COMPARISON OF MONOCULAR VERSUS BINOCULAR DEVELOPMENTAL EYE MOVEMENT (DEM) TEST RESULTS

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We, Holly Hoffman and Monica Narula, hereby release this paper as described above to the Michigan College of Optometry and Ferris State University with the understanding that it will be accessible to the general public. This release is required under the provisions of the Federal Privacy Act.

ABSTRACT

Background: This study will evaluate differences in binocular versus monocular performance on the Developmental Eye Movement (DEM) test in a normal adult population. The DEM is a tool that is used in the assessment and analysis of oculomotor and visual processing abilities, especially in school-aged children. *Methods*: Using a sample of 20 subjects with optimal vision and good oculomotor function, the DEM test was performed monocularly with each eye three times on day one, then binocularly three times on day two. The vertical subtest time, horizontal subtest time, and calculated ratio of horizontal to vertical times were recorded. *Results:* The data was analyzed using a paired student t-test. It was found that the monocular versus binocular times for the vertical and horizontal subtests had a statistically significant difference; however there is no statistically significant difference between the ratios of monocular versus binocular. *Conclusion:* Binocular performance on the DEM was significantly better in comparison to monocular. Considering that binocular testing followed monocular we largely attribute the enhancement of binocular performance to a learning effect.

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INTRODUCTION

The DEM is a tool that is used in the assessment and analysis of oculomotor and visual processing abilities in school-aged populations. An additional use of the test is in individuals that have suffered cerebral vascular accidents or traumatic brain injuries. These patients can develop strabismus, saccadic dysfunction or other binocular complications which the DEM may be useful in evaluating.

The DEM is a visual-verbal skills test that incorporates rapid automated naming (RAN) of numbers in separate vertical and horizontal subtests. The time required to read the numbers in the directed order is measured in seconds and these times are used to further score the test. The final calculation is a ratio achieved from the adjusted horizontal and the vertical time. The ratio is then referenced in the set of normalized tables based on age or scholastic grade level to achieve the percentile rank in binocular testing situations. The designated percentile rank is an indication of the student's oculomotor skills which can correlate to their reading abilities. Typically, the DEM test is administered binocularly.

This aim of this study is to evaluate differences in binocular versus monocular performance on the Developmental Eye Movement (DEM) test in a normal adult population.

METHODS

Twenty third year optometry students of the Michigan College of Optometry participated in this study. The mean age was 26.5 years +/-5, with an equal number of males and females. Approval for this study was obtained through the Ferris State University Human Subject Review Committee. A consent form was signed by all participants (see Appendix A). Prior to inclusion, all participants were required to pass visual acuity and oculomotor screenings. The acuity was measured by Snellen at 40cm, first monocularly then binocularly. Participants were required to have monocular acuities better than 20/20. Oculomotor screening was done to detect saccadic dysfunction using Northeastern State University College of Optometry (NSUCO) technique. Participants had to pass the minimum criterion for this screening test.

The DEM includes three subtests. The first two subtests consist of vertical columns of single digit numbers (Tests A and B). Each of these subtests has two columns of 20 numbers, ranging from 1-9, which participants read from top to bottom. The final subtest (Test C) consists of horizontal rows of numbers, spaced out sporadically in 16 rows containing a total of 80 numerical values. The time measured for Test C is then adjusted by any mistakes made. Mistakes include errors of substitutions, omissions, additional and transposition errors. The new horizontal adjusted time is calculated by multiplying the horizontal time by 80/(80 – omissions + additions). The final calculation is a ratio achieved from the adjusted horizontal and the vertical time. The ratio is then referenced in the set of normalized tables based on age or scholastic grade level to achieve the percentile rank in binocular testing situations.

For this study, each participant did subtests A, B, and C three times in a row. The instructions given to participants were to read a series of numbers out loud, in the set order, as quickly as possible. The testing took place over two days; on the first day participants did the test monocularly with the right eye (OD), followed by the left eye (OS). On the second day of testing, the subtests were done binocularly, with both eyes open (OU). The test was timed in seconds, using a standard stopwatch. The two vertical subtests were added together for the total vertical time. Any errors recorded during subtest C were used to calculate the adjusted horizontal times. Times from the vertical and horizontal subtests were used to calculate a ratio of the times. The data was analyzed using a paired student t-test, comparing vertical times, horizontal times, and the calculated ratios between OD to OU and OS to OU.

RESULTS

The mean times for each of the three trials of the subtests were calculated, then the total vertical and adjusted horizontal times were calculated, as well as the ratio for each participant's test. The mean times and standard deviations for each subtest are shown in Table 1. These times were then used to compare OD to OU and OS to OU for the vertical time, horizontal time and ratio. Table 2 shows the p-value for these comparisons. Graphs 1-6 show the times from each test. Based on the calculated data, the monocular versus binocular times for the vertical and horizontal tests show a significant difference, however there is no statistically significant difference in the ratios of monocular verses binocular.

Upon further evaluation of the data, a learning curve was noted depending on which eye was tested first. Graphs 7-9 demonstrate that OD testing, which was done first, generally had the longest time. The binocular testing had the shortest times and was tested after the right and left eyes individually.

	Mean	Std Deviation
Vertical OD	25.63	4.86
Vertical OS	25.75	4.70
Vertical OU	23.38	4.13
Horizontal OD	26.10	5.03
Horizontal OS	25.60	5.02
Horizontal OU	22.90	4.20
Ratio OD	1.01	0.09
Ratio OS	0.99	0.08
Ratio OU	0.98	0.08

Table 1: Mean and standard deviation of the 20 participants' vertical and horizontal subtests and ratios.

	Horizontal OD-OU	Horizontal OS-OU	Vertical OD-OU	Vertical OS-OU	Ratio OD-OU	Ratio OS-OU
p-value	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p=0.0523	p=0.4615

Table 2: p-values based off the paired student t-test analysis, p<0.0001 is statistically significant.

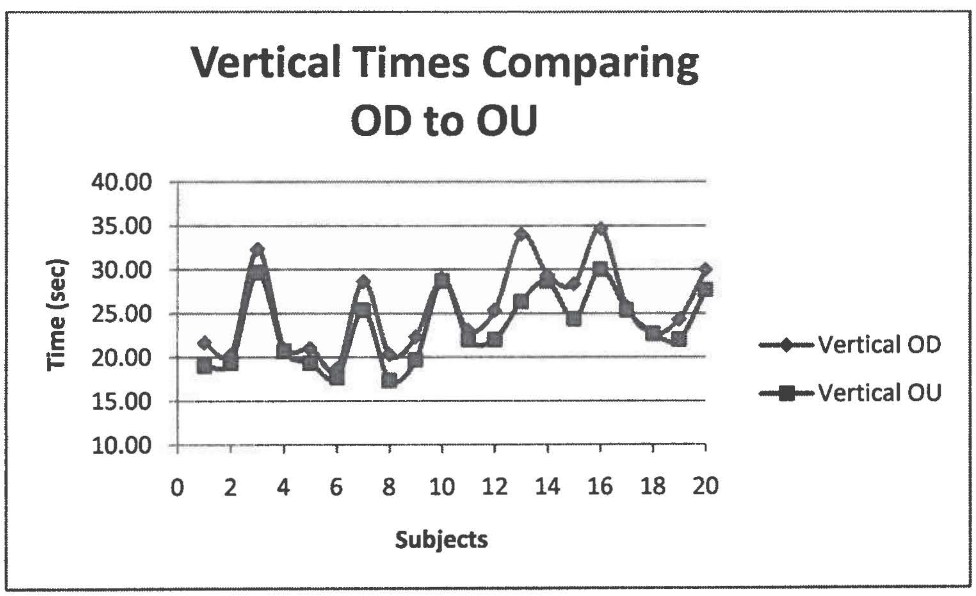

Figure 1: DEM Vertical Times Comparing OD to OU.

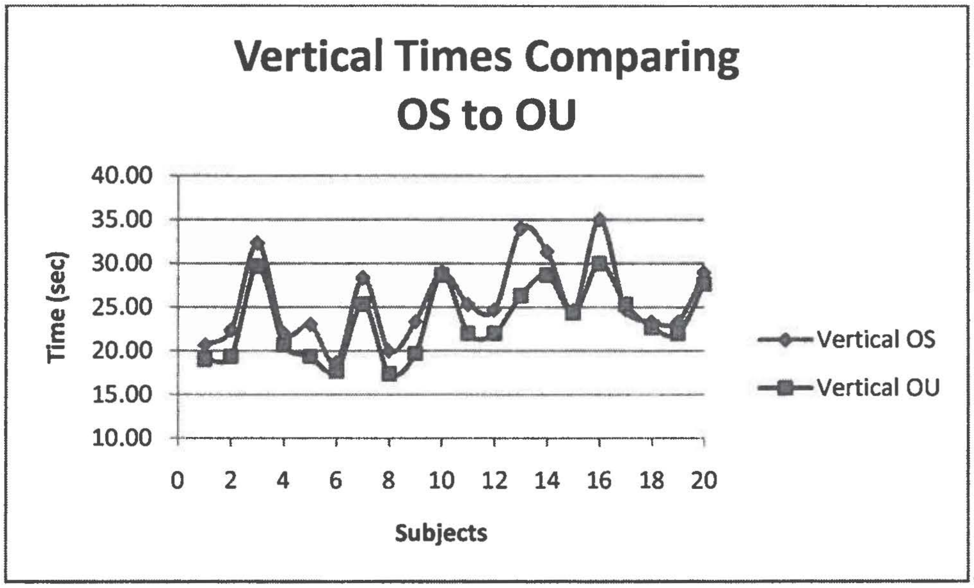

Figure 2: DEM Vertical Times Comparing OS to OU.

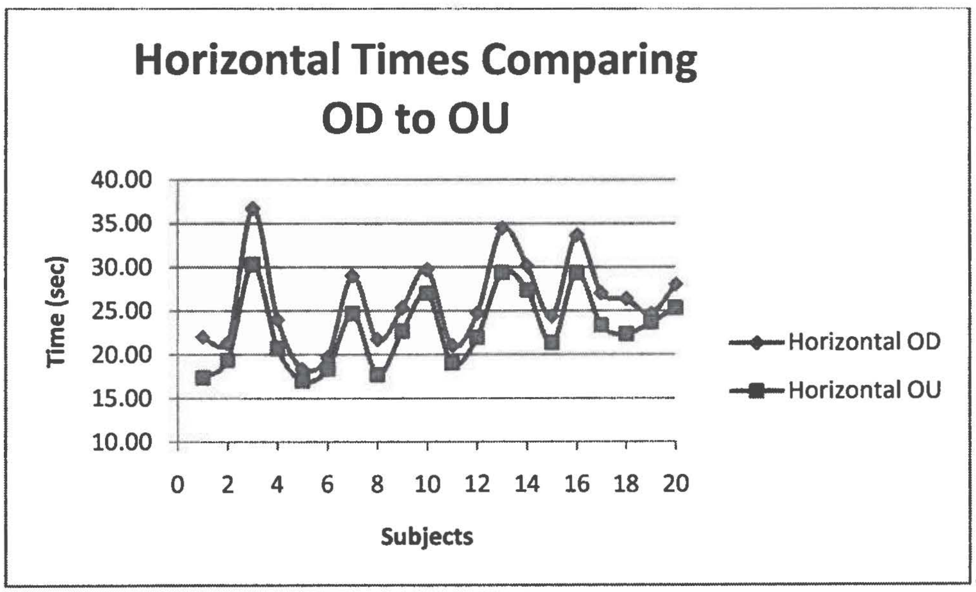

Figure 3: DEM Horizontal Times Comparing OD to OU.

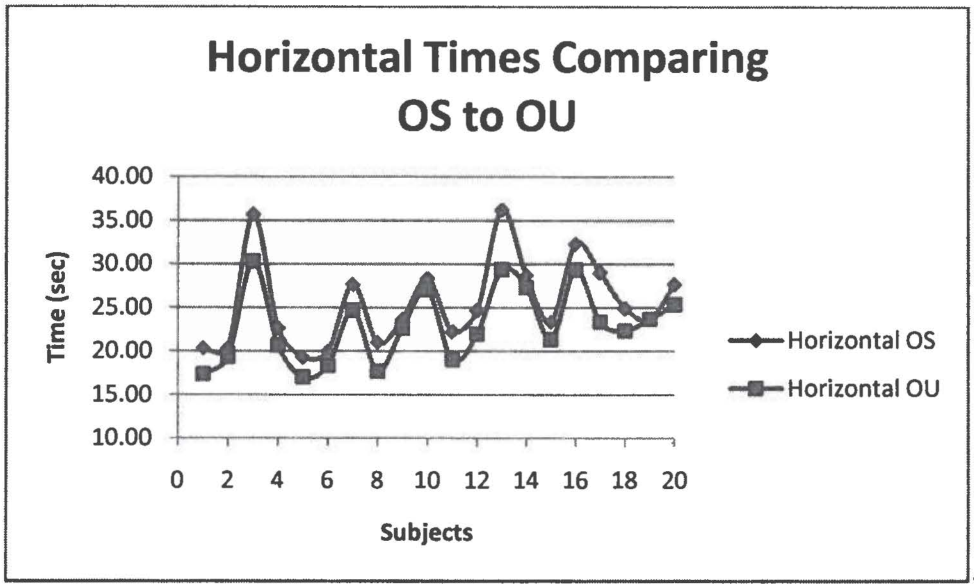

Figure 4: DEM Horizontal Times Comparing OS to OU.

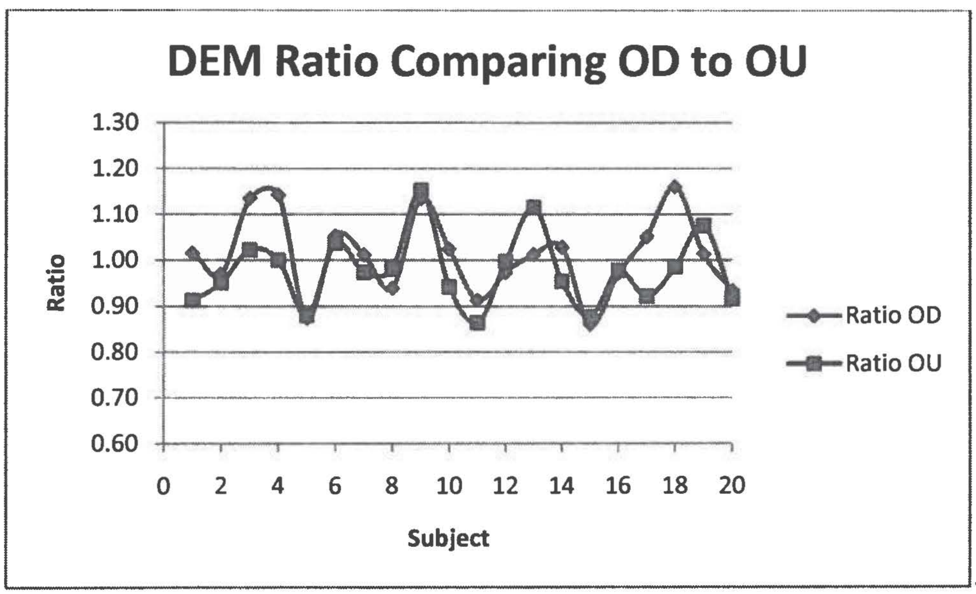

Figure 5: DEM Ratio Comparing OD to OU.

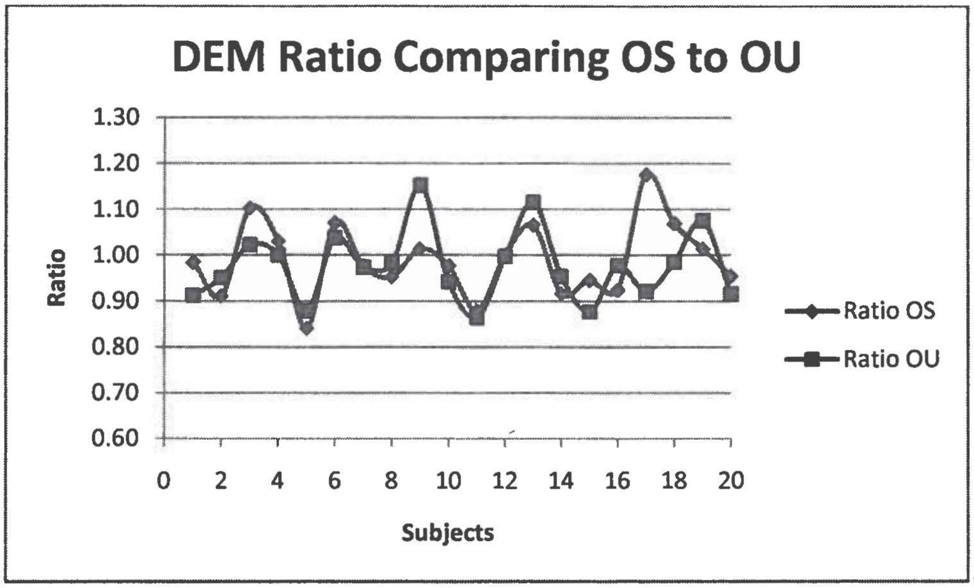

Figure 6: DEM Ratio Comparing OS to OU.

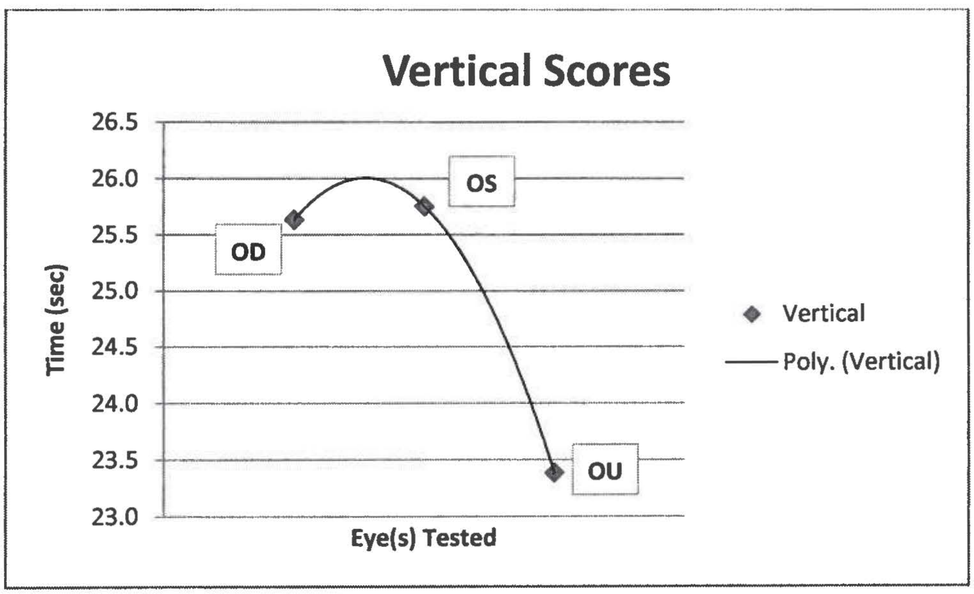

Figure 7: DEM vertical times demonstrating a possible learning curve based on the order of testing done. A 2nd order polynominal trendline has been fitted to the data.

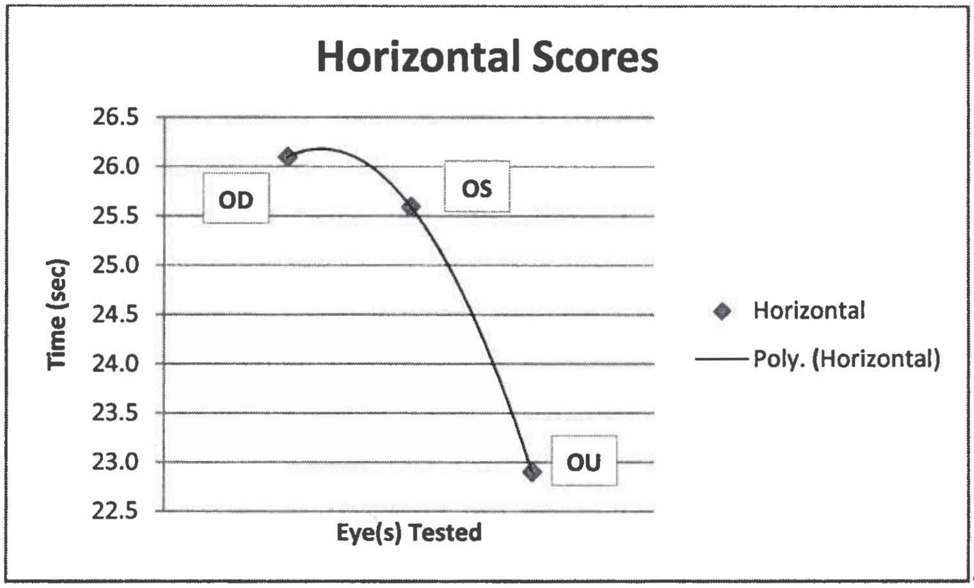

Figure 8: DEM horizontal times demonstrating a possible learning curve based on the order of testing done. A 2nd order polynominal trendline has been fitted to the data.

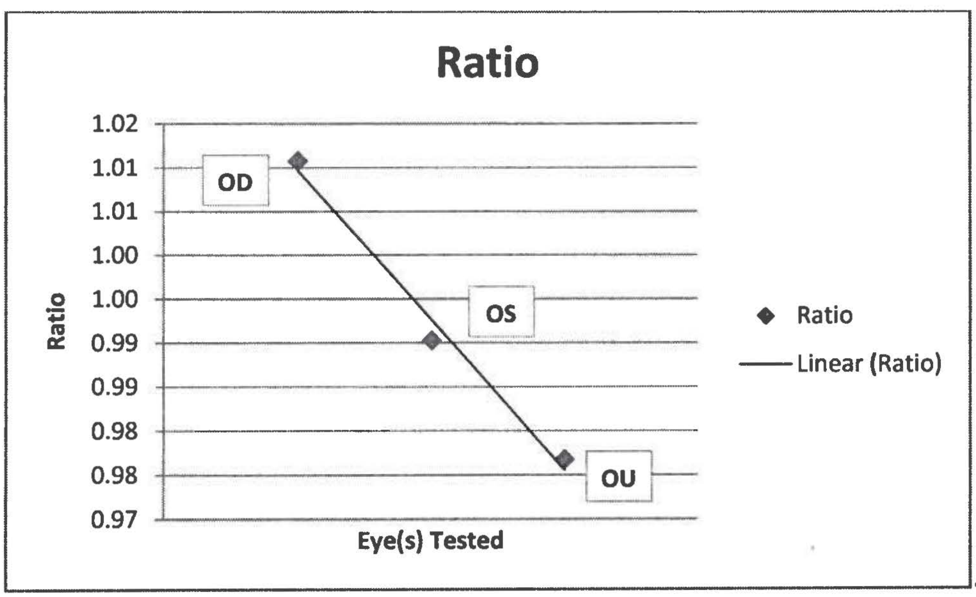

Figure 9: DEM ratio demonstrating a possible learning curve based on the order of testing done. A linear trendline has been fitted to the data.

DISCUSSION

The results of our study demonstrate a statistically significant difference between the monocular and binocular test results for the horizontal and vertical times of the Developmental Eye Movements test, with binocular performance being significantly better. The ratio scores fell just short of statistical significance.

We concede that the group of participants, 20 optometry students, had test times and consequently ratios that were outside of the range of normative values in the standard DEM tables. As would be expected from the average performance of normal subjects in this age range, all scores achieved were near the 99thpercentile. Therefore, the raw time in seconds for the vertical and horizontal tests, and the ratio were used in the data analysis, as opposed to the percentile rankings. Additionally, each participant served as his/her own control. Monocular testing (OD isolated, OS isolated) was done on day one, followed by binocular DEM testing on day two. This testing strategy also aided in reducing fatigue since each test was performed three times for reliability and averaging purposes.

In evaluating the enhanced binocular performance we have to consider the task-learning concept in our study. Although, binocular testing was done two days following monocular testing, it is likely that the subjects had learned the task and were able to perform it more efficiently. Previous studies have indicated a learning effect with the Pierce Saccade and King-Devick tests, predecessors to the DEM.[1] After the development of the DEM, Garzia et al. stated that the DEM did not suffer from these variables and is repeatable as well as reliable.[2] Further studies by Rouse et al. conversely determined a low correlation in the DEM retest two weeks later specifically for the DEM ratios; however the study did not isolate the learning curve.[3]

Although we showed a binocular improvement in DEM scores, our study cannot definitively indicate if the improvement was due to factors such as binocular summation or simply from a learning effect. Binocular factors may have played a role in our results, however we postulate that these effects are likely to be small and conflated within the much larger learning curve effects. Future studies could test this theory by randomizing the order of testing, for e.g. OU tested first, followed by OS and OD in a larger test population. Furthermore, the duration between sequential testing could be altered, for example by repeating the test at intervals of a few days, weeks and months to determine the time period over which the learning effect sustains itself.

Although this was a pilot study, the results have important clinical implications in the use of the DEM test especially in patients with oculomotor and/or visual processing deficits. Clinicians should bear in mind that improvement in performance on the DEM with repeated testing may be observed secondary to vision therapy, however such an improvement could as much be the result of a learning curve as from a true increase in saccadic and visual processing abilities as desired by the clinician.

REFERENCES

1. Oride M, Marutani JK, Rouse MW, et al. reliability study of the Pierce and King-Devick tests. *J Am Optom Assoc* 1986;63:419-424.

2. Garzia RP, Richman JE, Nicholson SB, et al. A new visual-verbal saccade test: the developmental eye movement test (DEM). *J Am Optom Assoc* 1990;61:124-135.

3. Rouse MW, Nestor EM, Parot CJ. A re-evaluation of the reliability of the development eye movement tests. *Optom Vis Sci* 1991;61:90.

APPENDIX A

Consent Form (2 pages)

Michigan College of Optometry

Ferris State University
1310 Cramer Circle
Big Rapids, MI 49307

Comparison of Monocular verses Binocular
Developmental Eye Movement (DEM) Test Results

INFORMED CONSENT STATEMENT

1. **Invitation to Participate and Description of the Project.** You are being asked to participate in our study of **Comparison of Monocular verses Binocular Developmental Eye Movement (DEM) Test Results.** We are investigating this topic in order to further our understanding of the DEM. Your participation in the research study is voluntary; before agreeing to be part of this study, please read the following information carefully. Feel free to ask questions if you do not understand something.

2. **Description of Procedure.** If you participate in this study, you will be asked to perform the DEM test which requires you to read a series of numbers for approximately one minute. You may be asked to re-perform the test multiple times.

3. **Risks and Inconveniences.** There are no risks (physical, psychological, mental, or social) with participating in this study.

4. **Benefits.** This study was not designed to benefit you directly, however, there is some possibility that you may learn about the DEM through your participation. In addition, what we learn from the study may help us to better understand the effect of being monocular on the results of the DEM.

5. **Financial (or other) considerations:** No compensation.

6. **Confidentiality.** Any and all information obtained from you during the study will be confidential. Your privacy will be protected at all times. You will not be identified individually in any way as a result of your participation in this research. The data collected however, may be used as part of publications and papers related to the DEM.

7. **Voluntary Participation.** Your participation in this study is entirely voluntary. You may refuse to participate in this research. Such refusal will not have any negative consequences for you. If you begin to participate in the research, you may at any time, for any reason, discontinue your participation without any negative consequences.

8. **Other considerations and questions.** Please ask any questions about anything that seems unclear to you and to consider this research and consent form carefully before you sign.

Authorization: I have read the above information and I have decided that I will participate in the project described above. The researcher has explained the study to me and answered my questions. I know what will be asked of me. I understand that the purpose of the study. If I don't participate, there will be no penalty or loss of rights. I can stop participating at any time, even after I have started.

I agree to participate in the study. My signature below also indicates that I have received a copy of this consent form.

Participant's signature___________________________________

Name (please print)_____________________________________

Date_______

Signature of Person Obtaining Consent _____________________________________

Regarding any questions or concerns that may be raised by participating in the study please contact:

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