

COMPARING SUBJECTIVE BINOCULAR VISION MEASUREMENTS USING
VIVID VISION AND TRADITIONAL METHODS

by

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VIVID VISION AND TRADITIONAL METHODS

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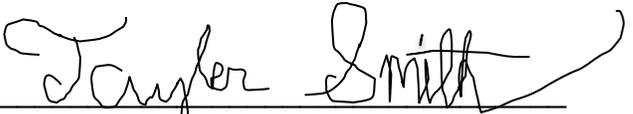


Faculty Course Supervisor

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Doctor of Optometry Senior Paper
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COMPARING SUBJECTIVE BINOCULAR VISION MEASUREMENTS USING
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ABSTRACT

Background: *Vivid Vision Clinical* is a new vision therapy software program that utilizes a virtual reality headset to help provide vision therapy for patients with strabismus, amblyopia and other binocular vision anomalies. In addition to therapy games, the device has the ability to measure subjective phoria, ocular dominance, and flat fusion. As this program is new technology, there are no studies evaluating the accuracy of results, or preliminary findings. As such, we decided to look at the simplest information to see if these digital methods of measurement compare to traditional methods of measurement. The question addressed in this research is whether there is a significant difference in results between measurements on the Vivid Vision and traditional clinical measurements.

Methods: A sample size of 30 optometry students had subjective distance phoria measurements taken using Maddox Rod, Worth 4 Dot testing performed at 10 feet, and ocular dominance testing by viewing a small target letter at distance through a hole between their hands. The same three measurements were then taken using the Vivid Vision device (distance phoria, flat fusion, and ocular dominance), and results between the two methods were compared.

Results: Ocular dominance measurements showed a 63.33% accuracy between testing methods, and flat fusion measurements showed 80% accuracy with Vivid Vision compared to clinical measurements. Average clinical horizontal phoric posture was measured at $0.61^{\Delta} \pm 7.49^{\Delta}$ exo and average Vivid Vision posture was $5.47^{\Delta} \pm 3.93^{\Delta}$ eso, which was a statistically significant difference. Average clinical vertical phoric posture was measured at $0.081^{\Delta} \pm 0.39^{\Delta}$ and average Vivid Vision posture was $0.037^{\Delta} \pm 0.92^{\Delta}$, which was not statistically significant.

Conclusions: We found a statistically significant difference in horizontal phoria measurements for our subject population, with the Vivid Vision showing a more eso posture. This may be attributable to a strong stimulus for proximal convergence, or the nature of the program itself. Worth four dot and ocular dominance measurements were also inconsistent, indicating that clinical values and Vivid Vision measurements should not be used interchangeably in a clinic or therapy setting.

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CHAPTER 1

INTRODUCTION OF VIVID VISION SOFTWARE AND BINOCULAR VISION TESTING

Vivid Vision Clinical is a vision therapy software program that consists of an Oculus Rift Virtual Reality headset paired with a variety of games and activities for patients with strabismus, amblyopia, and other binocular vision anomalies. The activities either use an X-Box controller, individual handheld controllers, or are interactive in free space using sensors to pick up the patient's hand, head, and body movements. The ability for movement and proprioceptive awareness adds to the overall achievement or improvement of depth perception. Vergence demand, stimulus size, and stimulus strength can be varied between each eye in order to emphasize and strengthen the weaker eye. In addition to the therapy activities, the device has the ability to measure subjective distance phoria, ocular dominance and flat fusion. These activities are frequently performed as a baseline measurement prior to starting an activity.

As a clinical device, the Vivid Vision aims to measure strabismus, assess binocular vision, and to treat suppression and amblyopia. It is intended to be used when traditional treatments such as eye patching and surgery have already failed to work.¹ The ability to alter the images shown to each eye in so many facets makes the technology a great avenue for vision training.

For patients with binocular anomalies and amblyopia, a variety of tests are performed prior to and throughout treatment in order to measure progress. Among these tests are commonly: monocular distance and near visual acuity, accommodative amplitude, response, and facility, a measurement of alignment, convergence and divergence amplitude and facility, and stereopsis and flat fusion. Change and progress of the results of these tests are the most common way to measure the success of therapy, along with subjective patient symptoms when applicable. Initial results of these tests are used to determine a starting point for different therapy exercises, as well as a guide for which therapy exercises will be most effective for the patient.

As the Vivid Vision program is relatively new technology, there are currently no studies available which evaluate the accuracy of results, or preliminary findings. However, some studies have evaluated the ocular effects of virtual reality headset use. Some have demonstrated that patients over converge and have a resultant esophoric posture and even an increased risk of myopia progression after the use of VR devices, while other studies show that there is no significant difference in visual status post-use of VR devices.^{2,3,4} With this in mind, we decided to look at baseline information on the Vivid Vision to see how digital methods of measurement compare to clinical measurements. The question addressed in this research is whether there is a significant difference in results when comparing measurements on the Vivid Vision Clinical to traditional exam methods for binocular vision testing.

CHAPTER 2

METHODS

An application for Human Subjects Research was submitted and approved by the Institutional Review Board (IRB). Eligible subjects included current Michigan College of Optometry students, staff, and faculty, who were above 18 years of age. Subjects were recruited through social media on the college's facebook page, and in person in the classrooms. All measurements were taken through the subject's distance vision correction (either glasses or contacts) if he or she required correction. A measurement of horizontal and vertical distance phoria were taken using a Maddox Rod while the patient viewed a white muscle light target on the distance acuity chart. Phoria was neutralized using a horizontal or vertical prism bar over the left eye until the subject reported that the red line created by the Maddox Rod intersected the target. Three measurements of each horizontal and vertical posture was taken. The test was performed in dark illumination, and was chosen to most closely compare to the testing procedure used by the Vivid Vision device.

A determination of the subject's dominant eye was performed by having the subject place their arms in an outstretched manner directly in front of them, palms facing away from them, overlapping to allow for an opening only large enough to view the distance white muscle light target between their hands. The subject's right eye was occluded, and then their left. The eye occluded when the target disappeared from view was recorded as the dominant eye. The plus lens

blur tolerance and hole-in-card/hole-in-hand are common methods, but the hole-in-hand method was chosen due to the fact that it most closely compared to the Vivid Vision test.

A determination of flat fusion was tested using a Worth 4 Dot at 10 feet. The subject used Red/Green glasses (red lens over right eye), worn over the subject's own glasses or contacts. The test was performed in dark illumination. The subject was asked to report the number of dots seen. If four dots were reported, the subject was asked to report the color of bottom dot. If the subject reported a number other than four, they were asked to describe what they saw, including the number and color of dots seen.

The subject was then seated in front of the Vivid Vision Device. The Oculus Rift VR headset was properly fit and adjusted on the subject (over the subject's glasses if applicable), who was then given the handheld X-Box controller. Measurements of ocular dominance, fusion, and distance phoria were then taken through the Vivid Vision software. The determination of the subject's dominant eye was performed using the following steps: The tests tab was selected from the main menu, and "Dominance" was selected from that category. The subject viewed a white ring next to a solid red circle. The subject used the joystick on the controller to move the red dot so that it was centered inside of the white ring. The software then reported the dominant eye based on the corrective movement with the joystick. Binocular fusion testing was performed using the following steps: The tests tab was selected from the main menu, and "Four Dot" was selected from that category. The subject then viewed a number of shapes.

Using the controller arrows, they selected the number of shapes that they saw, followed by the color of the bottom shape if they reported seeing 4 total shapes.

The measurement of distance phoria was taken using the following steps: The Tests tab was selected from the main menu, and “Angles” selected from that category. The subject viewed solid white circle (presented to one eye) and surrounding black ring (presented to the fellow eye), each with a red, green, orange and red triangle. The subject used the joystick on the controller to align the white circle within the black ring so that the corresponding colored triangles were in alignment. He or she made horizontal and vertical adjustments to achieve this. Once the circle was aligned, the subject confirmed the alignment. The subject was then asked to repeat this task an additional two times. After three measurements were taken, the software ended the test, and average results of horizontal and vertical phoria was presented.

CHAPTER 3

RESULTS

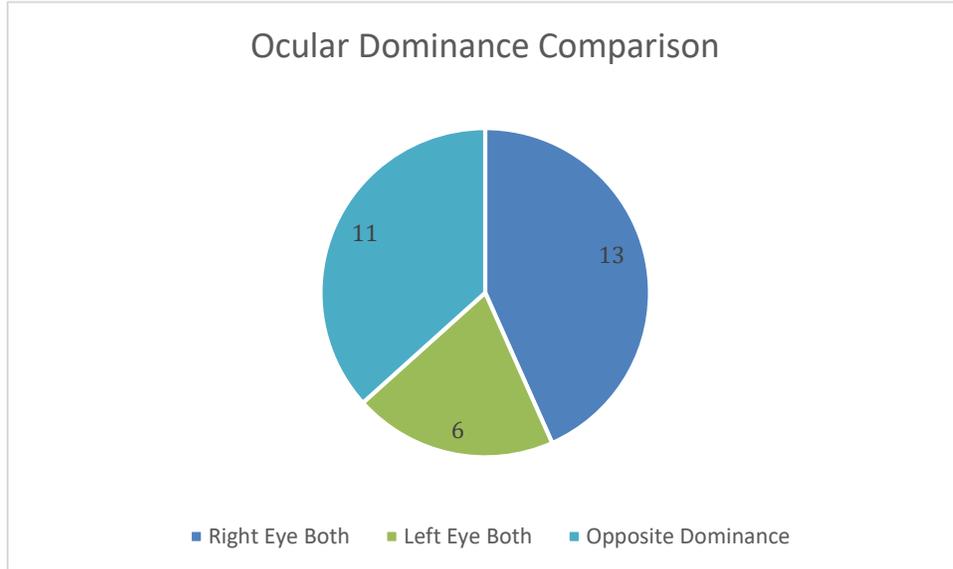
Subject Population

30 subjects consented and took part in the study 17 were female, 13 were male. They ranged in age from 22 to 27. All were first through fourth year optometry students.

Ocular Dominance

There were 19 subjects (63.33%) who had the same ocular dominance in both types of testing. Of those patients, 13 showed right eye dominance, and 6 showed left eye dominance. There were 11 out of 30 subjects (36.67%) who showed differing results on ocular dominance between the two testing methods. In those 11 subjects, the Vivid Vision ocular dominance test was repeated an additional two times, and in 4 out of the 11 subjects, the results of the three trials were also inconsistent (**See Chart 1**).

Chart 1: Ocular Dominance Results Comparison

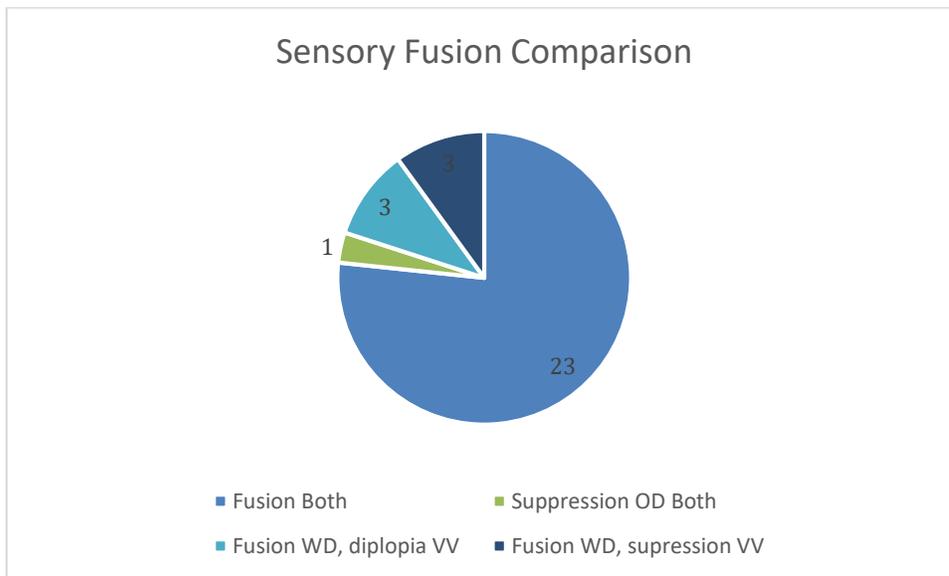


Flat Fusion

Results from Worth 4 Dot testing showed that 24 subjects (80%) had the same results for both traditional and Vivid Vision testing. When comparing only the number of dots/shapes the subject reported seeing. However, a more detailed analysis does reveal discrepancies between the two methods. Subjects tended to have a lower rate of true luster with the Vivid Vision. 3 subjects (10%) reported fusion with clinical testing, but reported diplopia with the Vivid Vision. 3 subjects (10%) reported fusion with clinical testing, but reported suppression with Vivid Vision. 1 subject reported suppression of an eye with both clinical testing and Vivid Vision, however, reported suppression of the opposite with Vivid Vision. 6 subjects (20%) reported fusion with luster of the bottom dot in clinical testing, but fusion without luster with Vivid Vision. 1 subject showed flat fusion

without luster in both methods, but reported the bottom figure in the opposite color, showing opposite ocular dominance between the methods (**See Chart 2**).

Chart 2: Sensory Fusion Results Comparison



Phoria

Both horizontal and vertical alignment were measured. Mean posture with Maddox Rod testing for the horizontal deviation was $0.61^{\Delta} \pm 7.49^{\Delta}$ exo. Mean horizontal posture with Vivid Vision was $5.47^{\Delta} \pm 3.93^{\Delta}$ eso (**see Figure 1**). These results were statistically significant ($P < 0.001$). Mean posture with Maddox Rod testing for the vertical deviation was $0.081^{\Delta} \pm 0.39^{\Delta}$. Mean posture with Vivid Vision was $0.037^{\Delta} \pm 0.92^{\Delta}$ (**see Figure 2**). These results were not statistically significant ($P = 0.81$).

Figure 1: Horizontal Phoria Statistical Comparison

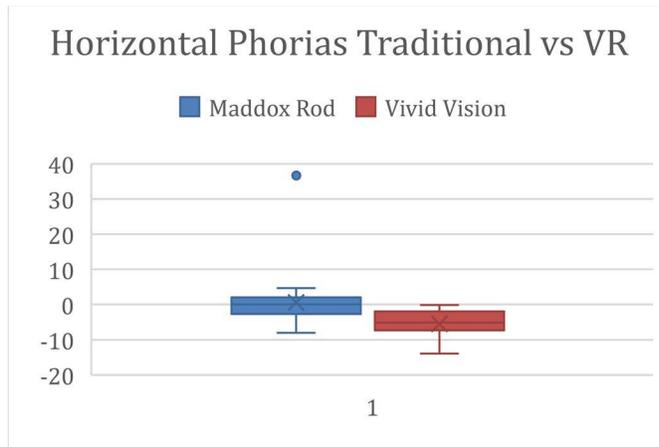
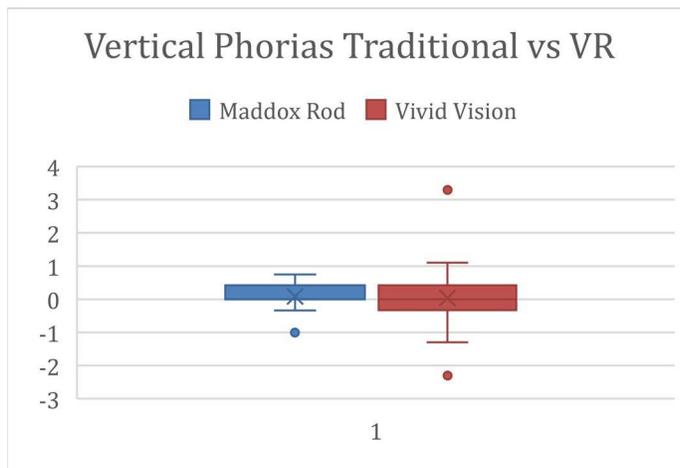


Figure 2: Vertical Phoria Statistical Comparison



CHAPTER 4

DISCUSSION

Ocular dominance is a binocular vision test that can be measured in several ways, but is one of the lesser precise tests performed when gathering comprehensive binocular vision data. Although the testing methods are available on the Vivid Vision software, it is also possible to manually enter the binocular vision test data manually from measurements found using traditional clinical measurements when creating a new patient profile in the system. In most cases, this data has already been gathered during the comprehensive exam or initial vision therapy evaluation and therefore may not be repeated by the practitioner or vision therapist in the digital environment. The accuracy of 63.33% for the ocular dominance testing could significantly lessen the effectivity of the program. For instance, if the right eye was found to be the dominant eye in clinical testing, but the patient was determined to be left eye dominant through the Vivid Vision program prior to beginning therapy, this could alter the progress of the therapy course. The system designs each activity based on which eye is dominant, and the non-dominant eye for the system is challenged at a greater level. The Vivid Vision is typically marketed as an amblyopia device, so that should be considered when using the Vivid Vision for other binocular disorders. We may have found a much higher consistency in testing had all of our subjects been amblyopes. In non-amblyopic individuals who are using the program to build vergence ranges, oculomotor, or other binocular vision skills, the visual demand

during each activity can be increased, but usually each eye is presented with an equal stimulus. Therefore, theoretically, this error would not be as detrimental in non-amblyopic patients. However, this finding still warrants further studies and analysis to improve and validate the results from a treatment course using Vivid Vision.

Phoria results show a significantly increased eso posture when tested with the Vivid Vision. The test is performed with a blank, black background that is void of any visual stimulus. There were many subjects that reported to the investigator that the longer they took to perform the test, the more the targets seemed to move further apart, requiring additional movements with the controller to align each target. This over convergence could be especially detrimental for those patients with esotropic strabismus/amblyopia, or convergence excess patients in which building divergence is the focus of treatment. Further convergence beyond normal status would very likely hinder progression. These results warrant additional studies to determine whether this treatment method is suitable for these patient types, or if non-digital free space activities would yield better success. It is important to note that the program developers have identified this problem, and are working on improving the testing methods. While we did not measure the variable of proximal convergence in our study, we suspect that this could be a strong influence on the higher eso posture, based on the design of the VR headset, rather than the program itself.

The lack of background visual stimulus in the modified Worth 4 Dot testing may also have led to the reduced accuracy during testing. Worth 4 Dot is largely

used as a suppression check, especially in those with amblyopia. However, it can give us great information about the progress a patient is making based on the response they give. Achieving flat fusion is one step closer to achieving some level of stereopsis in patients with suppression or diplopia, but noting the presence of binocular rivalry or luster shows even more progress. This was a major difference in the findings between clinical Worth 4 Dot flashlight testing and the modified digital version on the Vivid Vision. Six subjects did not observe binocular rivalry on the digital test, but did observe luster/rivalry in the traditional method.

There are several limits to this initial study which warrant further research. First, the low subject number with a very specific subject demographic does not allow us to draw concrete conclusions about the general population. Although clinical methods were chosen to most closely resemble Vivid Vision methods, they are not directly comparable. 29 of 30 subjects had a normal binocular vision status. Because of the fact that the Vivid Vision device is used to improve or correct binocular vision problems in patients who do not have a normal binocular vision status, a study with this type of subjects may yield very different results.

The Vivid Vision software is a unique instrument in the field of vision therapy in that it allows a patient to be completely submerged into their visual experience. The adaptability of the program and activities to reduce suppression and improve binocular skills can help improve the vision and lives of amblyopic patients. There is no doubt that this technology will continue to improve as it becomes more common in practice, however, it is clear that more research is

needed on the accuracy of testing methods and the comparison to traditional clinical testing before using results interchangeably.

CHAPTER 5

REFERENCES

1. Vivid Vision. Important Information. https://www.seevividly.com/doctor_locator. Accessed April 5, 2019
2. Ha, S., Na, K., Kweon, I., Suh, Y., & Kim, S. (2016). Effects of Head-Mounted Display on the Oculomotor System and Refractive Error in Normal Adolescents. *Journal of Pediatric Ophthalmology & Strabismus*, 53(4), 238-245. doi:10.3928/01913913-20160511-01
3. Mon-Williams, M., Warm, J. P., & Rushton, S. (1993). Binocular vision in a virtual world: Visual deficits following the wearing of a head-mounted display. *Ophthalmic and Physiological Optics*, 13(4), 387-391. doi:10.1111/j.1475-1313.1993.tb00496.x
4. Turnbull, P. R., & Phillips, J. R. (2017). Ocular effects of virtual reality headset wear in young adults. *Scientific Reports*, 7(1). doi:10.1038/s41598-017-16320-6

APPENDIX A

IRB APPROVAL LETTER



FERRIS STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD FOR HUMAN SUBJECT RESEARCH

1010 Campus Drive FLITE 410 Big Rapids, MI 49307 | (231) 591-2553 | www.ferris.edu/irb

Date: November 15, 2018

To: Paula McDowell

From: Gregory Wellman, R.Ph, Ph.D, IRB Chair

Re: IRB Application IRB-FY18-19-24 Comparing Subjective Binocular Vision Measurements Using Vivid Vision and Traditional Methods

The Ferris State University Institutional Review Board (IRB) has reviewed your application for using human subjects in the study, "Comparing Subjective Binocular Vision Measurements Using Vivid Vision and Traditional Methods" (IRB-FY18-19-24) and Approved this project under Federal Regulations Expedited Review 4. Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)

Approval has an expiration date of one year from the date of this letter . **As such, you may collect data according to the procedures outlined in your application until November 15, 2019** . Should additional time be needed to conduct your approved study, a request for extension must be submitted to the IRB a month prior to its expiration.

Your protocol has been assigned project number IRB-FY18-19-24. Approval mandates that you follow all University policy and procedures, in addition to applicable governmental regulations. Approval applies only to the activities described in the protocol submission; should revisions need to be made, all materials must be reviewed and approved by the IRB prior to initiation. In addition, the IRB must be made aware of any serious and unexpected and/or unanticipated adverse events as well as complaints and non-compliance issues.

Understand that informed consent is a process beginning with a description of the study and participant rights with assurance of participant understanding, followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document and investigators maintain consent records for a minimum of three years.

As mandated by Title 45 Code of Federal Regulations, Part 46 (45 CFR 46) the IRB requires submission of annual reviews during the life of the research project and a Final Report Form upon study completion. Thank you for your compliance with these guidelines and best wishes for a successful research endeavor. Please let us know if the IRB can be of any future assistance.

Regards,

A handwritten signature in black ink, appearing to read "Gregory Wellman".

Gregory Wellman, R.Ph, Ph.D, IRB Chair
Ferris State University Institutional Review Board