REPEATABILITY AND LEARNING CURVE EFFECTS OF THE DEVELOPMENTAL EYE MOVEMENT (DEM) TEST IN YOUNG ADULTS

by

Nathan Gilmore
Paul Kimbro

Has been approved

April, 2013

APPENDIX A
TITLE PAGE

REPEATABILITY AND LEARNING CURVE EFFECTS OF THE DEVELOPMENTAL EYE MOVEMENT (DEM) TEST IN YOUNG ADULTS

by

Nathan Gilmore
Paul Kimbro

This paper is submitted in partial fulfillment of the
Requirements for the degree of

Doctor of Optometry

Ferris State University
Michigan College of Optometry

May 2013

APPENDIX B
APPROVAL PAGE

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APPENDIX C
LIBRARY APPROVAL FORM

Ferris State University
Doctor of Optometry Senior Paper
Library Approval and Release

REPEATABILITY AND LEARNING CURVE EFFECTS OF THE DEVELOPMENTAL EYE MOVEMENT (DEM) TEST IN YOUNG ADULTS

We, Nathan Gilmore and Paul Kimbro, 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.

____
Doctoral Candidate

____
Doctoral Candidate

____
Date

APPENDIX D
SUBJECT CONSENT FORM

Michigan College of Optometry

Ferris State University
1124 S. State St.
Big Rapids, MI 49307

REPEATABILITY AND LEARNING CURVE EFFECTS OF THE DEVELOPMENTAL EYE MOVEMENT (DEM) TEST IN YOUNG ADULTS

INFORMED CONSENT FORM

1. Invitation to Participate and Description of Project. You are being asked to participate in our study of **Repeatability and Learning Curve Effects Of The Developmental Eye Movement (DEM) Test in Young Adults.** We are investigating this topic in order to further understand our DEM test in optometry. 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 future results of the DEM test performed in optometry.

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 at any time. 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.

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

MY SIGNATURE BELOW INDICATES I HAVE READ THE ABOVE INFORMATION AND AGREE TO PARTICIPATE IN THE STUDY ACCORDING TO THE GUIDELINES LISTED.

Participant's Signature ______________________________________

Name (Please Print) ______________________________________

Date ____________

Signature of Person Obtaining Consent

____

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

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APPENDIX E
ABSTRACT

ABSTRACT

The Developmental Eye Movement test (DEM) is used clinically for the assessment of eye movements in patients with presumed oculomotor deficiency. Research in this area suggests an association between poor scores on the DEM and inefficient reading.[2] Many of these patients go on to receive vision therapy directed at improving eye movements. Although, studies have been done showing the effects of attention and working memory on DEM results[3], few studies have demonstrated the influence of binocular summation or learning curve effects. These findings may have potential significance for vision therapists using the DEM to track oculomotor skill progress. The aim of the current study is twofold. First, to evaluate learning curve effects on DEM test results. Second, to study plausible effects of binocular summation on test resuts. A group of college students (N=38) in the age range 19 to 31 were included in the study. Subjects were pre-screened for adequate visual acuity and oculomotor skills. All participants were required to perform the DEM test monocularly and binocularly. The order of testing (monocular or binocular) was randomized. Furthermore, in order to evaluate the time period over which the learning effect sustains, testing was repeated over the following time intervals –4 hours, two days and one week. Repeatability of test results was analyzed using the Intraclass Correlation Coefficient in a one way random effects model. We hope that findings from this study will elicit the role of binocular factors and learning effects on DEM test results. This in turn can have many significant clinical implications in the use of this test in populations with saccadic and visual processing deficits.

ACKNOWLEDGEMENTS

We would like to thank Dr. Vandana Rajaram OD, Ph.D for her hard work and dedication to this project. Her detailed statistical analysis and guidance was paramount to its completion.

APPENDIX F
TABLE OF CONTENTS

TABLE OF CONTENTS

INTRODUCTION

Reading is undeniably a complex visual task. A prerequisite for efficient reading is the presence of efficient oculomotor skills, the most important of which are saccadic eye movements. Saccades are responsible for our ability to quickly scan text without conscious effort. Patients with oculomotor dysfunction may suffer from an inability to accurately accomplish this task resulting in symptoms of fatigue, slow reading, and poor comprehension.[1] The Developmental Eye Movement (DEM) Test (described below) is an important clinical tool frequently used in vision therapy to assess eye movements.

The DEM is a popular visual-verbal test presumed to evaluate ocular motor efficiency and rapid automatic naming (RAN) skills.[2] Prior to its development, other visual-verbal saccade tests including the Pierce and King-Devick did not control for rapid automatic naming (RAN) skills confounding test results.[2] The DEM test is divided into three subtests, consisting of single digits. Each subset assesses a different component in the overall reading process. The first two subtests typically called tests A and B, consist of 40 digits arranged in two vertical columns. In contrast, the third subtest (test C) consists of 80 digits comprising 16 horizontal rows. Within each test, the subject is required to quickly and accurately call out each number while the examiner measures the time in seconds to complete the task. In addition, the number of errors, omissions, transitions, or substitutions are recorded and used to calculate a score for each subtest. The vertical columns, which require no horizontal eye movement, assess the patient's capacity for rapid automatic naming commonly referred to as visual-verbal automaticity.[2] The horizontal rows of test C evaluate horizontal eye movements which may be poor in patients with oculomotor dysfunction.In order to quantify these skills, a ratio comparing visual-verbal automaticity to horizontal eye movements plus automaticity is calculated with an ideal ratio being close to one.[1] The ratio is then compared to a set of normalized tables based on age or grade level to establish a percentile rank. Using this information, the clinician can appropriately tailor a vision therapy program designed to improved oculomotor skills and decrease symptoms in patients suffering from oculomotor dysfunction. Because the DEM is administered on multiple occasions throughout a vision therapy plan, it is essential to identify if the scores obtained are the result of improved oculomotor skills or the byproduct of a learning curve effect from repeated testing. It is our belief that the findings may be significant in the future use of the DEM especially when it is used as a sole outcome measure in symptomatic patients being treated for oculomotor dysfunction.

PURPOSE

The goal of this study is twofold-

A) To compare monocular versus binocular DEM test results in order to evaluate any plausible effects of binocular summation.

B) To evaluate the repeatability and learning effect of the DEM through sequential testing. We feel this is essential for the future use of the DEM in measuring progress in symptomatic patients being treated for oculomotor dysfunction.

METHODS

Thirty eight students from the Michigan College of Optometry were chosen to participate in the study. The subject's ages ranged from 19 to 31. Each subject was required to have 20/20 visual acuity tested both monocularly and binocularly at 40 cm. Binocularity and normative saccades were required and assessed utilizing alternating cover test and the Northeastern State University College of Optometry (NSUCO) technique. In addition, patients must not have participated in vision therapy training at any time.

Each subject was required to complete subtests A, B, and C at three different time intervals of four hours, two days, and one week following the baseline evaluation. All participants were required to complete each subtest monocularly and binocularly at the first interval. The order of monocular vs. binocular testing was randomized by the examiners. Subjects were tested binocularly for the remaining sessions. The subtest times were measured using a standard stopwatch. The computations for each subject were performed appropriately. Errors, omission, substitutions, and transpositions were included in the new adjusted horizontal time and the DEM ratio was calculated. Data analysis included a measure of repeatability using the intraclass correlation coefficient (ICC) in a one way random effects model.

RESULTS

Repeatability of test scores at each time interval was calculated using the Intraclass Correlation Coefficient (ICC) in a one way random effects model. Bland Altman difference plots were used to plot differences between testing sessions as a function of the averages of the two sessions. At the four hour interval, subjects showed good repeatability in the adjusted horizontal times compared to the baseline evaluation (ICC (95% CI)) = .63 (.30.63), ($p<.03$)). The ICC is a global measure of repeatability with a value ranging between 0 and 1.[5] An ICC equal to 1 indicates perfect repeatability of test to retest scores. In contrast to our first interval, data at the two day and one week intervals showed poor repeatability with an ICC < 0.34. Similarly, vertical times for test C showed mild repeatability at four hours (ICC (95% CI) =0.51 (0.08-0.74), p <0.03) but poor repeatability at two day and one week intervals (ICC < 0.35). Ratio scores had low repeatability among all three time intervals with an ICC <0.24. (See appendix G)

In comparing monocular and binocular times we used a two-tailed, paired student T-test. All comparisons were statistically non-significant implying that binocular summation does not play a significant role in DEM test results. This is best evaluated by referring to the DEM ratio, a global measure used to assess visual verbal automaticity and saccadic eye movements. It offers the best overall quantification of these skills. As evidenced by figures 22-23, the DEM ratio between monocular and binocular trials is very consistent and no statistically significant difference appears.

DISCUSSION

The results of our study demonstrated poor repeatability at the two day and two week interval. This poor instrasubject repeatability is a reflection of improvement in test scores with repeated testing. This may be the consequence of a learning curve or due to a variation in the subject's attentional status. However, consistency with repeated testing leads us to believe a learning effect is the largest cause of variation in scores. Variation due largely to attentional status would be more observable at certain testing times. Furthermore, test performance would vary *randomly* between and within subjects depending on their attentional status.

To the best of our knowledge no study has looked solely at learning curve effects in the DEM. However, researchers have concluded that performance on many cognitive and neuropsychological tests may be improved by prior exposure to testing stimuli and procedures.[4] This test-retest improvement has been seen at intervals of weeks, months, and years.[4] Previously researchers have evaluated the role of fatigue and attention by manipulating DEM organization.[3] They have suggested that when given in reverse order subjects perform better, indicated by lower DEM ratios. The underlying theory presented is that subtest C is more attention demanding and when assessed first allows subjects to be more aroused with less fatigue.[3] While these studies are supported with good research and analysis, we set out not to investigate how we could obtain better scores for subjects, but instead to elucidate any factors inherent to the DEM that limit vision therapy success.

The results of our study become clinically relevant when we consider the effects it may have on vision therapy strategies for patients with oculomotor dysfunction. There is an appreciable improvement in both the DEM ratio (Figure 12) and Horizontal average mean (Figure 14) between the initial visit and one week later. This poor repeatability is further seen in the average vertical mean (Figure 10). Unfortunately, clinicians utilizing the DEM in the treatment of patients with poor saccadic movements may falsely assume current therapy is fully responsible for improvement in symptoms. Furthermore, practitioners basing saccadic deficiency therapy around the DEM may discontinue treatment due to improved DEM scores. Our study of patients, without any vision therapy or visual training, provides evidence for a learning effect that is responsible for the improvement of DEM scores.

In addition, our study also investigated the role of binocular summation in DEM results. We did not find statistically significant improvement in DEM times or ratios when comparing monocular vs. binocular data and thereby no evidence for a significant role of binocular summation in DEM test results. These results are interesting considering the myriad of research indicating a role for binocular summation in improving timed visual tasks. These tasks have included threading a needle, pouring water into a small container, and tracking an irregularly moving target. With all these tasks, subjects performed faster with more accuracy when using both eyes.[6]

While the results we obtained are significant, our study does have inherent limitations. The DEM test is not intended for adult populations. Therefore, the inclusion of 38 optometric students may have lead to above average performance. Furthermore, these students are more familiar with the procedural components of performing the DEM as they have administered the test in a clinical setting. This sample bias is a large limitation to our study. In future studies, this limitation could be addressed by repeating the study with the adult DEM test on a larger sample.

Furthermore, the test-retest intervals were determined based on a limited time scale. Subjects were evaluated at four hours, two days, and one week. It is likely that this time frame may not be an accurate representation of time intervals between vision therapy sessions. Patients are likely to miss vision therapy sessions which may lengthen test-retest intervals to longer than one week. Future studies may address this shortcoming by evaluating patients at one month and again at several months past initial testing.

Conclusion –

Young adult subjects included in this pilot study showed poor repeatability of DEM test results at the two-day and one week testing sessions. Poor repeatability was attributed to a significant improvement in test scores with repeated testing. In the absence of vision therapy or any form of visual training in this group, we speculate that our findings are largely the consequence of a learning effect. These findings may have clinical implications especially if the DEM test is used as the sole outcome measure in the evaluation of saccadic function during vision therapy. We did not find a significant difference between monocular and binocular scores and thereby no evidence for the role of binocular summation on DEM test results.

APPENDIX G
CHARTS AND FIGURES

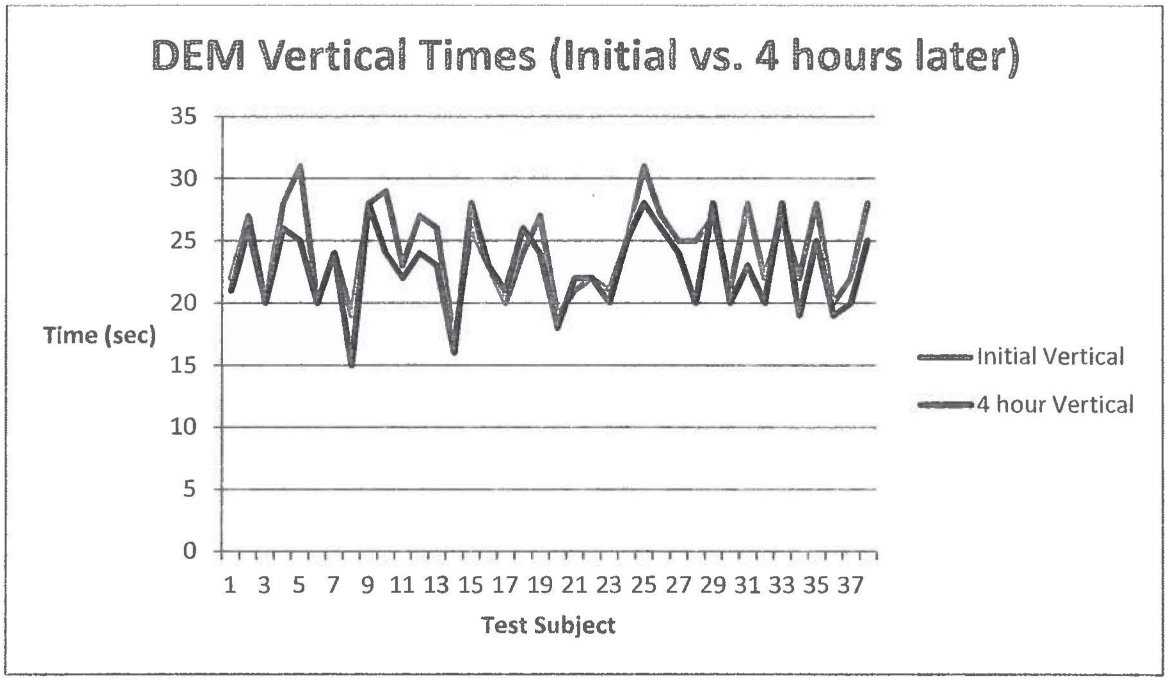

Figure 1 : DEM Vertical Times (Initial Trial vs. 4 hours later)

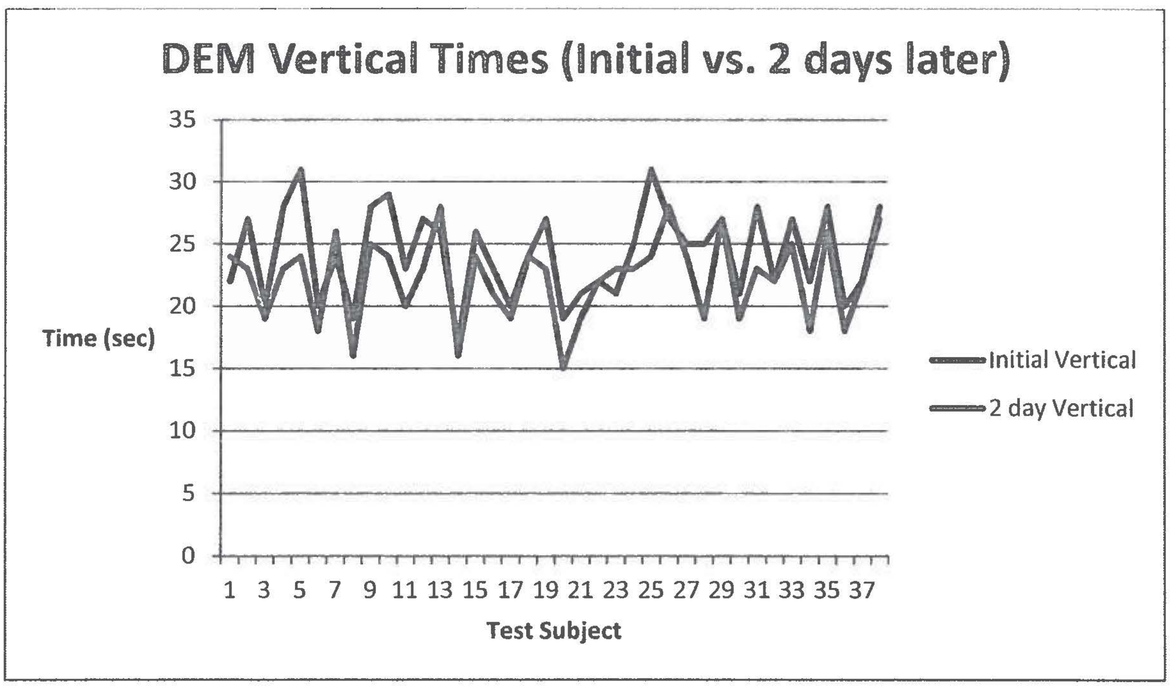

Figure 2 :DEM Vertical Times (Initial Trial vs. 2 days later)

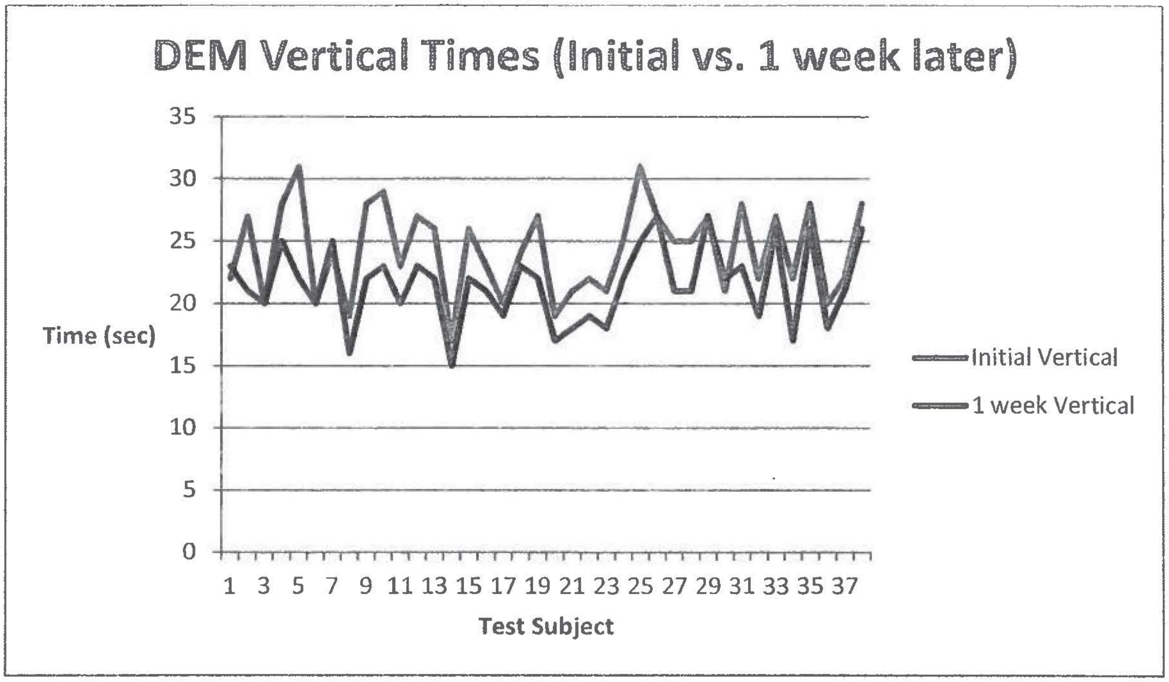

Figure 3: DEM Vertical Times (Initial Trial vs. 1 week later)

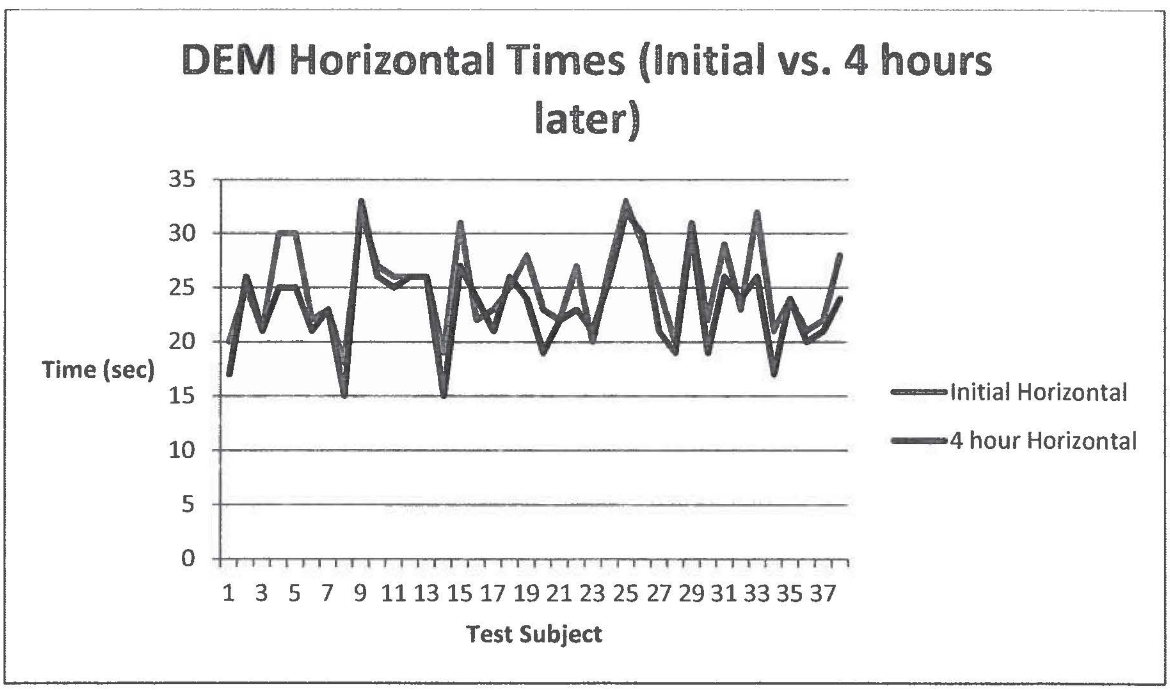

Figure 4 : DEM Horizontal Times (Initial Trial vs. 4 hours later)

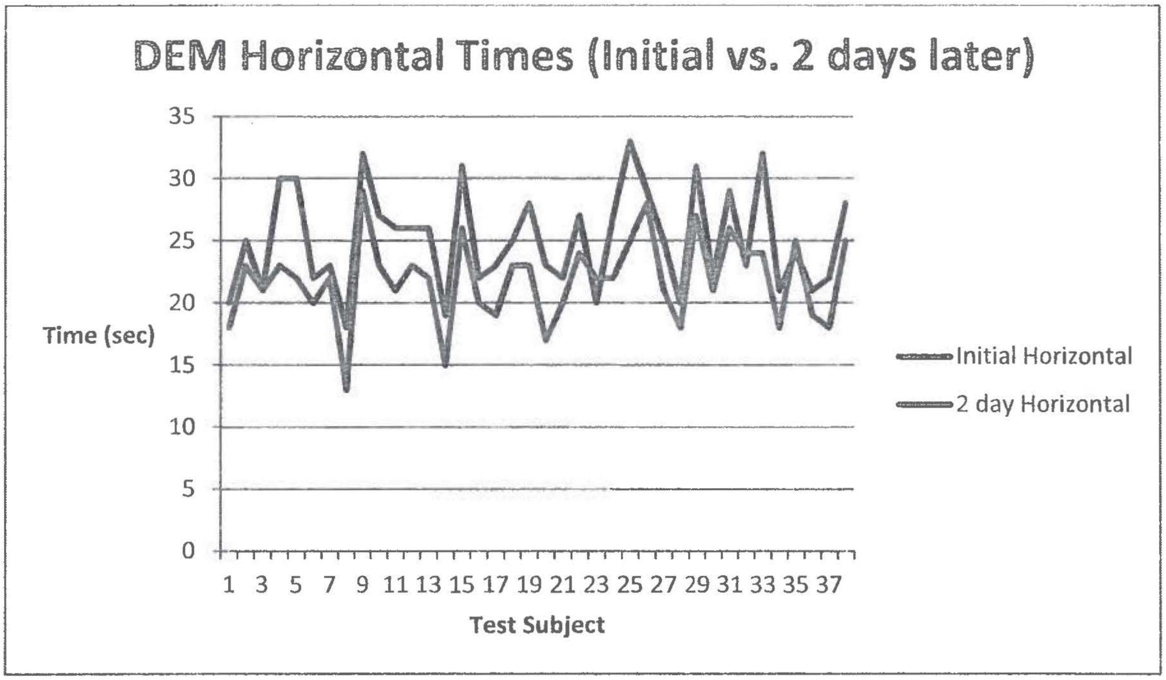

Figure 5 : DEM Horizontal Times (Initial Trial vs. 2 days later)

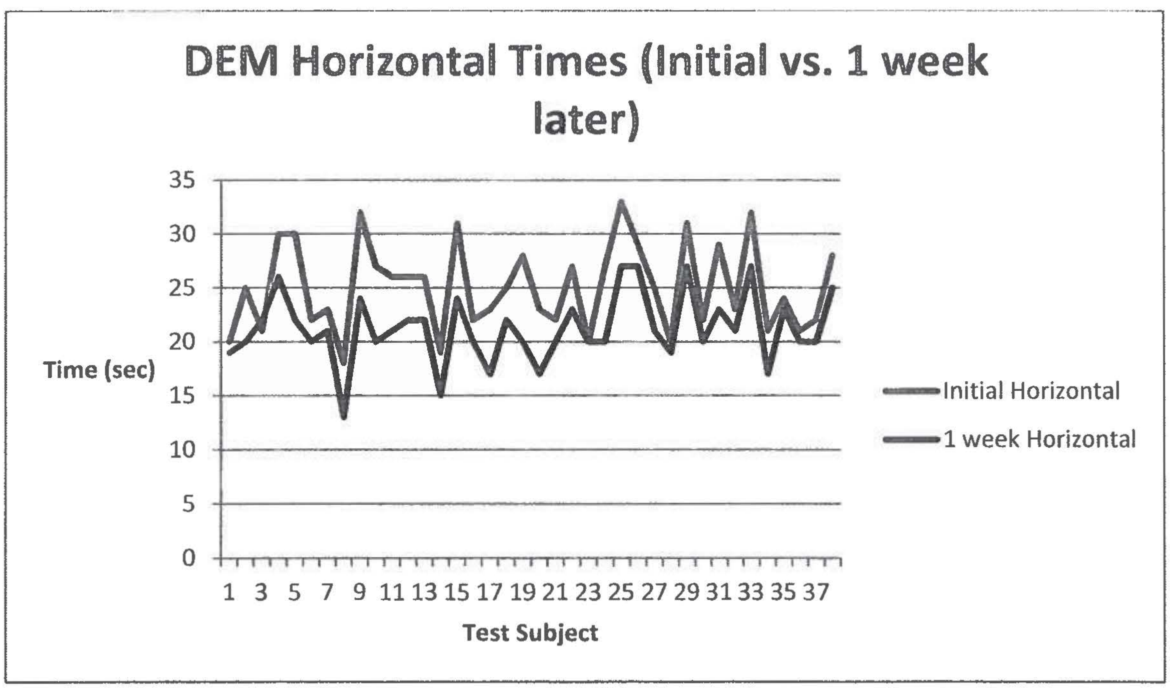

Figure 6 : DEM Horizontal Times (Initial Trial vs. 1 week later)

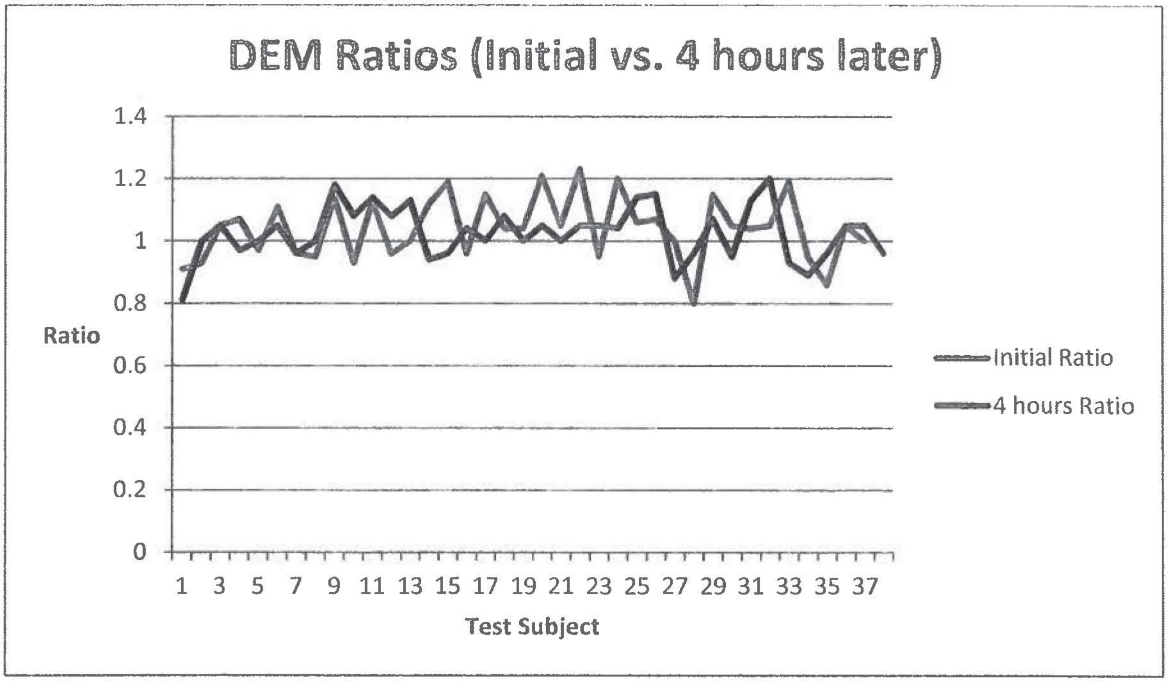

Figure 7 DEM Ratio (Initial Trial vs. 4 hours later)

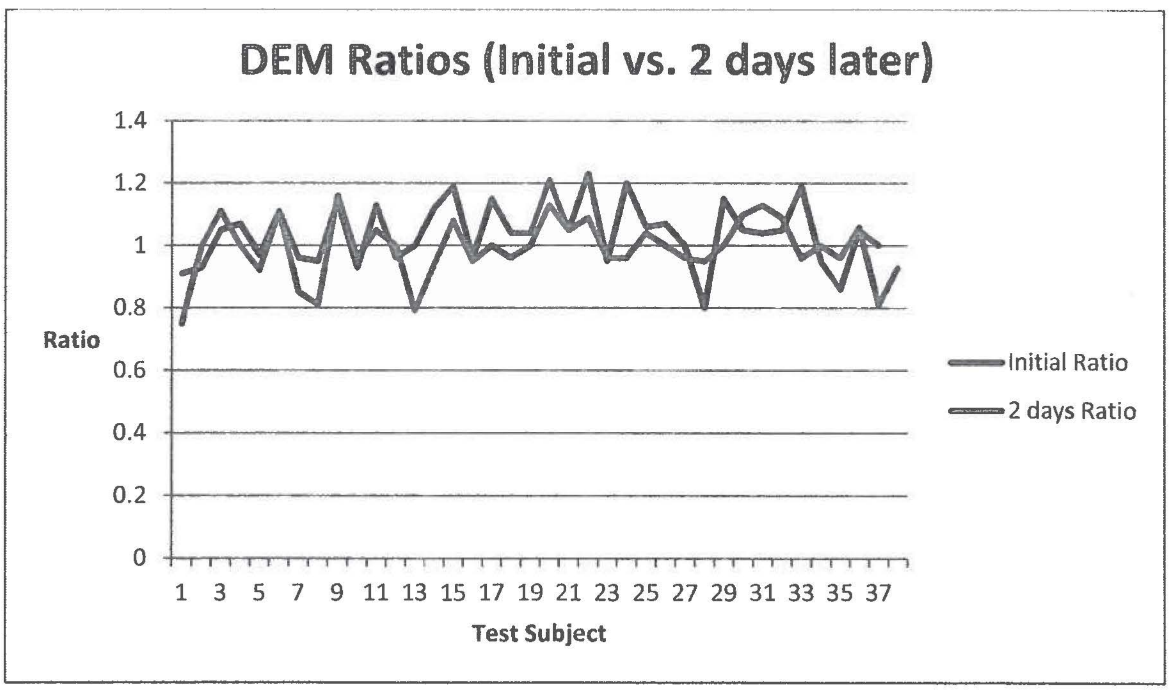

Figure 8 : DEM Ratio (Initial Trial vs. 2 days later)

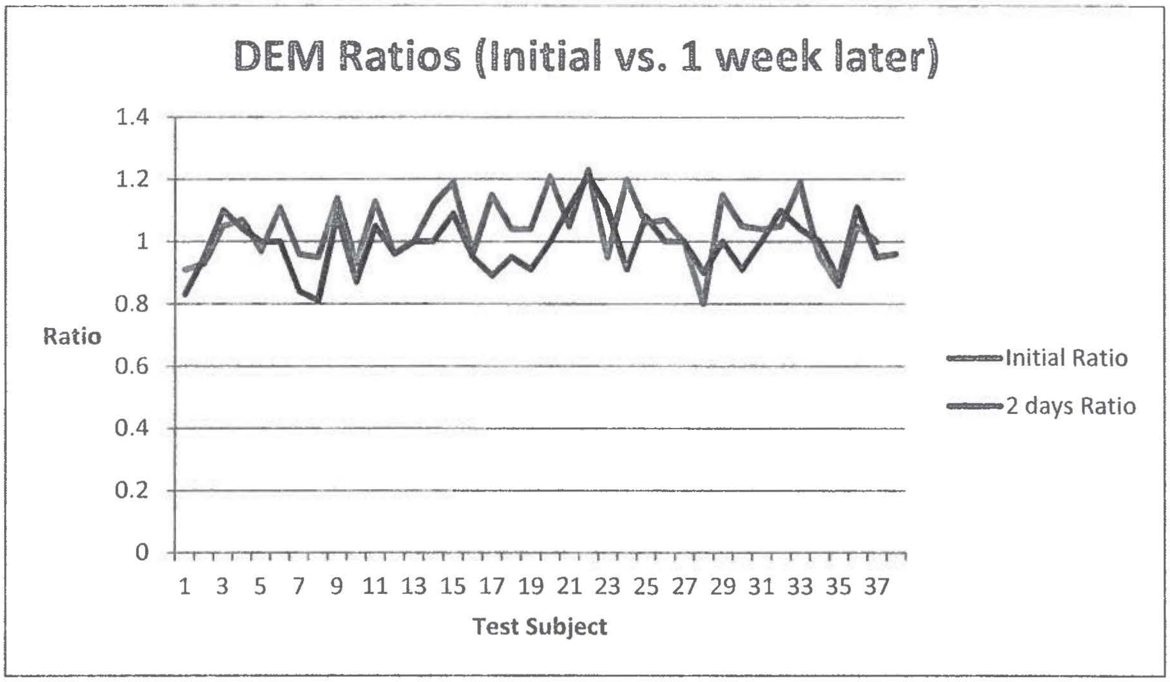

Figure 9 : DEM Ratio (Initial Trial vs. 1 week later)

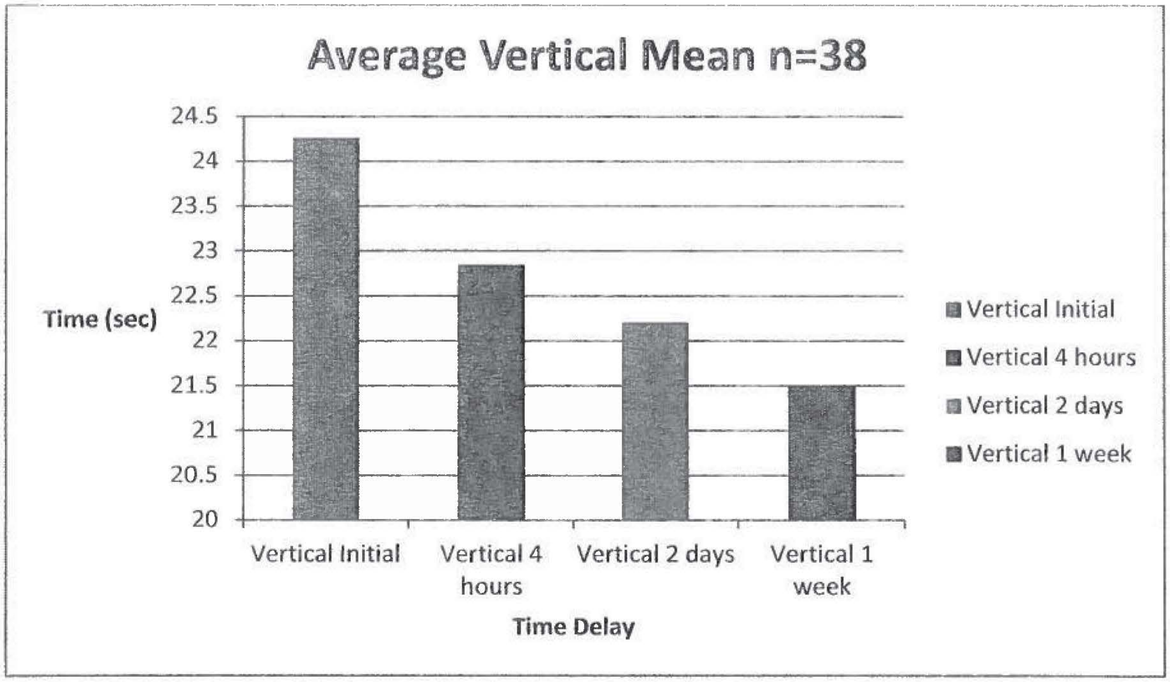

Figure 10: Average Vertical Mean Times

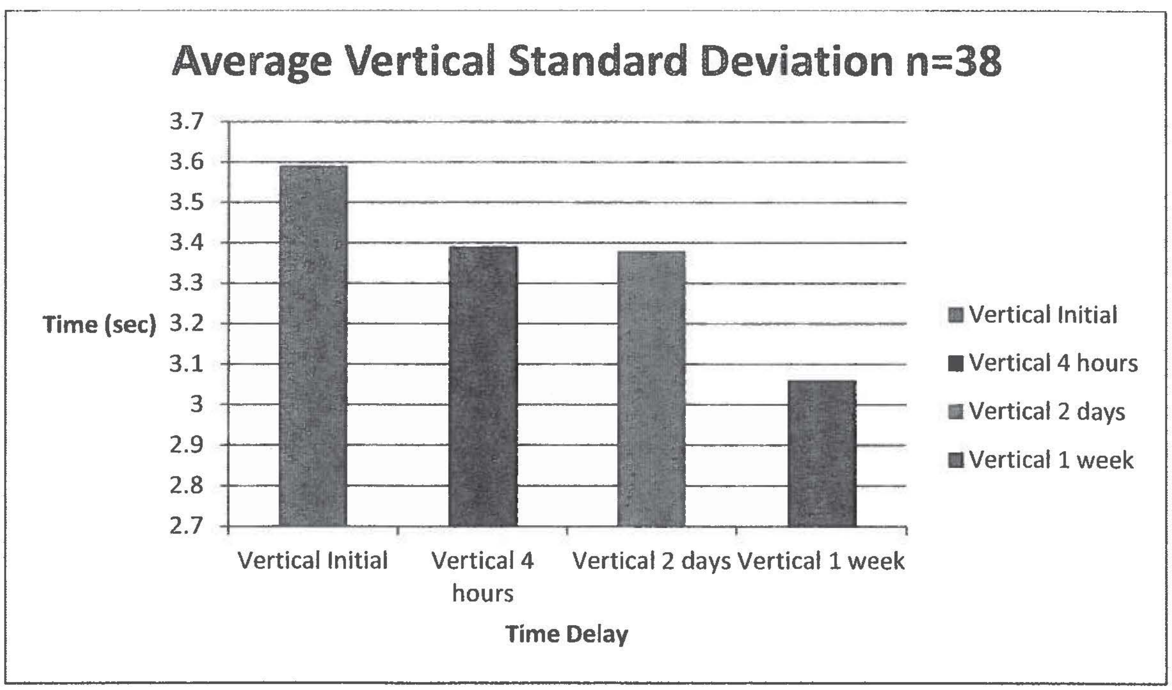

Figure 11 : Average Vertical Standard Deviation

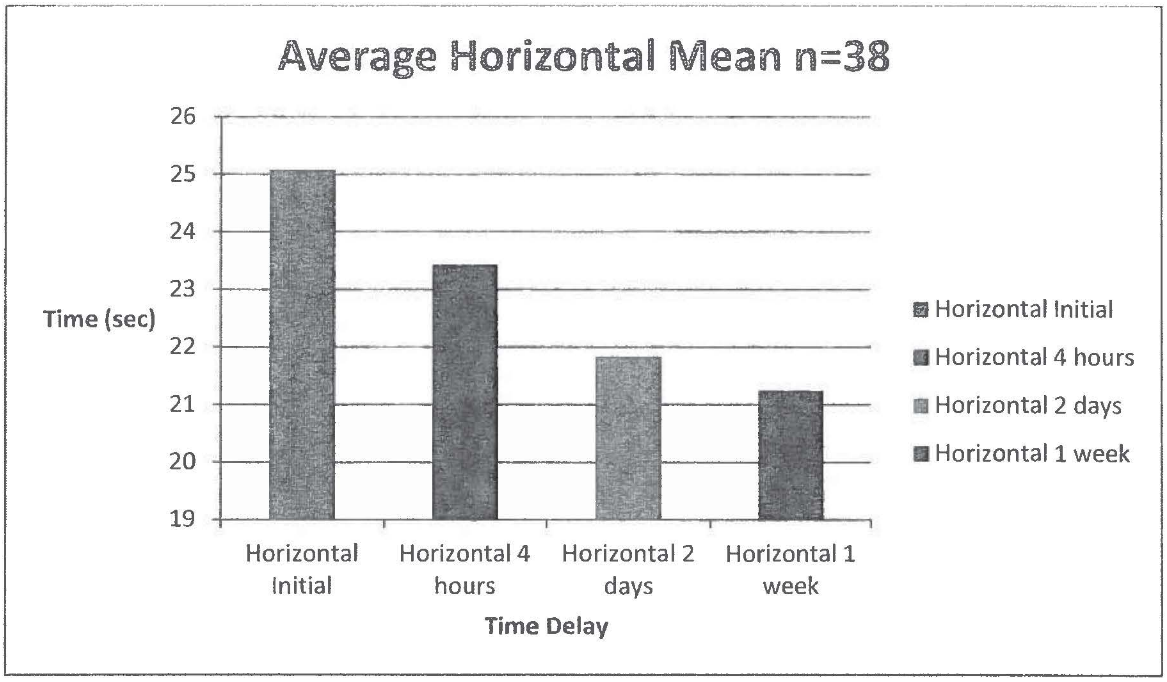

Figure 12: Average Horizontal Mean Times

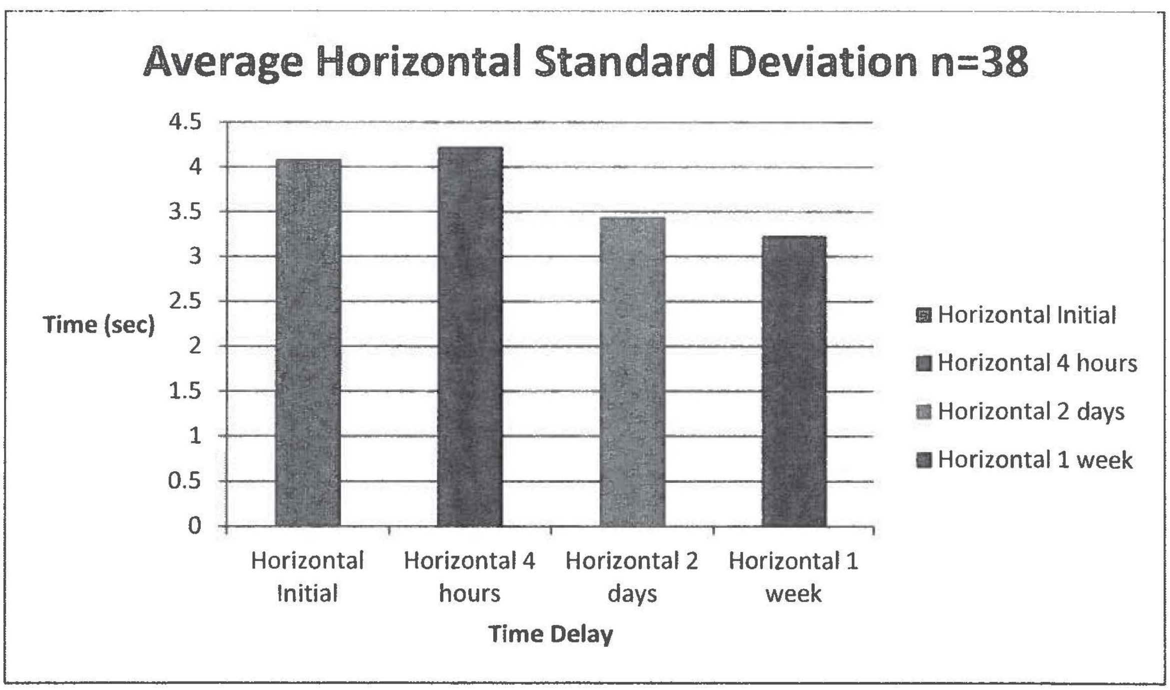

Figure 13 : Average Horizontal Standard Deviation

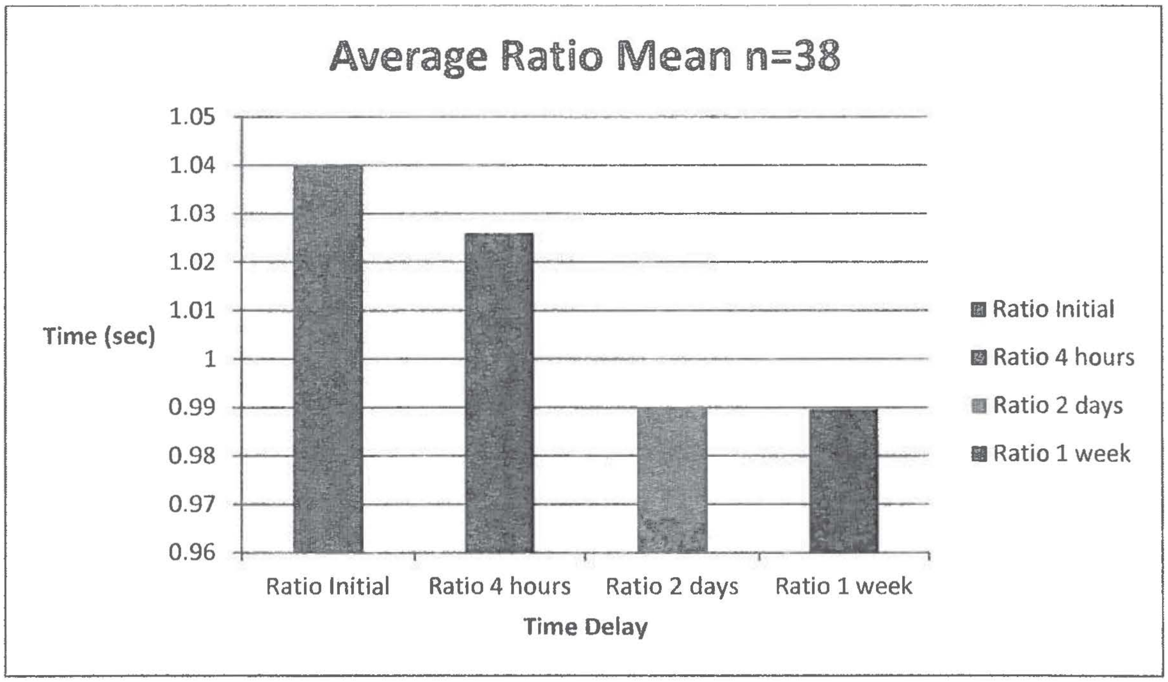

Figure 14: Average Ratio Mean

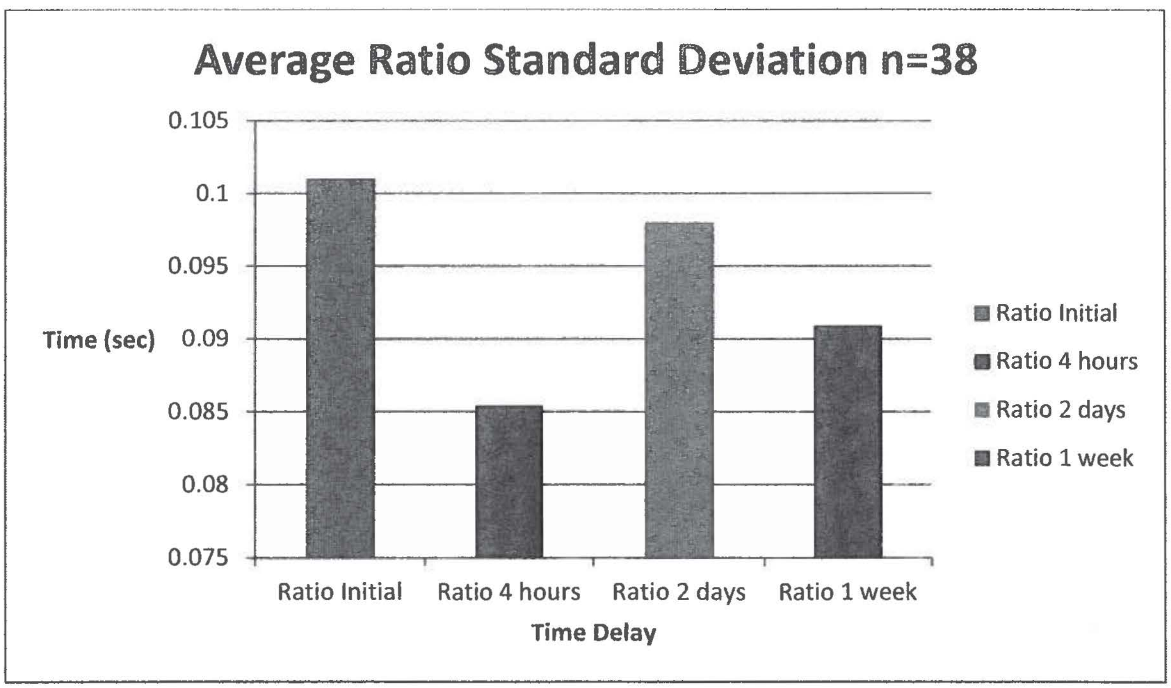

Figure 15 : Average Ratio Standard Deviation

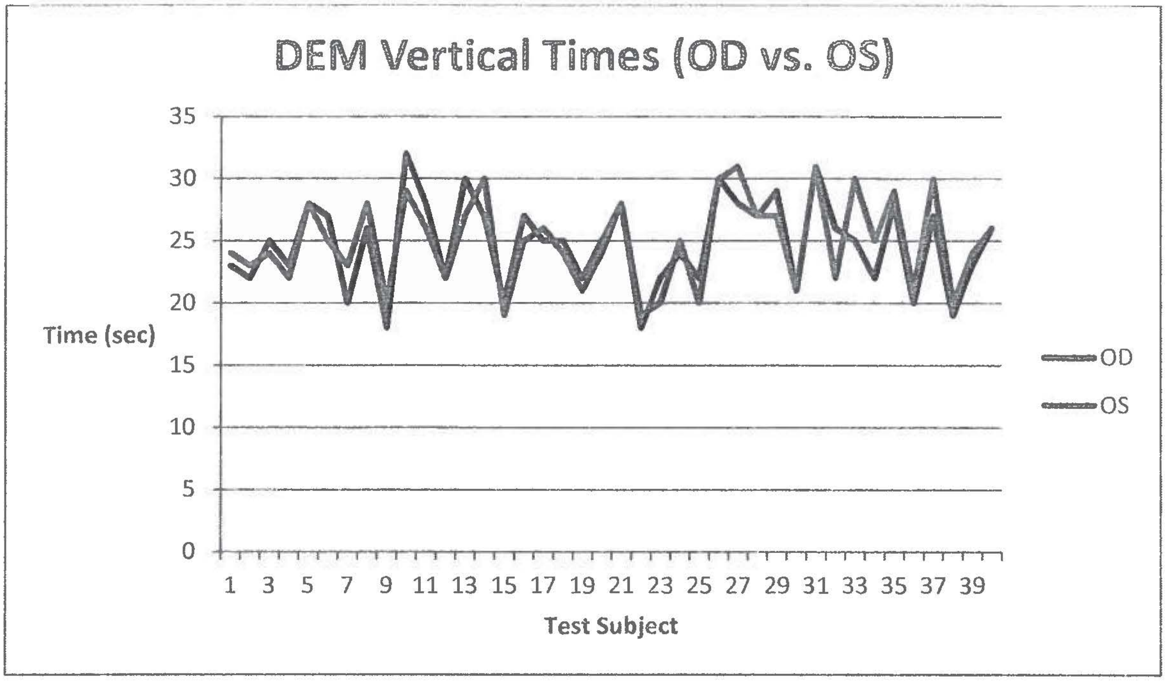

Figure 16 : DEM Vertical Times (OD vs. OS)

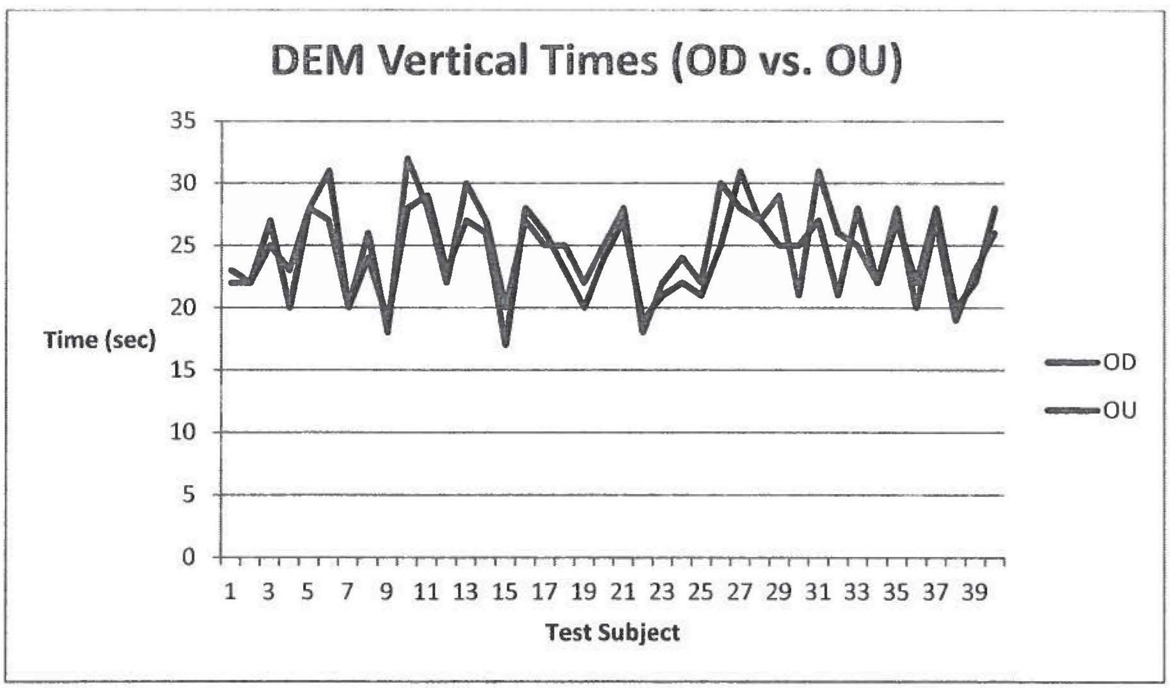

Figure 17 : DEM Vertical Times (OD vs. OU)

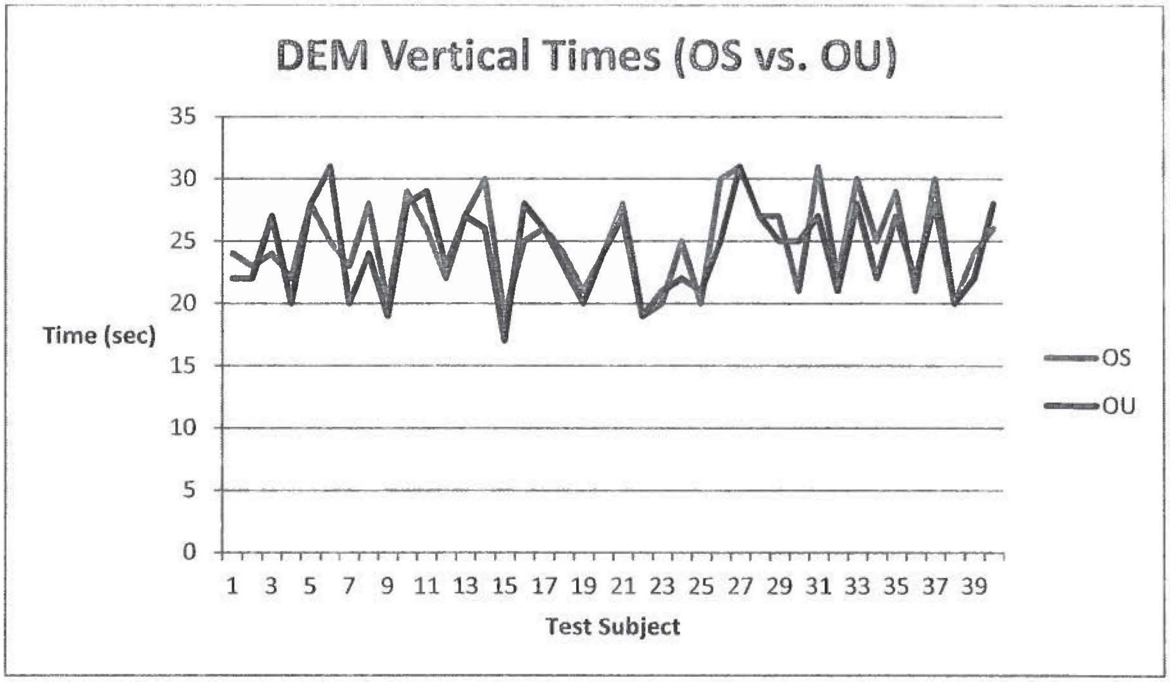

Figure 17 : DEM Vertical Times (OS vs. OU)

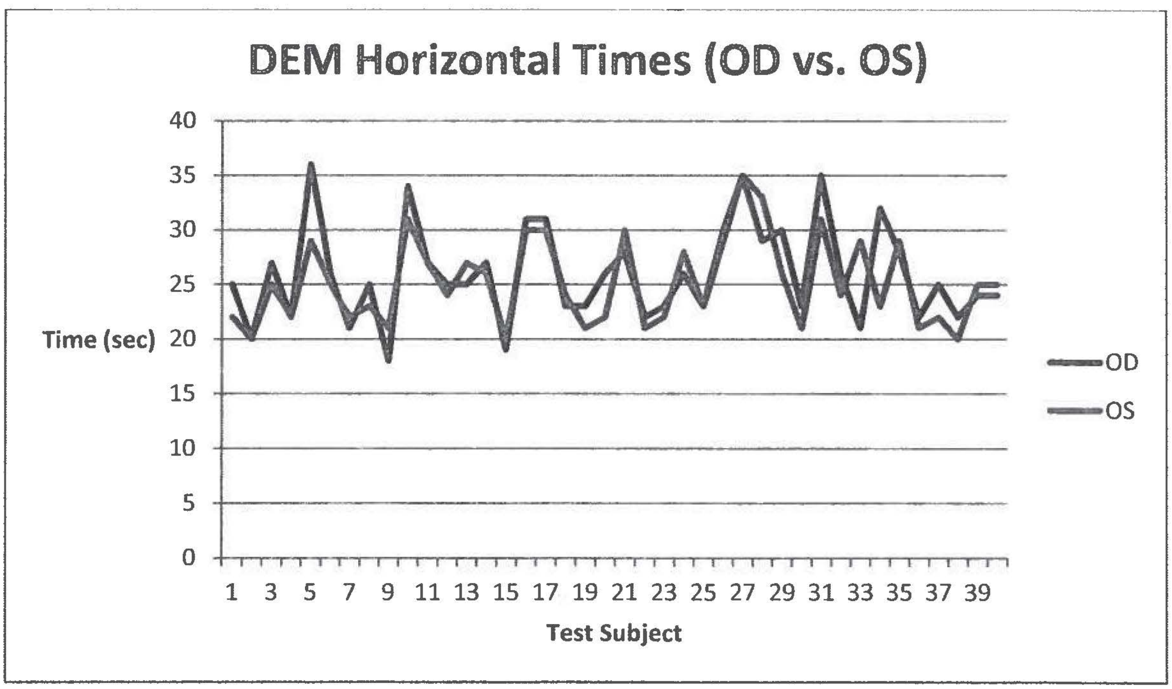

Figure 18 : DEM Horizontal Times (OD vs. OS)

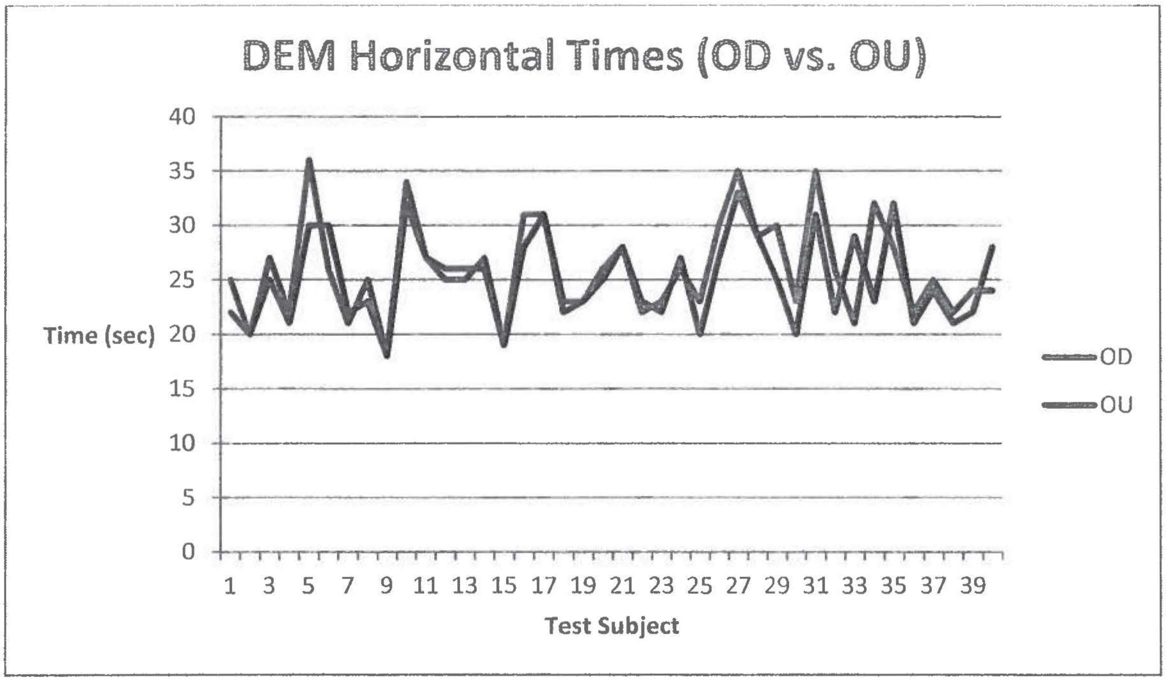

Figure 19 : DEM Horizontal Times (OD vs. OU)

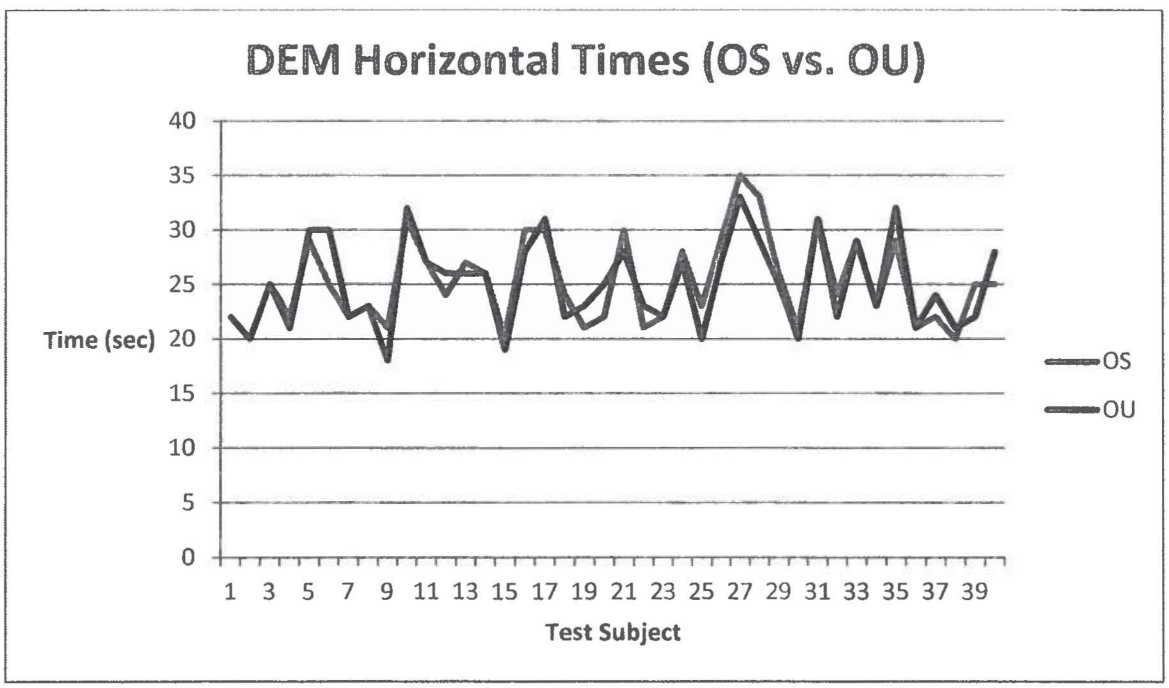

Figure 20 : DEM Horizontal Times (OS vs. OU)

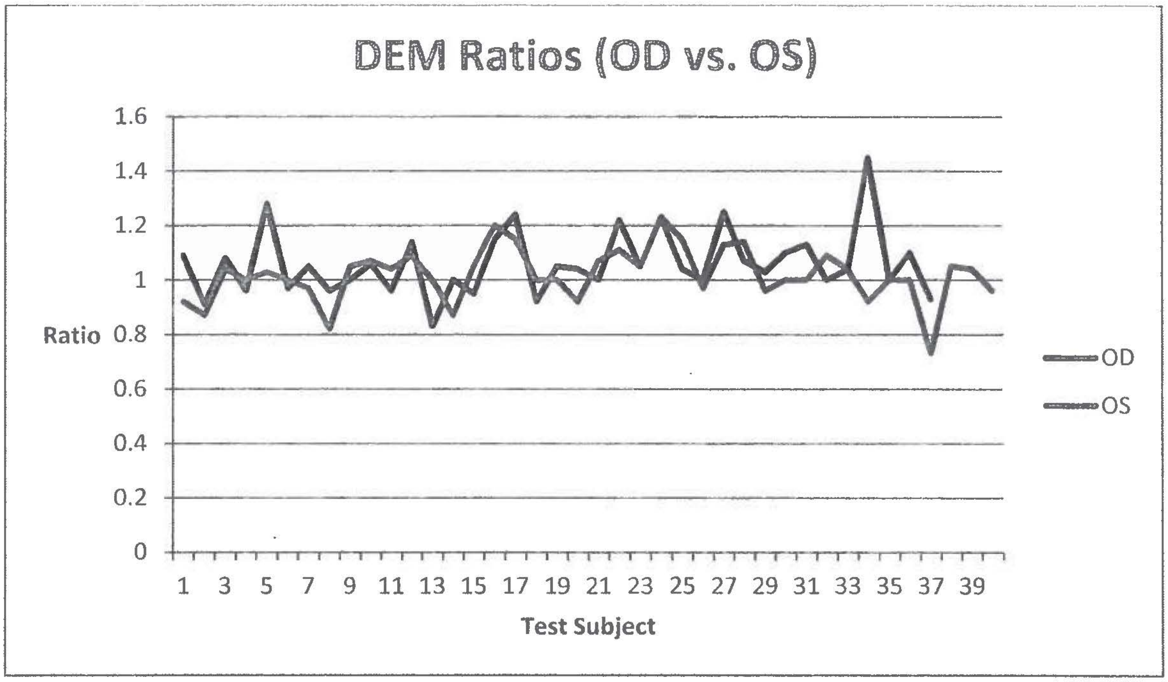

Figure 21 : DEM Ratio (OD vs. OS)

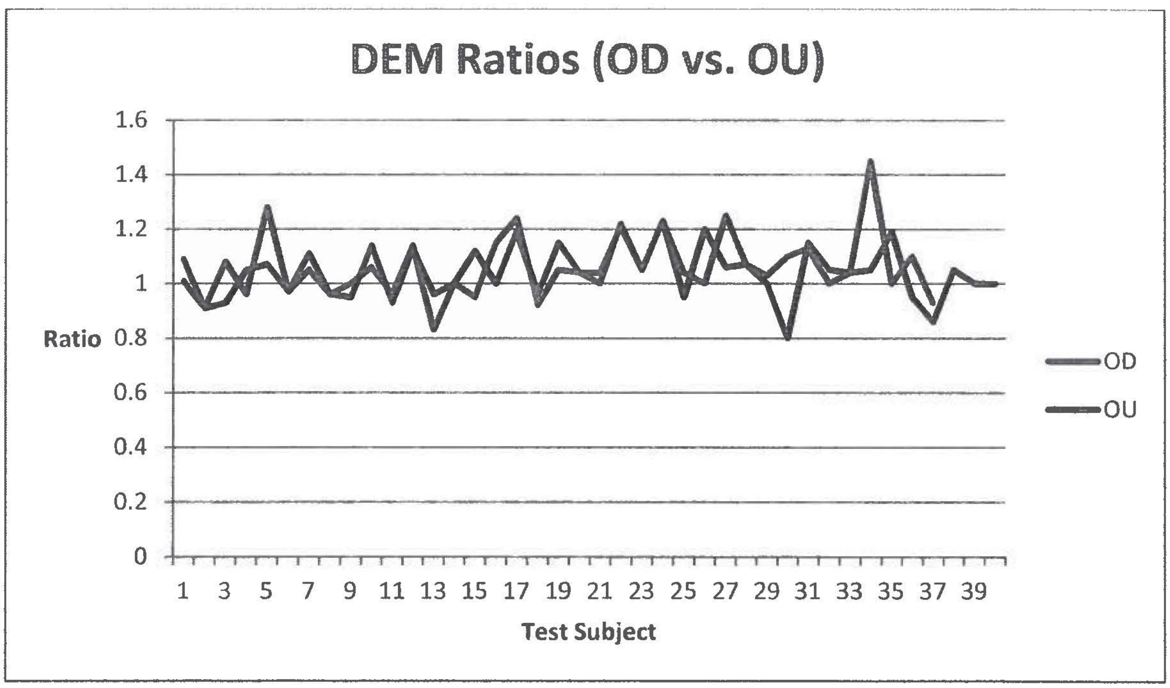

Figure 22 : DEM Ratio (OD vs. OU)

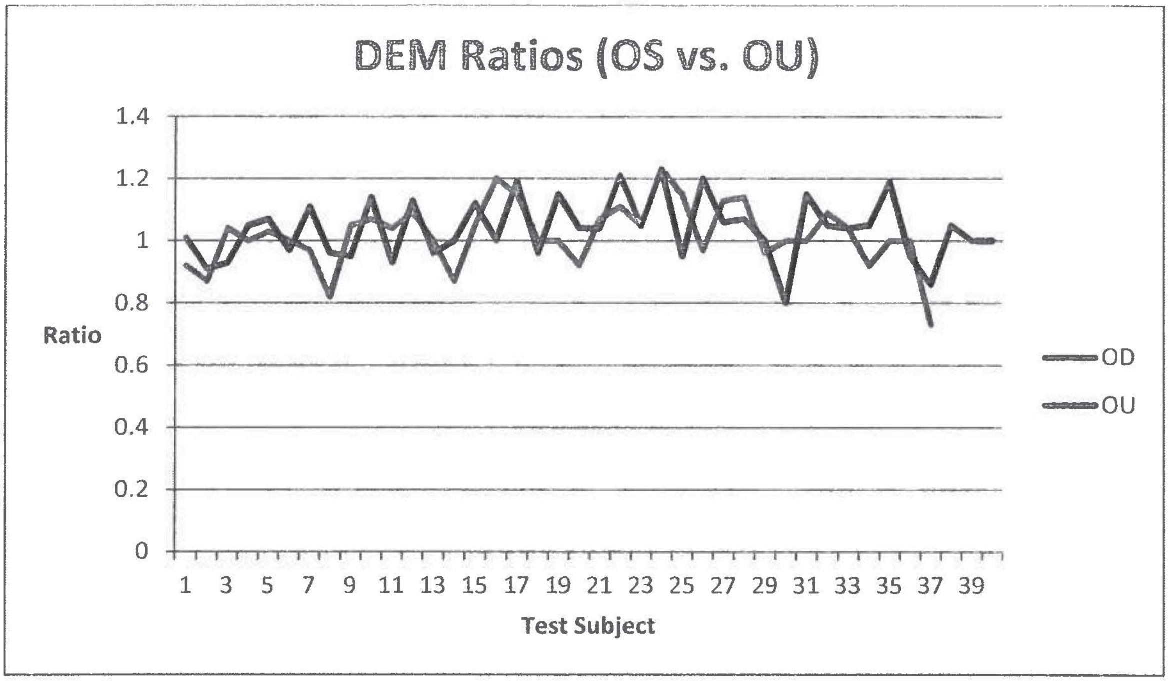

Figure 23 : DEM Ratio (OS vs. OU)

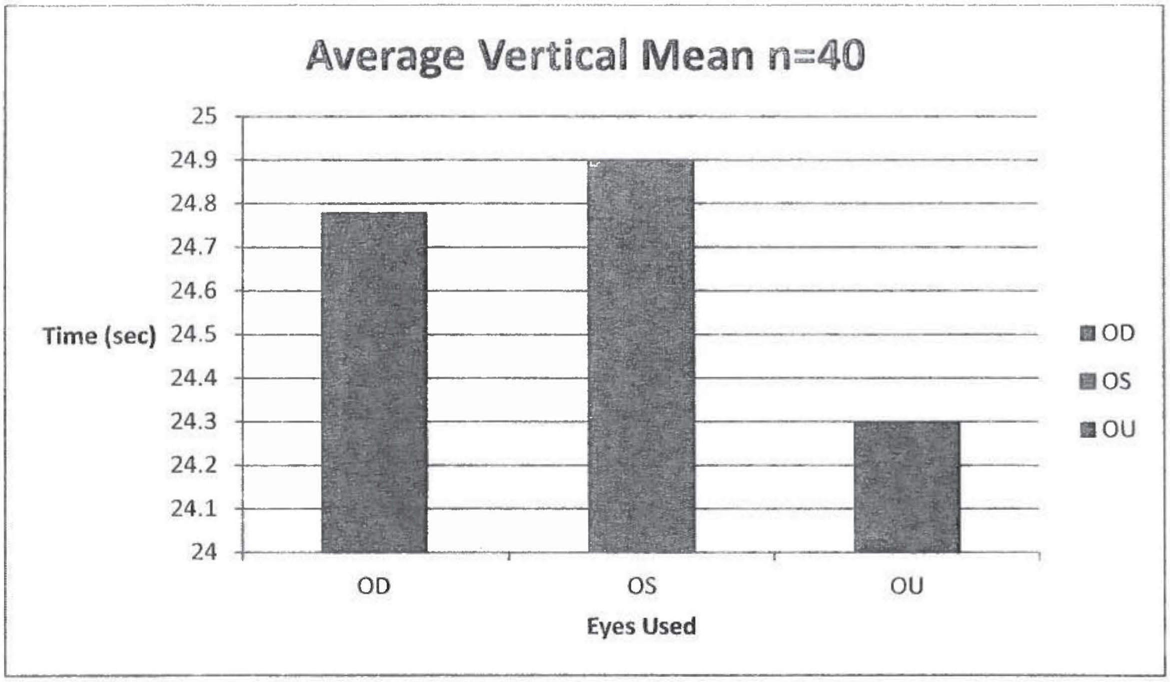

Figure 24: Average Vertical Mean Times

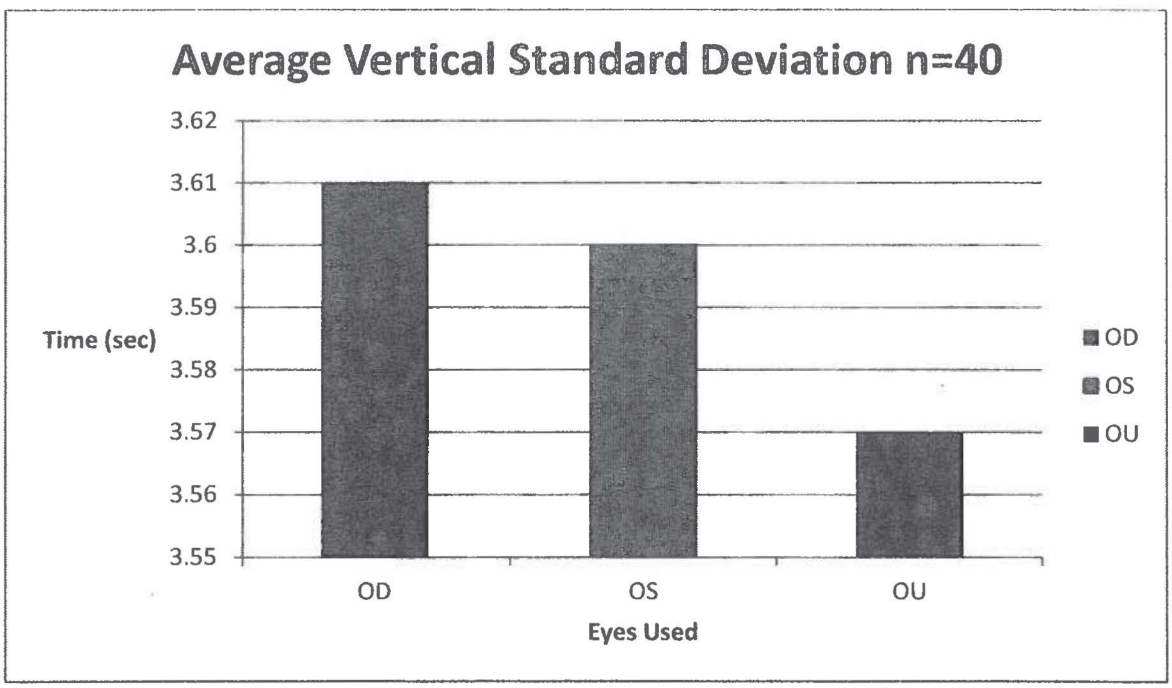

Figure 25: Average Vertical Standard Deviation

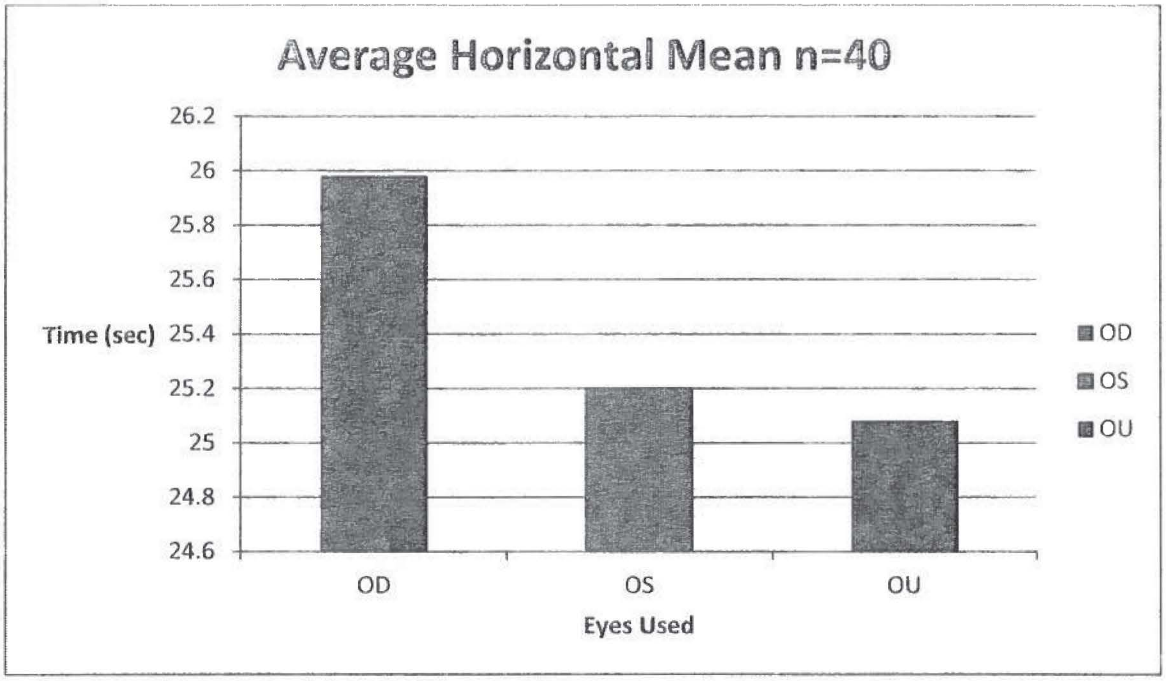

Figure 26: Average Horizontal Mean Times

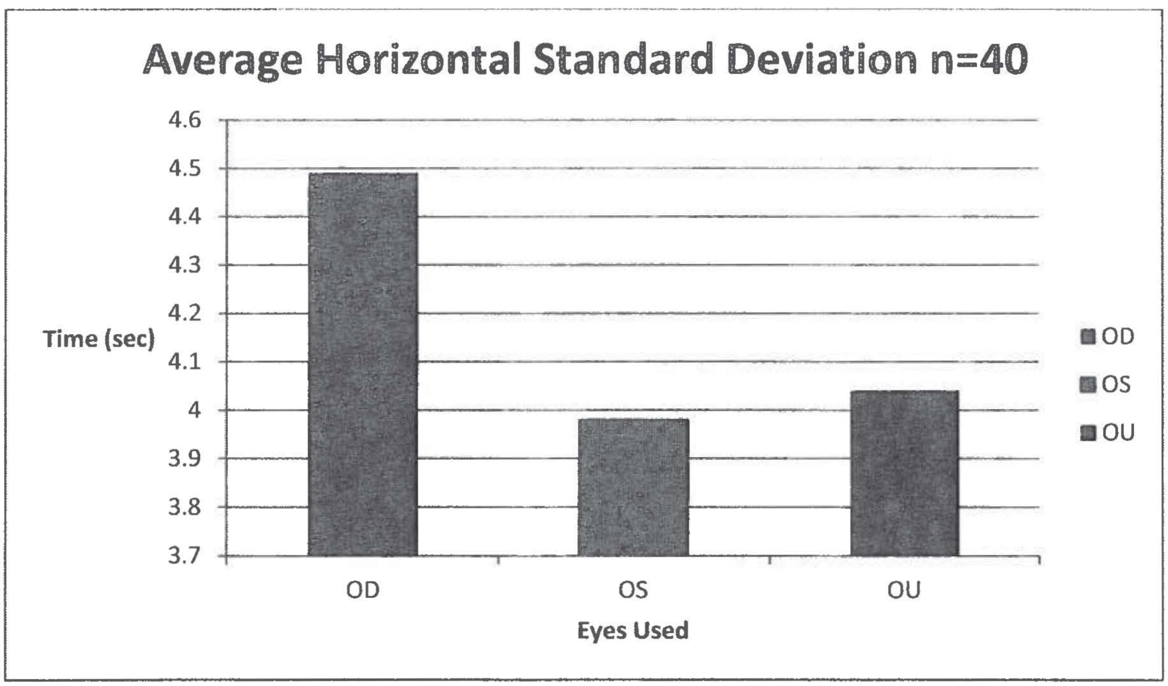

Figure 27: Average Horizontal Standard Deviation

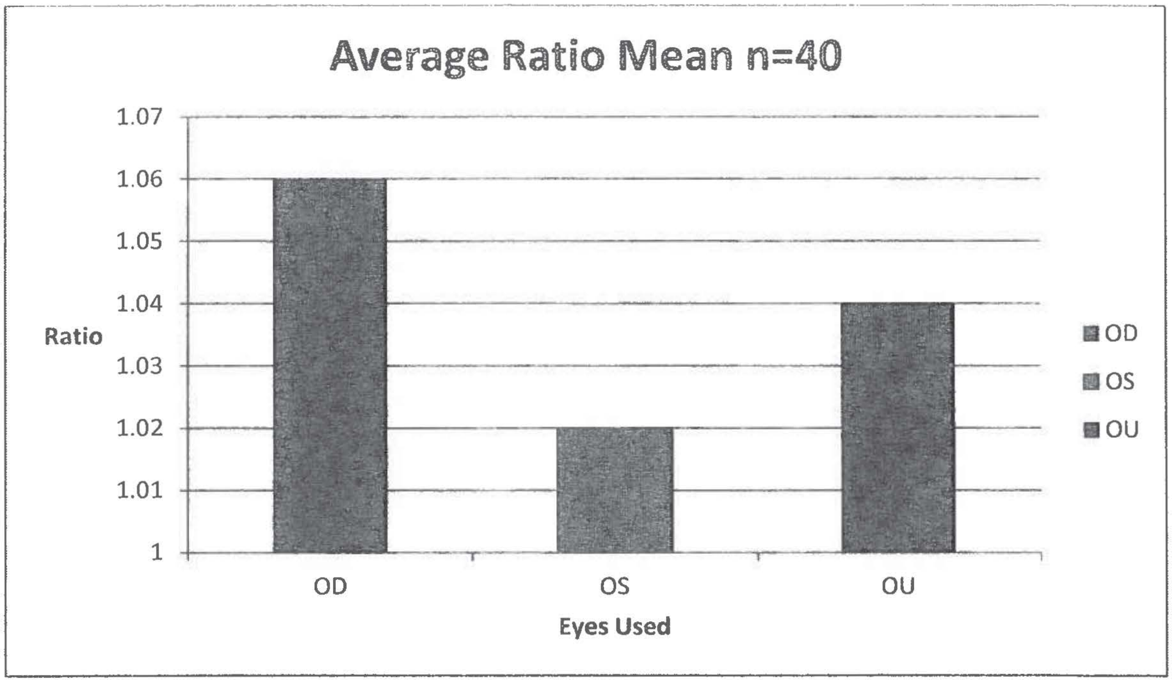

Figure 28: Average Ratio Mean

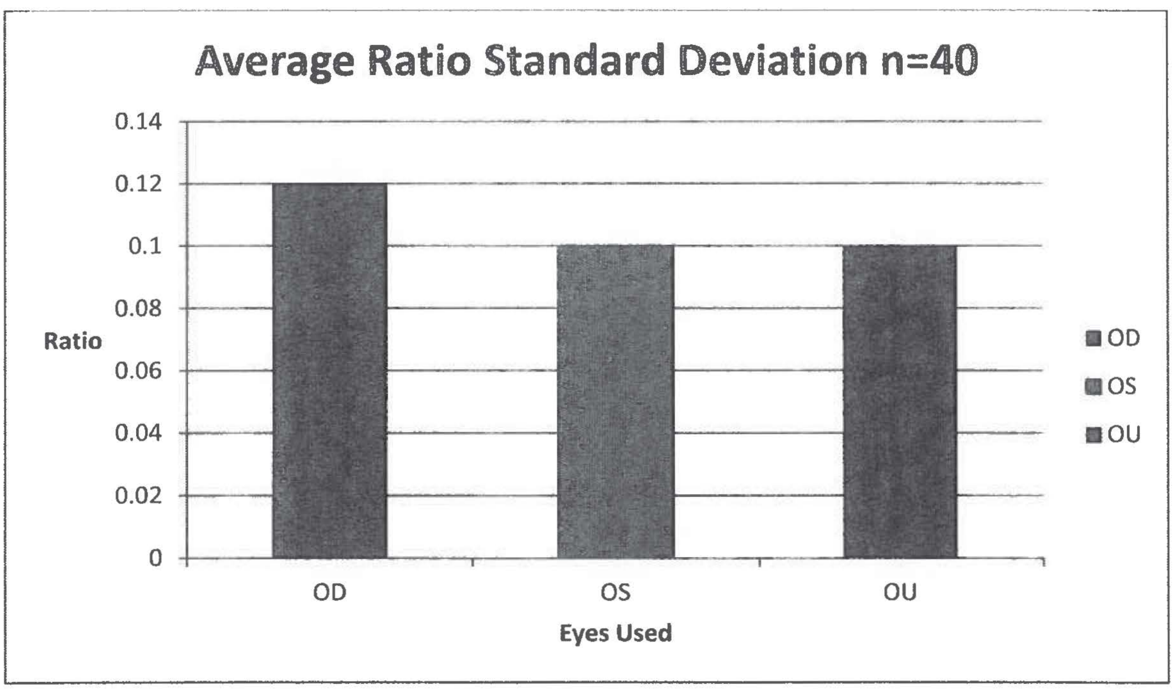

Figure 29: Average Ratio Standard Deviation

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