnosed using the following criteria: 1) NPC ≥ 6cm, 2) PFV not meeting Sheard's criteria of at least twice the near phoria or a range of ≤ 15Δ, 3) exophoria at near more than 4Δ greater than at far, and 4) CISS score of ≥ 21 for those 18 years and older.[1,8]

Quantitative eye movement assessments included response amplitudes, latencies, and peak velocities from vergence responses stimulated from 4 and 6 deg symmetrical convergence and divergence steps as shown by others were also collected pre- and post-therapy[9].

4 Results

Seven out of the nine subjects met success criteria for both clinical measures and symptoms, while the remaining two subjects showed clinical and symptomatic improvement. The mean **NPCs** improved from 10.4 ± 2.9 cm to 5.1 ± 2.1 cm; mean **PFVs** improved from 14.7 ± 3.0Δ to 26.5 ± 10.8Δ; and mean **CISS** scores improved from 35.6 ± 5.5 to 19.4 ± 5.6. Based on the definitions of a CI, seven subjects were classified as successfully remediated by VERVE.

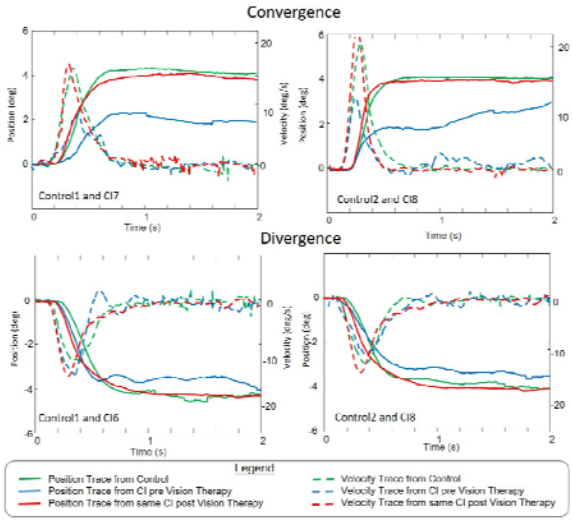

Figure 1: Pilot eye movement positional (solid) and velocity (dashed) data from a binocularly normal control subject (green) a CI subject pre-VERVE therapy (blue) and the same CIs post-VERVE therapy (red)

Figure 1 shows the vergence eye movements (positive position on the y axis is convergence rotation) from binocularly normal control (green traces), two CI patients before VERVE vision therapy (blue traces) and the same CI patients after VERVE vision therapy (red traces). The solid traces are the position traces, while dashes traces are the respective velocity traces. The responses are generated by the individuals from the presentation a symmetrical 4-degree vergence step stimuli. The control's eye movements are more accurate, meaning that they can respond to and hold the eye onto a new target. The eye movements are also precise, in that the subject can consistently make similar 4-degree vergence movements. The CIs initially (pre-VERVE therapy) have poor accuracy, meaning the eye cannot attain the 4-degree final position. Accuracy in the CI subjects improves post VERVE, and eye movements look more similar to the control subject.

5 Discussion and Conclusion

The results from this study show the potential for an effective therapy platform that can be conducted within a virtual reality setting and can be automated to produce quantitative metrics. Future work will include more subjects and a randomized clinical trial paradigm to test the effectiveness of VERVE compared to a control group.

Current vision therapy methodologies require the presence of a trained vision therapist for an effective treatment. None of the tools currently available to vision therapists provide objective, quantitative metrics of eye movements, which are available only through eye tracking. Thus, there is a need for a quantitative tool that will facilitate the treatment and track progress of vision performance in CI patients. Finally, if VERVE is shown to be successful when administered as home-based therapy, it may reduce the cost of vision therapy making it more accessible to a broader population that was previously unable to benefit either because of financial restrictions or the lack of availability of a licensed vision therapist.

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