Association of near ocular dominance with the monocular and binocular eye movements involved in reading ability

Lorayne Caroline Siesta-Middendorp

Pacific University

Recommended Citation
Siesta-Middendorp, Lorayne Caroline, "Association of near ocular dominance with the monocular and binocular eye movements involved in reading ability" (2001). College of Optometry. 95.
https://commons.pacificu.edu/opt/95
Association of near ocular dominance with the monocular and binocular eye movements involved in reading ability

Abstract

Background: The purpose of this study was to replicate and extend the study by Dr. Diem Thuy Nguyen, who found that less ocular dominant readers performed better than strong right or left ocular dominant readers in the areas of relative reading efficiency, reading comprehension, and reading rate with comprehension. This study was designed not only to evaluate ocular dominance and reading, but also to compare reading eye movements under monocular and binocular conditions.

Methods: Part I of this study included a survey to subjectively determine ocular dominance. The "preferred reading eye" was defined as the eye that the subject preferred to leave uncovered when alternately covering each eye with a piece of waxed paper while reading printed material at 40 cm. This test separated subjects into three groups: right eye dominant, left eye dominant, and mixed (no preference on the waxed paper test). Reading eye movements were recorded by the Visagraph II as each subject read several standardized paragraphs monocularly and binocularly, followed by comprehension questions. Part II involved comparing reading skills for each eye in binocular and monocular reading conditions. Sixty-one 1st and 3rd year optometry students from Pacific University were tested.

Results: ANOVA did not demonstrate any statistically significant relationship between the "preferred reading eye" and relative reading efficiency, reading comprehension, or reading rate with comprehension. No relationship was found between the "preferred reading eye" and other reading skill indicators tested, including the number of fixations, regressions, span of recognition, or duration of fixation when reading with the Visagraph II. No improvement or degradation in reading eye movements or reading efficiency were found when reading in monocular or binocular conditions in any of the ocular dominance groups.

Conclusions: Ocular dominance does not play an obvious role in the eye movements required for reading efficiency in most readers.

Degree Type
Thesis

Degree Name
Master of Science in Vision Science

Committee Chair
Hannu Laukkanen

Keywords
ocular dominance, preferred reading eye, reading eye movements, reading efficiency, Visagraph II

Subject Categories
Optometry

This thesis is available at CommonKnowledge: https://commons.pacificu.edu/opt/95
Copyright and terms of use

If you have downloaded this document directly from the web or from CommonKnowledge, see the “Rights” section on the previous page for the terms of use.

If you have received this document through an interlibrary loan/document delivery service, the following terms of use apply:

Copyright in this work is held by the author(s). You may download or print any portion of this document for personal use only, or for any use that is allowed by fair use (Title 17, §107 U.S.C.). Except for personal or fair use, you or your borrowing library may not reproduce, remix, republish, post, transmit, or distribute this document, or any portion thereof, without the permission of the copyright owner. [Note: If this document is licensed under a Creative Commons license (see “Rights” on the previous page) which allows broader usage rights, your use is governed by the terms of that license.]

Inquiries regarding further use of these materials should be addressed to: CommonKnowledge Rights, Pacific University Library, 2043 College Way, Forest Grove, OR 97116, (503) 352-7209. Email inquiries may be directed to: copyright@pacificu.edu
ASSOCIATION OF NEAR OCULAR DOMINANCE WITH THE MONOCULAR AND BINOCULAR EYE MOVEMENTS INVOLVED IN READING ABILITY

By
Lorayne Caroline Sietstra-Middendorp

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
For the degree of
Doctor of Optometry
December 2001

Advisors:
Hannu Laukkanen, O.D., M. Ed., F.A.A.O.
W. Thomas Griffith, Ph.D.
Signature Page

Lorayne Caroline Sietstra-Middendorp, Author


Thomas Griffith, Ph.D., Thesis Advisor
Biography

Lorayne C. Sietstra-Middendorp

Lorayne was raised Boyden, Iowa where she was active in her church, school, and community. She was most influenced to choose the health professions as her career by observing her Uncle Phil, as their family optometrist, and later by her work in vocational and daily living skill training of mentally and physically challenged adults.

Lorayne graduated from South Dakota State University in Brookings, South Dakota with Highest Honors in 1998. She completed her Bachelors of Science with a major in Biology and minor in Chemistry. She was also an active member of Golden Key and Mortar Board National Honor Societies. She currently attends Pacific University in Forest Grove, Oregon and is a member of Beta Sigma Kappa Honor Society. Lorayne will graduate with her Doctor of Optometry in May 2002. This is her first published work.

Lorayne currently lives in Beaverton, Oregon with her husband, Matthew Middendorp. They enjoy exploring the Pacific Northwest and activities outdoors. After graduation, she plans to practice optometry in the United States Army.
Contents:

SIGNATURE PAGE .................................................................................................................. 2
GRADE PAGE ....................................................................................................................... 3
BIOGRAPHY .......................................................................................................................... 4
ABSTRACT ............................................................................................................................. 6
ACKNOWLEDGMENTS .......................................................................................................... 7
INTRODUCTION .................................................................................................................. 8

SUBJECTS AND METHODS .............................................................................................. 12
  SUBJECTS ......................................................................................................................... 12
  INSTRUMENTATION ......................................................................................................... 12
  METHODS .......................................................................................................................... 13
RESULTS ............................................................................................................................... 15

DISCUSSION ...................................................................................................................... 20

REFERENCES: .................................................................................................................... 22

APPENDIXES: ..................................................................................................................... 24
  HANDEDNESS AND PREFERRED EYE SURVEY .............................................................. 24
Abstract

Background: The purpose of this study was to replicate and extend the study by Dr. Diem Thuy Nguyen, who found that less ocular dominant readers preformed better than strong right or left ocular dominant readers in the areas of relative reading efficiency, reading comprehension, and reading rate with comprehension. This study was designed not only to evaluate ocular dominance and reading, but also to compare reading eye movements under monocular and binocular conditions.

Methods: Part I of this study included a survey to subjectively determine ocular dominance. The "preferred reading eye" was defined as the eye that the subject preferred to leave uncovered when alternately covering each eye with a piece of waxed paper while reading printed material at 40 cm. This test separated subjects into three groups: right eye dominant, left eye dominant, and mixed (no preference on the waxed paper test). Reading eye movements were recorded by the Visagraph II as each subject read several standardized paragraphs monocularly and binocularly, followed by comprehension questions. Part II involved comparing reading skills for each eye in binocular and monocular reading conditions. Sixty-one 1st and 3rd year optometry students from Pacific University were tested.

Results: ANOVA did not demonstrate any statistically significant relationship between the "preferred reading eye" and relative reading efficiency, reading comprehension, or reading rate with comprehension. No relationship was found between the "preferred reading eye" and other reading skill indicators tested, including the number of fixations, regressions, span of recognition, or duration of fixation when reading with the Visagraph II. No improvement or degradation in reading eye movements or reading efficiency were found when reading in monocular or binocular conditions in any of the ocular dominance groups.

Conclusions: Ocular dominance does not play an obvious role in the eye movements required for reading efficiency in most readers.

Key Words: ocular dominance, preferred reading eye, reading eye movements, reading efficiency, Visagraph II
Acknowledgments

There are many people I would like to thank who helped make the completion of this project possible.

First I want to thank my advisors, Dr. Hannu Laukkanen and Dr. Thomas Griffith, for their guidance and encouragement in helping design and execute this project. Thank you also to Dr. Robert Yolton for his wisdom in statistical analysis.

Thank you to my family and to all my friends at Pacific University College of Optometry for your support during a project that was intended to be small, but grew, causing a mild amount of insanity. I especially appreciate the help from my Aunt Marcia and Uncle Phil for their optometric and grammar advice and my friend, Mark, for his computer abilities.

And most importantly, I want to thank my husband, Matthew, for his support, inspiration, and guidance during my time in Optometry school and throughout the completion of this project. Without his love and encouragement, I could not have achieved the goals that I have.

Thank You.
Introduction

Reading is fundamental in today's society. Children learn to read, then read to learn, adults read to work, and most of us read for leisure. Some individuals are better readers than others. Researchers have tried to dissect the sub-skills necessary for reading: phonetic and eidetic skills, clarity of print, eye movements, fixations, and the list goes on. The ultimate goal of this research is to diagnose and remedy deficient sub-skills in order to produce better readers. One area of continuing interest has been ocular dominance. Porta was the first to publish his observations concerning ocular dominance in 1593. He noticed that when sighting a distant target, only one eye was aligned with both the pointer and the target, yet the common perception was that both eyes were aligned.21 Since then, a large number of studies have focused on the phenomenon of ocular dominance and its relationship with reading skills, with no definite conclusion in sight.

Supportive evidence for dominance in non-lateral functions, such as vision and language, begins with Broca's work. He worked with individuals who had suffered localized, traumatic brain damage and discovered that the speech center of a right handed man was located in the left hemisphere, but the speech center of a left handed man was unpredictable in location.16 Larson et al documented that phonological weakness is associated with absence of the normal left hemisphere processing for linguistics.4 Additionally, post mortem and MRI research have shown that one area of the brain, the planum temporal, is larger in the left hemisphere for all groups except those with reading-based learning disabilities like dyslexia.1, 4, 15

Part of the confusion as to the importance of ocular dominance may be due to its many definitions. Porac and Coren define the dominant eye as “the eye whose input is favored in behavioral coordinations in which only one eye can be used, the eye preferred when monocular views are discrepant, or the eye manifesting physiological or refractive superiority.”21 Included in this statement are several sub-definitions of ocular dominance: cerebral dominance, motor dominance, sensory dominance, and binocular controlling eye.

Cerebral dominance implies control of one eye by one side of the brain, as the right side of the brain controls the left side of the body. This definition does not appear to be consistent with the neuroanatomic pathways between the eyes and the brain. The retinogeniculocortical fibers and the occipital cortex do not follow the simple cross over pattern found for motor control and sensory input that the arms and legs exemplify. Cranial nerves VI and the inferior and medial branches of nerve III have ipsilateral control of the extraocular eye muscles while cranial nerve IV and the superior branch of nerve III maintain contralateral control. Additionally, visual information from each eye is sent to both hemispheres by nerve decussation at the optic chiasm. This means that
one point in the visual field is seen by both eyes but is processed by the same area on only one side of the cerebral cortex.

Motor dominance, or the sighting eye, refers to the eye innately chosen by an individual for monocular tasks, looking through a camera for example and when performing the 'hole in the card' test. This eye is also thought to be the fixating eye when fusion is broken by fixation disparity, tropia, or near point of convergence. Clinical optometrists have also found that patients adapt better when prism, aniseikonic lenses, and strabismus treatments are applied to the non-dominant eye as determined by the sighting method. Another common definition of ocular dominance is the binocular controlling eye. The controlling eye executes complex binocular coordinations while the contra-lateral eye follows as the supporting eye. Clare, Porac, and Coren found that while each eye performed equally efficiently when tested monocularly, the right eye displayed "greater recognition ability" in post-eye movement tasks. This phenomenon was found for all groups including right and left sighting eye dominant subjects and right and left-handers. This suggests that the presence of a stimulus input in the right eye suppresses recognition of an input to the left eye. Western left to right reading patterns would thereby reinforce a right controlling eye for maximum efficiency. A forth type of dominance is sensory. This is the basis behind ocular imbalance, also known as retinal rivalry, and may be demonstrated by the red lens test.

The anatomy of the eyes and supporting structures in the brain may not at first appear to support the notion of ocular dominance, but admittedly the neurology of the brain is amazingly complex. Recall that one point in the visual field may be seen by both eyes but is processed by the same area on one side of the cerebral cortex. This means that the right visual field is processed by the left occipital cortex and visa versa. Perhaps the idea of dominant eye must be expanded to dominance of one half of the visual field. For example, the number of words or letters perceived per fixation when reading is called the perceptual span. Some letters fall directly on the fovea while surrounding letters are processed by parafoveal retina. The sensitivity of the parafoveal retina is not symmetric; a reader can process words and letters 15 characters to the right of fixation, but only 4 characters to the left. Individuals with hemispheric brain damage exemplify this effect. Those with damage to the left occipital lobe or optic radiations with a corresponding visual field loss in the right peripheral field have severe reading difficulty, while those with damage to the right brain with left visual field loss show little or no reading problems.

Further support of the role of ocular dominance in reading includes reports of asymmetric reading eye movement speeds. Porac and Coren reported that right dominant subjects, based on the preferred sighting eye,
displayed shorter saccade latencies to the right than to the left while left dominant subjects did not show this asymmetry. Pirozzolo and Rayner reported the same results in a similar study where dominance was determined by handedness. They found that right-handers displayed faster saccade latencies of 176 milliseconds to the right vs. 192 milliseconds to the left, but left-handers displayed similar saccade latencies of 188 milliseconds to the right vs. 186 milliseconds to the left. This would indicate that the left hemisphere is more efficient in performing visual motor tasks than the right hemisphere.

There is one area of concern with the results of the previous studies. Is the response of more rapid reading eye movements to the right vs. the left eye a matter of ocular dominance or experience? All of the subjects in the previous studies were preformed using English-speaking subjects and English words whereas Western reading styles require left to right eye movements. A comparison of English and Hebrew speaking test subjects (Hebrew is read right to left) indicate that English speakers’ recognition of English words was significantly faster when the words were presented in the right visual field while Hebrew speakers recognized words faster in the left visual field if Hebrew was their first language.

More support for ocular dominance may come from a group of individuals with extreme reading and writing difficulties. Dyslexia is a disorder of written language acquisition, in part, due to poor phonological awareness. Many dyslexics also display poor reading eye movements compared to their age-matched classmates when reading age-appropriate text. This includes excessive regressions and fixations, smaller perceptual span, cogwheel saccades (when attempting to perform pursuits), and inability to maintain fixations. Stein and Fowler hypothesized that failure to develop consistence dominance of one eye impedes interpretation of visual direction, especially when the eyes are converged. They used the Dunlop Ocular Dominance Test to discover that 63% of dyslexic children and 52% of ‘backward readers’ tested displayed unstable ocular dominance while only one of the eighty age-matched control group subjects showed an unstable dominance. They also examined primary school children to determine at what age a dominant eye developed. Both reported that 50% of 5 year olds had developed a stable dominant eye, which increased by approximately 8% per year. By age 8, 75% had a stable dominant eye and by age 10 more than 85% had developed a stable eye. Students who had developed a stable dominant eye read approximately 4 months above their chronological age, while their peers with unstable eye dominant peers read 1 month below their chronological age through age 12. Stein and Fowler treated dyslexic and learning disabled children with spectacles and monocural occlusion therapy to encourage them to convert from unstable to stable ocular dominance and found a significant increase in reading age; an improvement of 12 months vs. their untreated peers who improved by 6 months.
On the other hand, there are those that report that little or no ocular dominance preference is associated with better reading skills. Annett’s genetic research and his Right Shift Theory states that the best readers show a mild bias to the right hand and left-brain. Those with strong a right or left hand tendency show a disadvantage; strong right-handers with poor left hand skills were poorer readers and strong left-handers with poor right hand skills showed lower intelligence.\(^3\) Nguyen et al reported that individuals with no ocular dominance preference preformed better in certain areas of reading efficiency than those with strong right and left eye dominant tendencies.\(^24\)

The initial purpose of this study was to repeat Nguyen’s research exploring the relationships between ocular dominance and various aspects of reading eye movement efficiency (as reported in the thesis, “Association of Eye Movement Patterns with Handedness and Eye Dominance” by Diem Thuy Nguyen, Griffith, and Laukkanen). Nguyen modified a survey used by Kundart that included daily tasks to establish motor eye and hand dominance.\(^11\) The survey included a question that incorporated a waxed paper occlusion test to subjectively determine the preferred reading eye. Subjects were instructed to alternately cover each eye with opaque paper to simulate light perception only in one eye while reading printed material with the other eye. The preferred reading eye was defined as the eye that the subject preferred to leave uncovered. This variation of a motor eye dominance test appears to overlap with the definition of the binocular controlling eye, as the subjects were asked to read binocularly while compromising acuity in one eye. Subjects were grouped by their responses to the waxed paper test into preferred reading eye groups: right eye dominant, left eye dominant, and mixed (no preference with the waxed paper test). Reading eye movement efficiencies were recorded by the Visagraph II system as each subject read several standardized paragraphs, followed by comprehension questions. Binocular reading efficiency data were compared between the preferred reading eye groups. Nguyen et al reported statistically significant relationships between several areas of ocular dominance and reading efficiency including:

1. Better relative reading efficiency in the mixed eye group versus the left and right eye groups when reading binocularly,
2. Higher reading comprehension in the mixed eye group in comparison to the right and left eye groups when reading binocularly,
3. Faster reading rate with comprehension in the mixed eye group versus the right eye group when reading binocularly.\(^24\)

The second purpose of this study was to further examine the relationship between ocular dominance and reading efficiency by comparing reading skills for each eye in monocular and binocular reading conditions. It
was expected that the relationships found between ocular dominance groups and reading efficiency would remain consistent when reading monocularly versus binocularly. This means that a person who is right eye dominant based on the waxed paper test will maintain better reading efficiency when reading with their right eye alone compared to the left eye alone.

**Subjects and Methods**

**Subjects**

Sixty-one subjects volunteered and were included in this study: 23 first year and 38 third year optometry students from Pacific University. Each subject reported that they were corrected to 20/20 at near and wore their near prescription as needed. All spoke fluent English and were not known to have any reading disabilities or dyslexia. Each subject read well enough to have completed an undergraduate program, to have been accepted into optometry school, and to have successfully completed at least one semester of reading-intensive optometric coursework. All subjects signed an informed consent prior to testing.

**Instrumentation**

The Taylor Visagraph II is an eye movement-monitoring device that gives objective information about a subject’s reading eye movements. It is composed of infrared emitters and detectors mounted in safety-type goggles that detect changes in the corneal and scleral reflections when the eye moves. The information is monitored and recorded by software on an IBM PC-compatible. This program not only records fixations, regressions, and other reading eye movements, but also compares these values to stored normative data and computes scores including grade-level equivalent (Table 1).
Table 1: Names, Abbreviations, and Definitions of Data produced by the Visagraph II

<table>
<thead>
<tr>
<th>Name and abbreviation</th>
<th>Measurement or calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixations (FIX)</td>
<td>Number of eye pauses per 100 words read.</td>
</tr>
<tr>
<td>Regressions (REG)</td>
<td>Number of significant right-to-left eye movements (excluding return sweeps) per 100 words.</td>
</tr>
<tr>
<td>Span of Recognition (SPAN)</td>
<td>Number of words read divided by the number of fixations made.</td>
</tr>
<tr>
<td>Duration of Fixations (DUR)</td>
<td>Total reading time (in seconds) divided by number of fixations made.</td>
</tr>
<tr>
<td>Reading Rate with Comprehension (RATE WITH COMP)</td>
<td>Reading rate (in words per minute) determined for all lines in the paragraph, excluding the first and last.</td>
</tr>
<tr>
<td>Directions of Attack (DIR ATTACK)</td>
<td>Number of regressions divided by number of fixations.</td>
</tr>
<tr>
<td>Relative Efficiency (REL EFFIC)</td>
<td>Reading rate (in words per minute) divided by the sum of fixations plus regressions.</td>
</tr>
<tr>
<td>Reading Rate Adjusted for Rereading (ADJ READ RATE)</td>
<td>Reading rate (in words per minutes), excluding any lines or parts of lines that are reread.</td>
</tr>
<tr>
<td>Percentage Correct on Quiz (%) COR)</td>
<td>Percentage of correct answers given to 10-questions comprehension quiz given after paragraph has been read.</td>
</tr>
<tr>
<td>Grade-Level Equivalent (GRADE)</td>
<td>An equivalent academic grade (ranging from 1-18) determined by converting the Relative Efficiency to a Grade Level Equivalent using norms provided by Taylor. This is a nonlinear conversion.</td>
</tr>
<tr>
<td>Visagraph Eye Dominance</td>
<td>Dominant eye as chosen as the eye with the most fixations (or regressions in case of a tie).</td>
</tr>
</tbody>
</table>

Methods

A twenty-three-question survey (Appendix A) was given to test subjects prior to Visagraph II testing to determine ocular dominance. Nguyen, Griffith, and Laukkonen adapted this survey from a previous study by Kundart to subjectively determine hand and motor eye dominance in various daily activities. This same survey was used in this study to maintain inter-test consistency, but the thirteen questions pertaining to hand dominance were not included in our data analysis and one question referring to number of left handed family members was not used. There were seven questions pertaining to ocular dominance, and the last three questions referred to gender and refractive status of each eye.

The questions pertaining to ocular dominance included: (1) which eye was used to sight a distant object through a hole in a flat card, (2) which eye was used to site a clock at the far end of the classroom through a tube made of paper, (3) which eye was used to aim a camera when taking a photograph, (4) which eye was used to look through a handheld magnifier at a near target, (5) which eye was used to look into a monocular microscope, and (6) which eye was used to sight a pool cue. The seventh ocular dominance question involved a 4 x 4 inch square of opaque, translucent "Reynolds Cut-Rite" wax paper that was used as an occluder that would allow light perception only in the occluded eye. Each subject was asked to read printed material at 40 centimeters while alternately covering each eye with the piece of translucent paper and report which eye felt more natural to leave...
uncovered. This test appears to incorporate a test of motor dominance with the definition of binocular controlling eye, creating a ‘hybrid’ of ocular dominance. Subjects were asked to grade each of the hand and ocular dominance questions on an a-e scale, ‘a’ left hand/eye always, ‘b’ left hand/eye mostly, ‘c’ either hand/eye, ‘d’ right hand/eye mostly, and ‘e’ right hand/eye always. Based upon their response to the survey answers, the subjects were separated into right, left, and mixed (no preference) preferred eye groups. The results of the first six ocular dominance questions were used to determine the “preferred eye” and “preferred near eye”. The waxed paper test determined the “preferred reading eye” which was used exclusively in data analysis of ocular dominance and reading eye movements in this study.

Stereopsis and fixation disparity were measured using a Super Stereo Test and a Wesson Fixation Disparity Card. Fine global stereo acuity tests better differentiate and quantify depth perception skills as opposed to local stereo acuity tests. It was expected that most of the subjects would demonstrate very high levels of stereo acuity and small fixation disparities, as subjects with binocularity problems consisting of strabismus or amblyopia and learning disorders such as dyslexia were excluded from testing.

The procedure used to measure eye movements was adapted from the Visagraph II user’s manual. Testing took place in a well-illuminated room with natural daylight and subjects were positioned to minimize glare from the text and avoid direct sunlight on the goggle sensors. Each subject was seated comfortably and was asked to put on the Visagraph goggles. The examiner adjusted the goggles for stability, comfort, interpupillary distance and centered the eyes in the apertures so that they did not block any of the text from the subject’s view. Subjects were instructed to hold the booklet at 40 cm, look at the circle at the top of the page, and begin reading silently when the examiner said, “begin”. There was no time limit and each subject was instructed to close their eyes when they reached the end of the passage. The examiner stopped the recording, took away the booklet at the end of each passage, and required each subject to answer 10 comprehension questions about the reading passage just completed.5

Eight passages from the Taylor Level 10 booklet, designated as college level, were randomly chosen. Each passage was double-spaced in 12-point Times bold font (approximately 20/70 Snellen) on bond white paper and consisted of 12 or 13 lines of text. An earlier study by Colby, Laukkanen, and Yolton reported poor correlation between the scores of the first test versus subsequent tests; consequently, first paragraph data for each subject were not used.5 Each subject first read the Houdini or Paganini paragraphs and these results were not included in the data analysis. Two sets of passages were counter balanced for the 3 included readings: Braille, John Roebling, and Dorothea Dix, or Frank Lloyd Wright, Sir Ernest Shackleton, and Clara Barton. Six variations of
monocular and binocular reading orders were written on pieces of paper and the examiner randomly chose one for each subject prior to testing.\footnote{5}

**Results**

Sixty-five subjects completed the survey and Visagraph II testing. Four subjects were excluded from the study: 2 due to operator error, 1 subject did not complete all the survey questions, and 1 subject who spoke English as a second language. All calculations were computed using data from the remaining 61 subjects.

The survey was designed with an a-e scale, ‘a’ left hand/eye always, ‘b’ left hand/eye mostly, ‘c’ either hand/eye, ‘d’ right hand/eye mostly, and ‘e’ right hand/eye always. These scores were converted to a 1-5-point scale for statistical analysis where ‘a’ equals ’1’, ‘b’ equals ‘2’, etc. These calculations indicated that for all survey questions pertaining to ocular dominance, there was a distinct bias towards mixed and right ocular dominance (Table 2). These data were comparable to the averages reported by Nguyen: Question 14 - 3.28, Question 15 - 3.42, Question 16 - 3.63, Question 17 - 3.63, Questions 18 - 3.49, Question 19 - 3.63, and most importantly Question 20 - 3.72. Note that each of Nguyen’s results were skewed towards mixed ocular dominance in comparison to this study. The greatest variance was found in question 20, the waxed paper test, which was used to determine ocular preference and dominance groupings in the following data analysis in Nguyen’s and this study.

**Table 2: Mean Scores and Standard Deviations of Survey Questions**

<table>
<thead>
<tr>
<th>Ocular dominance Questions</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 14</td>
<td>3.37</td>
<td>1.64</td>
</tr>
<tr>
<td>Question 15</td>
<td>3.42</td>
<td>1.89</td>
</tr>
<tr>
<td>Question 16</td>
<td>3.92</td>
<td>1.56</td>
</tr>
<tr>
<td>Question 17</td>
<td>3.82</td>
<td>1.41</td>
</tr>
<tr>
<td>Question 18</td>
<td>3.67</td>
<td>1.49</td>
</tr>
<tr>
<td>Question 19</td>
<td>3.75</td>
<td>1.54</td>
</tr>
<tr>
<td>Question 20 – the waxed paper test</td>
<td>3.16</td>
<td>1.31</td>
</tr>
</tbody>
</table>

Refractive error calculations were included to indicate subject consistency between Nguyen’s and this study (Table 3). This study found a slight shift from myopic to emmitropic and hyperopic prescriptions. Nguyen reported: Myopia greater than 5D – 16.3% OD, 13.9% OS, Myopia between 2.75 and 5D – 32.6% OD, 32.6% OS, Myopia between 1 and 2.5D – 27.9% OD, 30.2% OS, Emmitropia – 23.3% OD, 23.3% OS, Hyperopia – 0% OD, 0% OS.\footnote{24}

15
Table 3: Refractive Status per Eye as reported on the Survey

<table>
<thead>
<tr>
<th>Refractive Status</th>
<th>Right Eye</th>
<th>Percenta</th>
<th>Left Eye</th>
<th>Percenta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopia greater than 5D</td>
<td>4</td>
<td>6.6%</td>
<td>4</td>
<td>6.6%</td>
</tr>
<tr>
<td>Myopia between 2.75 and 5D</td>
<td>14</td>
<td>23.0%</td>
<td>13</td>
<td>21.3%</td>
</tr>
<tr>
<td>Myopia between 1 and 2.5D</td>
<td>18</td>
<td>29.5%</td>
<td>15</td>
<td>24.6%</td>
</tr>
<tr>
<td>Within 0.75 of Emmitropia</td>
<td>21</td>
<td>34.4%</td>
<td>26</td>
<td>42.6%</td>
</tr>
<tr>
<td>Hyperopia equal or greater than 1D</td>
<td>4</td>
<td>6.6%</td>
<td>3</td>
<td>4.9%</td>
</tr>
</tbody>
</table>

Stereopsis and fixation disparity measurements were also averaged within each ocular dominance group. As expected, all groups showed acceptable levels of depth perception and fixation disparity (Table 4). This test was not part of the original study by Nguyen.

Table 4: Stereopsis and Fixation Disparity

<table>
<thead>
<tr>
<th>Ocular Dominance Group</th>
<th>Stereopsis (sec of arc)</th>
<th>Fixation Disparity (min of arc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>20.9</td>
<td>6.18</td>
</tr>
<tr>
<td>Mixed</td>
<td>22.2</td>
<td>4.52</td>
</tr>
<tr>
<td>Right</td>
<td>23.7</td>
<td>4.94</td>
</tr>
</tbody>
</table>

Subjects were grouped into right, left, and mixed preferred ocular dominance groups by their survey answers. Three areas of ocular dominance – preferred eye, preferred near eye, and preferred reading eye – were established by averaging the appropriate survey questions. The averaged values ‘1’ and ‘2’ were labeled as left eye dominant, ‘3’ as mixed, and ‘4’ and ‘5’ as right eye dominant. The “preferred eye” included all eye related questions, 14-20, and included both distance and near targets. The “preferred near eye” included only the near sighting tasks, questions 17 to 20. The “preferred reading eye” was based solely on question 20, the waxed paper test.

Analysis of variance (ANOVA) indicated a statistically significant correlation (p<0.0001) between the three areas of ocular dominance – preferred eye, preferred near eye, and the preferred reading eye. This indicated that the waxed paper test is a valid test for determining motor ocular dominance/binocular controlling eye. The numbers of subjects per group and percentage of total sample are included in Table 5. Again, comparison to Nguyen’s study shows strong similarities. She reported the percentages of preferred near eye as: left - 30.2%, mixed - 23.3%, and right - 58.1%. Preferred reading eye was reported as: left - 18.6%, mixed - 23.3%, and right - 58.1%. Preferred eye data was not reported.24
Table 5: Survey Results for Ocular Dominance for all Subjects

<table>
<thead>
<tr>
<th></th>
<th>Number of Subjects per Group</th>
<th>Percentage of Total Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preferred Eye</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>16</td>
<td>26.2%</td>
</tr>
<tr>
<td>Mixed</td>
<td>9</td>
<td>14.8%</td>
</tr>
<tr>
<td>Right</td>
<td>36</td>
<td>59.0%</td>
</tr>
<tr>
<td><strong>Preferred Near Eye</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>12</td>
<td>19.7%</td>
</tr>
<tr>
<td>Mixed</td>
<td>8</td>
<td>13.1%</td>
</tr>
<tr>
<td>Right</td>
<td>41</td>
<td>67.2%</td>
</tr>
<tr>
<td><strong>Preferred Reading Eye (Q 20)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>16</td>
<td>26.2%</td>
</tr>
<tr>
<td>Mixed</td>
<td>18</td>
<td>29.5%</td>
</tr>
<tr>
<td>Right</td>
<td>27</td>
<td>44.2%</td>
</tr>
</tbody>
</table>

Reading results were compiled and separated based on the preferred reading eye groups: left, mixed, and right, and the subtest of the Visagraph II testing: OD, OS, and OU reading. Data for fixations, regressions, average span of recognition, and average duration of fixation are shown only for the unoccluded eye during its monocular reading test (Table 6a) and both right and left eye data are presented during the binocular reading test as both eyes were unoccluded for this part of the test (Table 6b).

Table 6a: Monocular Eye Movement Data from the Visagraph II separated by Ocular Dominance and Reading Eye

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Right Eye Reading Monocularly</th>
<th>Left Eye Reading Monocularly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominance Groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixations/100 words</td>
<td>100.9 95.8 95.3</td>
<td>102.1 98.1 98.6</td>
</tr>
<tr>
<td>Regressions/100 words</td>
<td>11.8 10.3 10.6</td>
<td>11.9 8.6 10.7</td>
</tr>
<tr>
<td>Average Span of Recognition (words)</td>
<td>1.07 1.13 1.15</td>
<td>1.06 1.06 1.08</td>
</tr>
<tr>
<td>Average Duration of Fixation (seconds)</td>
<td>0.258 0.28 0.27</td>
<td>0.25 0.26 0.26</td>
</tr>
<tr>
<td>Rate of Comprehension (words/min)</td>
<td>258.5 240.0 256.4</td>
<td>249.7 238.2 250.6</td>
</tr>
<tr>
<td>Grade Level Equivalent</td>
<td>10.7 11.0 11.5</td>
<td>10.4 10.8 11.0</td>
</tr>
<tr>
<td>Directional Attack</td>
<td>0.106 0.096 0.113</td>
<td>0.111 0.098 0.106</td>
</tr>
<tr>
<td>Rate Adjusted for Rereading (words/min)</td>
<td>281.4 263.9 264.2</td>
<td>274.6 263.9 270.1</td>
</tr>
<tr>
<td>Comprehension Questions Correct</td>
<td>7.9 7.9 8.1</td>
<td>7.5 8.4 8.2</td>
</tr>
<tr>
<td>Cross Correlation</td>
<td>0.936 0.957 0.914</td>
<td>0.910 0.954 0.918</td>
</tr>
<tr>
<td>Visagraph Ocular Dominance (1=left eye, 2=right eye)</td>
<td>1.31 1.22 1.59</td>
<td>1.44 1.44 1.44</td>
</tr>
</tbody>
</table>
Table 6b: Binocular Eye Movement Data from the Visagraph II separated by Ocular Dominance and Reading Eye

<table>
<thead>
<tr>
<th>Dominance Groups</th>
<th>Left Eye Dominant Group</th>
<th>Mixed Eye Dominant Group</th>
<th>Right Eye Dominant Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td>Fixations/100 words</td>
<td>100.0</td>
<td>101.5</td>
<td>101.4</td>
</tr>
<tr>
<td>Regressions/100 words</td>
<td>12.2</td>
<td>12.2</td>
<td>12.1</td>
</tr>
<tr>
<td>Average Span of Recognition (words)</td>
<td>1.04</td>
<td>1.03</td>
<td>1.04</td>
</tr>
<tr>
<td>Average Duration of Fixation (seconds)</td>
<td>0.245</td>
<td>0.241</td>
<td>0.261</td>
</tr>
<tr>
<td>Rate of Comprehension (words/min)</td>
<td>257.8</td>
<td>241</td>
<td>258</td>
</tr>
<tr>
<td>Grade Level Equivalent</td>
<td>10.7</td>
<td>10.6</td>
<td>11.5</td>
</tr>
<tr>
<td>Directional Attack</td>
<td>0.116</td>
<td>0.221</td>
<td>0.107</td>
</tr>
<tr>
<td>Rate Adjusted for Rereading (words/min)</td>
<td>283</td>
<td>273</td>
<td>273</td>
</tr>
<tr>
<td>Comprehension Questions Correct</td>
<td>7.88</td>
<td>7.94</td>
<td>8.44</td>
</tr>
<tr>
<td>Cross Correlation</td>
<td>0.942</td>
<td>0.901</td>
<td>0.894</td>
</tr>
<tr>
<td>Visagraph Ocular dominance (1=left eye, 2=right eye)</td>
<td>1.50</td>
<td>1.28</td>
<td>1.59</td>
</tr>
</tbody>
</table>

When examining the data from the Visagraph Ocular Dominance row, it appeared that there was a bias toward left ocular dominance in the monocular right and left eye reading tests. Visagraph Ocular Dominance calculations showed an averaged left eye bias in the left and mixed ocular dominance groups when reading with the right eye and left, mixed, and right ocular dominance groups with reading with the left eye. This was not as apparent in the binocular reading conditions as the right and left eye showed right eye Visagraph Dominance and the mixed eye showed left eye Visagraph Dominance. Recall that the Visagraph program chooses the dominant eye based on the eye with the most number of fixations (or regressions in case of a tie). Whether this was an actual trend in ocular dominance, an anomaly of the Visagraph software, or a statistical anomaly is unknown at this time.

Nguyen’s investigation included only binocular reading and reported only the average of each eye movement. Table 7 has been included for the sole purpose of comparison between this and Nguyen’s study. None of the following information was included in this data analysis. Note that all of the values correspond closely, with the exception that Nguyen reported Comprehension Question Correct as a decimal of 1 whereas this study reports this value as X out of 10.
Table 7: Comparison of the Sietstra-Middendorp and Nguyen Studies

<table>
<thead>
<tr>
<th></th>
<th>Sietstra-Middendorp</th>
<th>Nguyen</th>
<th>Standard</th>
<th>Sietstra-Middendorp</th>
<th>Nguyen</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixations/100 words</td>
<td>98.13</td>
<td>20.38</td>
<td>93.86</td>
<td>23.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regressions/100 words</td>
<td>11.50</td>
<td>7.78</td>
<td>12.21</td>
<td>9.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Span of Recognition (words)</td>
<td>1.06</td>
<td>0.23</td>
<td>1.13</td>
<td>0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Duration of Fixation (seconds)</td>
<td>0.25</td>
<td>0.03</td>
<td>0.24</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of Comprehension (words/min)</td>
<td>253.2</td>
<td>63.82</td>
<td>276.3</td>
<td>76.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade Level Equivalent</td>
<td>11.01</td>
<td>3.13</td>
<td>11.63</td>
<td>3.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directional Attack</td>
<td>0.14</td>
<td>0.25</td>
<td>0.12</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate Adjusted for Rereading (words/min)</td>
<td>276.03</td>
<td>69.39</td>
<td>302.07</td>
<td>77.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comprehension Questions Correct</td>
<td>8.15</td>
<td>1.31</td>
<td>0.79</td>
<td>0.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross Correlation</td>
<td>0.91</td>
<td>0.12</td>
<td>0.95</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visagraph Ocular dominance (1=left eye, 2=right eye)</td>
<td>1.48</td>
<td>0.50</td>
<td>1.37</td>
<td>0.49</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A statistical analysis using analysis of variance (ANOVA) was preformed comparing preferred reading eye as determined by survey question 20, the waxed paper test, to reading eye movement values as reported by the Visagraph II for each of the ocular dominance groupings: right, mixed, and left eye dominant. This analysis showed no statistical significance between the preferred reading eye and reading efficiency, comprehension, or reading rate with comprehension using the Visagraph II with binocular or monocular reading conditions. This is in disagreement with the data reported by Nguyen, who found statistical relationships in these areas for certain ocular dominance groups. Specifically, she reported significant relationships between preferred reading eye and better relative reading efficiency in the mixed eye group versus the left and right eye groups when reading binocularly, preferred reading eye and higher reading comprehension in the mixed eye group in comparison to the right and left eye groups when reading binocularly, and preferred reading eye and improved reading rate with comprehension in the mixed eye group versus the right eye group when reading binocularly.\textsuperscript{24}

Additionally, this study found no statistical significance between the preferred reading eye and other reading efficiency indicators including: the number of fixations, number of regressions, span of recognition, duration of fixation, grade level equivalent, directional attack, rate adjusted for rereading, cross correlation, or Visagraph Ocular Dominance when reading with the Visagraph II in any of the preferred reading eye groups or monocular vs. binocular reading conditions.
Discussion

The data and analysis from this study does not appear to support the previous research linking mixed ocular dominance and superior reading performance as reported by Nguyen. In fact, we found that the comparisons of preferred reading eye with better reading efficiency, higher reading comprehension, and improved reading rate with comprehension when reading binocularly did not even have a statistically suggestive relationship.

The next question to ask is, "Why do the results of this study not compare to the previous study?" One possibility could be the test giver or the subjects. Every effort was made to reproduce the original testing conditions and attain the same subject samples. However, not all variables can be accounted for. It is assumed that each class has similar ranges of abilities and skills when compared at the same level of education, but this may not hold true in a small sample from 2 classes of 85 approximately students each. It was noted that some variation in populations exists. Nguyen's subject group displayed consistently more mixed preferred eye tendencies on all the ocular dominance survey questions, particularly question #20, the preferred reading eye. Her subjects, on average, also displayed greater myopic refractions than this study. Personality variations could have also caused the subjects to answer the questions differently, question 20 in particular. Finally, Annett suggests that studies based on university students and staff or other professionals are unreliable because they are highly successful readers and do not reflect the general population.¹

The reliability of the waxed paper test to subjectively determine ocular dominance must also be considered. A high correlation was found between the ocular dominance areas—preferred eye, preferred near eye, and preferred reading eye (p<0.0001). However, lack of consistency between these two studies may indicate that the subject groups were more diverse than anticipated, or that the waxed paper test lacks validity. There may also be more variables to the waxed paper test than originally believed. For example, during testing a subject mentioned to the test giver that their answer depended on in which hand the opaque paper was held. This phenomenon should be noted and compensated for in future research on ocular dominance.

The other possibility, of course, is that ocular dominance plays no role in reading efficiency. When performing statistical analysis, there is always a chance that the correlations found are due to chance and not an actual finding. This value is expressed as p. Testers generally accept p<0.05 as a 5% chance that the correlation found is in error. Nguyen found that the relationship between mixed preferred reading eye group and relative reading efficiency as p=0.05 vs. the right and left groups, the relationship between mixed preferred reading eye group and reading comprehension questions p<0.02 vs. right and p<0.01 vs. left groups, and mixed preferred
reading eye group and reading rate with comprehension \( p<0.05 \) vs. right and \( p<0.06 \) vs. left groups. With the exception of the last value, mixed vs. left preferred reading eye and reading rate with comprehension, all are within the range acceptable doubt. However, there is always the small chance that the correlations found were a statistical error.

Lastly we must ask, “Can this information be applied clinically?” Data from this study suggest that with normal readers, ocular dominance does not play a role in reading eye movements or efficiency, and that visual training to stabilize ocular dominance will not improve reading eye movements and efficiency.

Years of research have not been able to conclusively prove or disprove the importance of ocular dominance in our activities, specifically in reading eye movements. There are years of research on either side of this debate, and no concrete answer in sight. This author suspects that until a definitive method of remedying deficient reading eye movements and improving reading efficiency is identified, ocular dominance will remain an indefinite part of optometric research and vision therapy.
References:


Appendixes:
A: survey

Handedness and Preferred Eye Survey

For questions 1-13, please try to visualize yourself doing each of the action listed (even if you never actually do them) and indicate your hand preference using the following scale:
   a) left hand always    b) left hand mostly   c) either hand
   d) right hand mostly   e) right hand always

1. Hand used to hold a pen or pencil when writing.
   a) b) c) d) e)

2. Hand used to hold a pen or pencil when drawing.
   a) b) c) d) e)

3. Hand used to throw a ball or a Frisbee.
   a) b) c) d) e)

4. Hand used to hold a racquet when playing racquetball or similar game.
   a) b) c) d) e)

3. Hand used to shave or apply makeup.
   a) b) c) d) e)

4. Hand used to brush teeth.
   a) b) c) d) e)

7. Hand used to hold a knife when cutting bread.
   a) b) c) d) e)

8. Hand used to hold a hammer when pounding a nail.
   a) b) c) d) e)

9. Hand used for turning a screwdriver.
   a) b) c) d) e)

10. Hand used to hold the match when striking a match.
    a) b) c) d) e)

11. Hand used to hold a brush when combing your hair.
    a) b) c) d) e)

12. Hand used to hold a spoon when eating with a spoon.
    a) b) c) d) e)

13. Indicate which of the following drawings below best describes the manner in which you hold a pen or pencil when writing:

   Tape picture of hands here.
For questions 14-21, please try to visualize yourself doing each of the action listed (even if you never actually do them) and indicate your eye preference using the following scale:

a) left eye always  b) left eye mostly  c) either eye  d) right eye mostly  e) right eye always

14. Eye used to sight a distant object through a hole in a flat card.
   a)  b)  c)  d)  e)

15. Roll this survey into a tube and sight the clock at the far end of the classroom. Which eye did you use to look through the tube?
   a)  b)  c)  d)  e)

16. Eye used for aiming the camera when taking a photograph.
   a)  b)  c)  d)  e)

17. Eye used when looking through a handheld magnifier.
   a)  b)  c)  d)  e)

18. Eye used for looking in a monocular microscope.
   a)  b)  c)  d)  e)

19. Eye used to sight a pool cue.
   a)  b)  c)  d)  e)

20. Remove the square of translucent material attached to this survey and hold it in front of an eye while you re-read this question. Which eye does it feel most natural to leave uncovered?
   a)  b)  c)  d)  e)

Miscellaneous questions:
21. What is your gender:
   a) Female  b) Male

22. Which one of the following best describes the refractive status in your right eye?
   a) myopia greater than 5D  d) within 0.75 of emmitropia
   b) myopia between 2.75 and 5D  e) hyperopia great than 1D
   c) myopia between 1 and 2.50D

23. Which of the following best describes the refractive status in your left eye?
   a) myopia greater than 5D  d) within 0.75 of emmitropia
   b) myopia between 2.75 and 5D  e) hyperopia great than 1D
   c) myopia between 1 and 2.50D

Please, return this survey to one of the testers who will measure you depth perception.

Stereopsis measured at: __________________________

1. The above questions were adapted from: Diem Thuy Nguyen, Thomas Griffith, Ph.D., Hannu Laukkanen, O.D., M.Ed., Association of Eye Movement Patterns with Handedness and Eye Dominance, 1998.