Summer 2017

The effects of ocular dominance on visual processing in college students

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The Effects of Ocular Dominance on Visual Processing in College Students

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An Honors College Project Presented to

the Faculty of the Undergraduate

College of Science and Mathematics

James Madison University

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by William Alexander Holland

May 2017

Accepted by the faculty of the Department of Biology, James Madison University, in partial fulfillment of the requirements for the Honors College.

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PUBLIC PRESENTATION

This work is accepted for presentation, in part or in full, at [venue] The Honors Symposium on [date] 4/21/17 .

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This work would not have been possible without Dr. Corey L. Cleland, Dept. of Biology, Dr. James S. Sochacki, Dept. of Mathematics, and Dr. Roger Thelwell, Dept. of Mathematics. I am grateful to have worked with these professors during the time that this project took place. I also give special thanks to Lumos Labs, Inc. for the use of their product Lumosity which was pivotal to my research here at James Madison University. I thank all my volunteers for their participation in my experiments. Lastly, I thank the Honors College for their patience with the delivery of my honor's capstone project.

V. Abstract

The role of ocular dominance in processing visual memory and analytic tasks is unknown. Previous research variably showed both significant effects and no effect of ocular dominance on visual perception, motor control and sports performance. Consequently, the goal of this study was to determine if there is a relationship between ocular dominance and visual processing under a variety of computer gaming tasks. This was accomplished by first determining subjects' ocular dominance through the use of the Miles test, and then proceeding to examine the subjects' visual performance on four different Lumosity games under three conditions: left eye, right eye and both eyes. The results revealed that there was a relationship between ocular dominance and score in one of the games tested: Raindrops. However, there was no relationship between ocular dominance and accuracy measured in this game nor was there a relationship within any of the other games. It is possible that a relationship between ocular dominance and score in the game Raindrops may have been due to the simplicity of the task. Raindrops only measures arithmetic ability whereas the other games measure a variety of different abilities. A small sample size (n = 20) may have also contributed to the inability to detect significant effects.

VI. Introduction

Throughout history it has been appreciated that a person may be more adept with one hand than the other. Most people have either a dominant right or left had; few are equally adept with both hands (Llaurens et al. 2009). More recently it has become clear that humans also preferentially use one eye over the other, which is known as ocular dominance (Miles 1929). It is unclear, however, whether or not the dominant eye processes or perceives visual information better than the other eye. The goal of this study is to determine if there is any relationship between ocular dominance and visual processing under a variety of computer gaming tasks.

Visual System

Ocular dominance arises from the anatomical and physiological organization of the visual system. The eye consists of the pupil, iris, cornea, sclera, and retina. The pupil is a small black-looking aperture in the center of the eye which admits light. The iris is a circular pigmented muscle which regulates how much light is transmitted through the pupil by controlling the pupil’s size; the iris also gives the eye its color. The cornea is the outside layer of the eye covering the iris and pupil whose purpose is to work with the lens to generate a sharp image at the retinal photoreceptor layer on the inner surface of the eye. The sclera is the supportive wall of the eye. Regarding the neural elements, the retina is the inner lining of the eye where neurons and photoreceptors, structures sensitive to light, are located. The retina consists of three layers, the outermost containing rod and cone photoreceptors, which allow for monochromatic and color vision, respectively. The middle layer contains bipolar cells which processes and conveys signals from the photoreceptors to the ganglion cells in the innermost layer. The ganglion cells in turn project through the optic tract to the lateral geniculate nucleus (LGN) in the thalamus (Kolb et al. 2007).

The LGN, located in the dorsal thalamus of the brain, consists of two lobes, the right LGN and the left LGN. Each half of the LGN is made up of 6 layers; half of these layers receive input from the nasal medial retinas, the other half receive input from the temporal lateral retinas. Neurons in the LGN transmit information to the primary visual cortex (Bear et al. 2016).

The primary visual cortex, also known as the striate cortex, is located in the occipital lobe of the brain. The primary visual cortex is the primary synaptic target of the LGN. The primary visual cortex is also made up of 6 layers and layer 4 is divided into 3 parts. Layer 4C is different from the other layers of the primary visual cortex in that it receives synaptic input from only the contralateral eye. The other layers of the primary visual cortex receive input from both eyes (Bear et al. 2016). The secondary visual cortex, also known as the pre-striate cortex, processes visual information from the primary visual cortex. The secondary cortex differs from the primary cortex in that more complex features of the visual scene are recognized, perhaps also leading to visual memories. The secondary visual cortex also sends input back to the primary visual cortex (Gazzaniga et al. 2002). The associative cortex includes most of the cerebral cortex and is responsible for the complex processing that underlies the integration of multi-sensory information, the control of movement and conscious behavior. The parietal association cortex in particular is responsible for responding to complex stimuli in the internal and external environment and the frontal associative cortex may be important for planning behavior in response to stimuli (Augustine et al. 2001).

Ocular dominance must arise from the separate processing of information from each eye. Therefore, it is relevant that information from the left and right eyes remains at least partially separate up through the primary visual cortex. In particular, there are ocular dominance columns in the primary cortex that may mediate monocular processing, such as depth perception and possibly ocular dominance (Miller et al. 1989; Brendan 2016).

Ocular Dominance

Ocular dominance is defined as having an eye that is used to preferentially sight with, or is favored when there is conflicting information being presented to both eyes (Coren and Kaplan, 1973). The term ocular dominance was first coined by Porta in 1593. Although Porta suggested that if a person is right handed and footed, then they are necessarily right-eyed., more recently it has become clear that there is not a direct relationship between the sighting eye and the body's limbs (Coren and Kaplan, 1973).

Coren and Kaplan used 13 different methods to test for ocular dominance. These included pointing, alignment, hole test, Ascher and the Miles ABC test , which I used in my research. The authors argued that ocular dominance is a complex phenomenon which consists of three different types of ocular dominance: sighting, sensory, and acuity dominance (Coren and Kaplan 1973). In contrast, Brendan (2016) was skeptical that the phenomenon of ocular dominance could be clinically demonstrated, pointing out the lack of agreement between the various tests of ocular dominance. For example, there are inconsistencies in test results for the same individual which further complicate findings.

Most humans have a dominant eye, typically the right eye. Miles (1929) tested 172 grade school children. Of these, 61 % were right-eye dominant and only 22 % were left-eye dominant. The remaining 17% showed inconsistent or no dominance. Similarly, Heilman et al. (2002) found that right eye dominance is more common than left eye dominance in terms of demographics and Porac and Coren (1976) showed that right eye dominant individuals make up between 65% and 70% of the population.

It is generally believed that binocular vision is superior to monocular vision, even in the case of subjects using their dominant eyes. It is also known that fatigue under binocular and dominant eye monocular viewing conditions is less pronounced than in non-dominant monocular viewing conditions, and that subjects may perform better at tasks involving tracking moving objects with binocular vision as opposed to monocular vision (Madan, 1980). However, while past research suggests that performance in the dominant eye will surpass that of the non-dominant eye when ocular dominance is pronounced, it is still not totally understood how ocular dominance directly relates to visual processing, because performance can vary depending on the task at hand.

There is evidence that ocular dominance may have a genetic basis. Using a mathematical model, Annett (1999) suggested that genetically-linked asymmetry in humans may account for right-sidedness above the 50% that would be expected by chance. Similarly, Annett's results indicate a positive correlation between handedness and eye preference.

Ocular Dominance and Visual Motor Performance

Color vision may vary between dominant and non-dominant eyes. Color perception error scores were lower in dominant eyes vs non-dominant eyes for red/green discrimination. However, eye dominance had no effect on blue/yellow discrimination. Thus, when the subjects were using their dominant eyes, they were better able to perceive red/green color than with their non-dominant eyes. Ocular dominance displayed no effect on perception of blue/yellow colors (Altintas et al. 2016).

Critically important for visual orientation and balance are the phenomenon of saccades. Saccades are rapid eye movements that change a point of fixation quickly and abruptly (Augustine et al. 2001). In binocular tasks, subjects with more pronounced ocular dominance showed greater amplitude of saccades towards a target. Furthermore, performance was better for saccade target locations contralateral to the dominant eye (Tagu et al., 2016).

Lateral eye movements, which are a reaction to distracting stimuli, also vary with ocular dominance. In Borod et al.'s 1988 research on lateral eye movements and emotion, non-emotional tasks yielded right lateral eye movements in right eye dominant subjects, while the same non-emotional tasks yielded left lateral eye movements in left eye dominant individuals. For emotional tasks, no statistically significant difference was found between the two ocular dominance groups.

In humans, the dominant eye not only processes more information than the non-dominant eye, it may also inhibit perception of items arising from the non-dominant eye (Madan 1980; Shneor and Hochstein, 2006).

Hand-eye coordination relies on both ocular dominance and visual processing. Because hand-eye coordination is an important determinant of sports performance, much of the research literature on ocular dominance in sports is related to testing hand-eye coordination (Kirschen and Laby, 2011).

Ocular dominance can affect performance in sports. Frelich et al. (1995) compared the golfing success of two groups: cross dextral golfers (right-handed with left eye dominance) and pure dextral golfers (both right eye dominant and right-handed). The study concluded that pure dextral golfers have a statistically significant advantage over cross dextral golfers in putting accuracy (Frelich et al. 1995).

There is also evidence that ocular dominance may play a critical role in reaction time. Blouin et al. (2014) showed that the time required for cross and pure dextral subjects to press a button in response to a lateralized visual stimulus was faster for pure dextral subjects than their cross dextral counterparts (Blouin et al. 2014).

Spatial perception performances may also vary between left and right dominant subjects. Heilman et al. (2002) showed that right eye and left eye dominance groups may differ in spatial perception. Left eye dominant individuals exhibited a bias towards near space in their right visual fields and towards far space in their left visual fields. Another study also suggests a difference in spatial perception between right eye dominant and left eye dominant individuals by showing that right eye dominant subjects walking through a doorway shifted their position away from the center of that doorway when the right eye was covered. In contrast, left eye dominant individuals with left eye occlusion yielded a less significant result (Fujikake et al. 2014). Although there are conflicting results, previous research has demonstrated that the dominant eye can be superior to the non-dominant eye for diverse visual and motor tasks. However, there is no evidence that eye dominance influences visual memory and arithmetic processing.

Development

Research has shown that in mammals, ocular dominance develops early in life (Kandel et al., 2013). Ocular dominance cannot be inhibited or changed after a specific critical period early in a mammal's development. In mice, as in cats and monkeys, closure of an eye during the critical period for ocular dominance markedly shifts the preference of binocular neurons to inputs from the contralateral eye. Closure before or after the time of this normal critical period, however, fails to alter the preference of the neurons. Furthermore, performance in ocular dominance cannot be changed in adults by monocular occlusion (Kandel et al. 2013). It is also known that subjects will tend to perform better at visual tasks with binocular vision even after monocular occlusion has been introduced for a period of up to 5 days (Sheedy et al. 1986).

Specific Aim

Given the lack of research of the effects eye dominance has on visual memory and simple analytic processing, the primary objective of this study was to determine if ocular dominance influenced performance on four different computer gaming tasks. This goal was achieved by comparing the performance in four Lumosity games which relied on different aspects of visual memory and analytic processing for three visual conditions: dominant eye, non-dominant eye, and binocular vision.

VII. Methodology

Approvals

Institutional Review Board (IRB) approval was received on November 3, 2016. Permission was obtained from Lumos Labs, Inc. (San Francisco, California) on November 4, 2016 to use specific games featured on the website www.lumosity.com. Participants recruited were required to sign a consent form previously approved by the Institutional Review Board (IRB) at James Madison University.

Participants

Undergraduate participants (n = 20) from James Madison University were recruited by either myself or a teacher reading a standard blurb during Science, Technology, Engineering, and Mathematics (STEM) classes and during a meeting of the math club. Solicitation of acquaintances was also used for recruitment. The time of day in which students participated in the experiment varied due to school conflicts. All participants were above 18 years of age and ranged from 18 to 26 years of age. All but one subject showed left or right eye dominance.

Determining ocular dominance

To determine subjects' ocular dominance, the Miles Test for Ocular Dominance (Miles, 1929) was used, which consists of a subject forming an aperture with their hands and then being asked to focus their attention on an object, in this case either a red or green target on a whiteboard placed 2.5 meters from the subject. The object the subject focuses on is not as relevant as their distance away from the object. The subject was then asked to close one eye at a time to report in which eye the object shifted. If the subject reported a shift of the object in their left eye, then that subject was classified as right-eye dominant. If the subject reported a shift of the object in their right eye, then that subject was classified as left-eye dominant. If the subject reported no shift of the object in either eye, that subject was classified as having no eye dominance.

Measuring mental processing ability

All tests of visual mental processing ability used the Lumosity program. After eye dominance was recorded, the participants were subjected to four different Lumosity games that tested different abilities within mental processing. The four games were: Raindrops, Disillusion, Chalkboard Challenge, and Memory Matrix. All subjects participated in the games in this order respectively. Before testing in a specific game began, all subjects were asked to participate in a practice session of the game in which they were being examined to acquaint the subject with the rules and play of the game. The practice session was similar to the actual tests but the subject had both eyes open. The practice session lasted as long as the scored session. No data was recorded during this practice session. The practice session for game 4 was designed to determine at what level the subject should start the game. An eye patch was used to examine visual mental processing ability in a specific eye. All subjects were asked to play each of the four games with their right eye covered, their left eye covered, and with both eyes open. The sequence in which eyes were covered was randomized for each game.

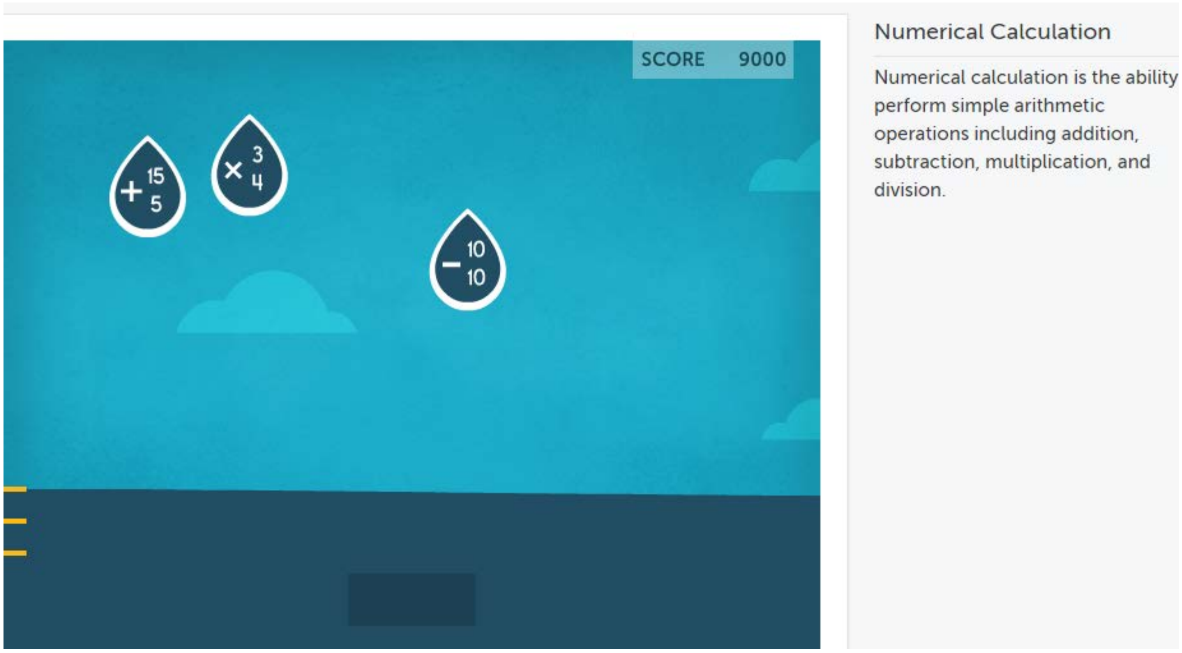


Figure 1. This is a representation of what subjects were expected to accomplish in the game: Raindrops. The 3 yellow bars on the left of the screen indicate that the subject has used up all of their strikes and the number in the top right corner of the screen indicates the subject's score. The bottom middle bar on the screen is where the subject's number input is. Specific scores such as accuracy or total problems solved are shown after the trial is complete.

The first game the subjects were asked to play was Raindrops, which is focused on basic arithmetic ability (Fig. 1). The objective of this game is to complete basic arithmetic questions inside of raindrops before they dropped to the bottom of the screen. Subjects had a sufficient amount of time to play this game until the "raindrops" reached the bottom of the screen three times. However, the experimenter requested them to stop if the subjects exceeded the time limit permitted by the IRB. A maximum of 5 minutes was allowed for each trial. The difficulty of the game progressed as the subjects completed more arithmetic questions. Therefore, the experimenter was never required to ask the subjects to cease playing the game due to its sheer difficulty in later stages. The total number of questions answered correctly in each trial, the time it took for the subject to complete each trial, and the accuracy of the subject in each trial were all recorded.

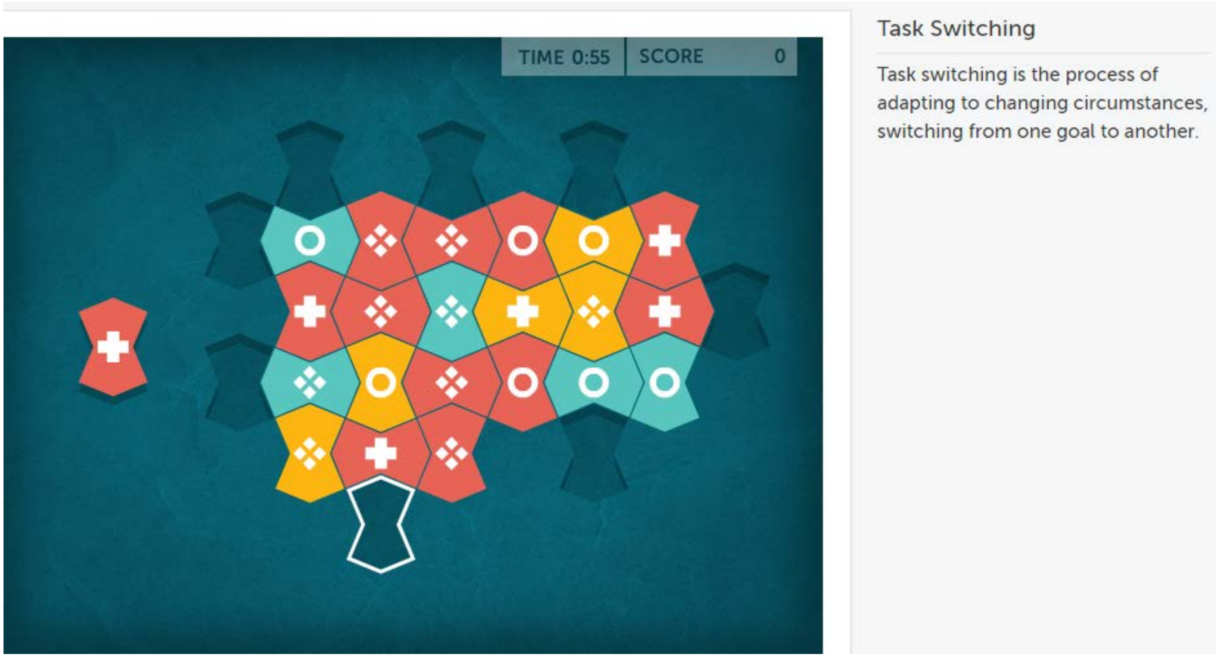


Figure 2. This is a representation of what subjects are expected to accomplish in the game Disillusion. The time and score are indicated in the upper right hand corner of the screen.

The second game that subjects were asked to play was Disillusion, which is focused on subject's ability to visually process and change tasks within a set time (Fig. 2). Subjects have 60 seconds to complete this game but may be able to complete the game in less time than they were allotted. The objective of this game is to match puzzle pieces to a board based on the color of the symbol within the puzzle piece if the puzzle piece was vertical and based on the shape of that symbol within the puzzle piece if the puzzle piece was horizontal. The subjects effectively clear pieces on the board when they match them to the appropriate puzzle piece(s) on the board. This process is repeated four times with four different boards until the subject clears all the puzzle pieces on each board. If the subject matches the puzzle piece with an incorrect piece on the board there would be a delay in time between boards and a delay for the space in which the subject selected the incorrect piece. Subjects could clear as many as three puzzle pieces at a time as long as all of the pieces matched the appropriate color or shape of the symbol depending on alignment of the puzzle piece they were given (vertical or horizontal). The total number of pieces correctly matched on each trial and amount of time taken for each respective trial were recorded.

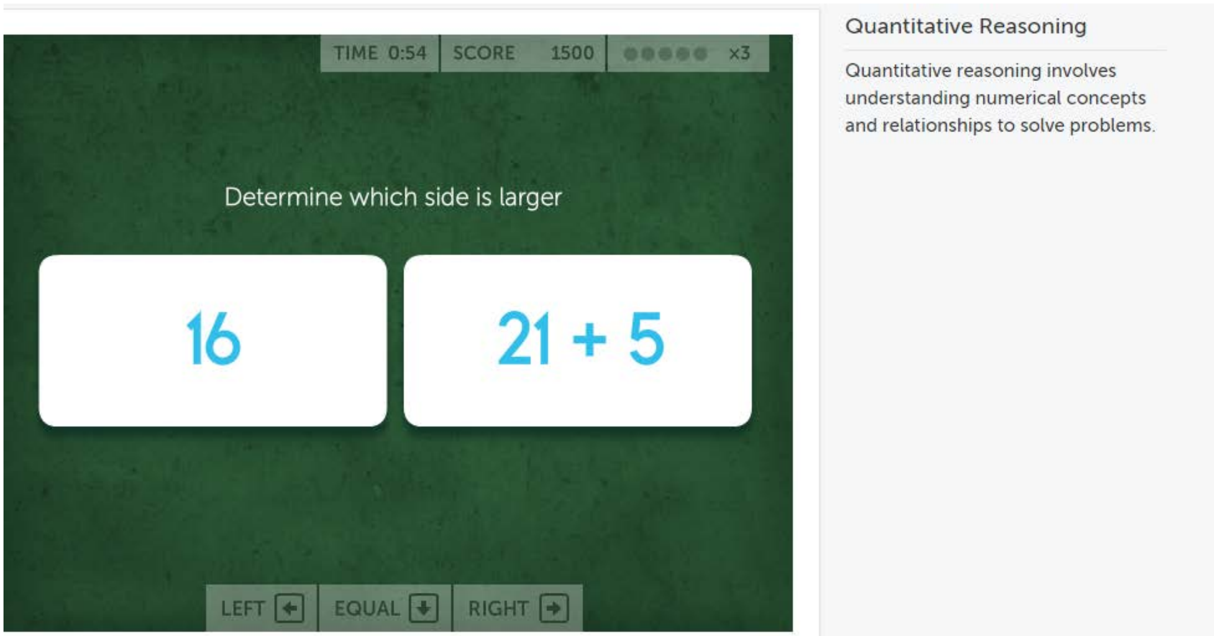


Figure 3. This is a representation of what subjects are expected to accomplish in the game Chalkboard Challenge. The arrow keys are indicated at the bottom of the screen and where the time left, score, and multiplier for score (level) are all indicated in the upper right corner of the screen. The two quantities that the subject is expected to identify as greater than, less than, or equal to are located in the center of the screen.

The third game subjects were asked to play was Chalkboard Challenge, which is also focused on basic arithmetic ability but may additionally test the subject's field of vision (Fig. 3). The objective of this game is to indicate which of two basic mathematical quantities was greater using only the left, right, and down arrow keys on the subject's keyboard. Respectively, the left arrow key indicates that the left quantity is larger, the right arrow key indicates that the right quantity is larger, and the down arrow key indicates that both quantities are equal. The subjects begin with a time of 50 seconds to complete the questions presented. Like the Raindrops game described earlier, Chalkboard Challenge increases in arithmetic complexity as the subjects progressed. The difference is, that unlike Raindrops, the actual complexity of the mathematical quantities in Chalkboard Challenge increases instead of the amount of questions presented or the speed at which they were expected to be answered. For every 5 quantities that subjects correctly classified as greater or equal, the questions increased in difficulty and ten seconds is added to the subjects' time. If the subjects identify the quantities incorrectly, 3 seconds are deduced from the subject's time left. The total number of correctly identified quantities for each trial, the time the subject takes for each trial, and the accuracy of the subjects during each trial were recorded for this game.

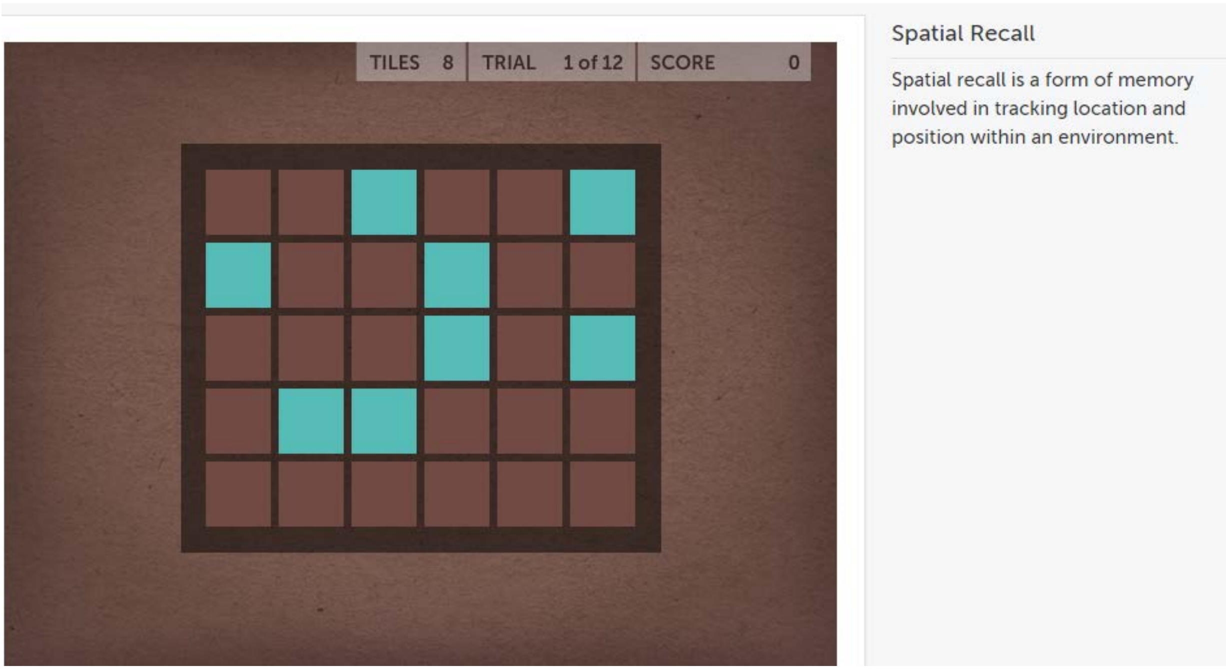


Figure 4. This is a representation of what subjects are expected to memorize in the game Memory Matrix where the blue tiles represent what the subject is expected to memorize and where the number of tiles shown, the trial, and the score are all represented in the top right hand corner of the screen.

The last game that subjects were asked to play was Memory Matrix, which focuses entirely on the subjects' ability to process and remember a pattern of tiles (Fig. 4). The objective of this game is to memorize a pattern of tiles in roughly one second and then match the tiles on a board exactly as they had been presented. The game increases in difficulty after every two boards the subject memorizes entirely. With each tier in difficulty the game adds an additional tile for the subject to memorize. The game begin with three tiles for the subjects to memorize but then changes depending on how well the subjects perform in prior trials. This made a practice session compulsory as the practice session sets the difficulty of the initial board. If the subjects do not match every tile on the board exactly as it was shown to them, then the game will not add additional points to the subjects score. The game will also not increase in difficulty if the subjects make an error. If the subject fails to memorize all the tiles presented for 2 trials in a row, then the game decreases in difficulty by removing a tile which the subject needs to memorize. The game requires the subject to complete 12 of these trials per game, meaning that the subjects attempted to memorize a total of 48 boards throughout the course of the experiment. The first 12 boards were part of the practice tests and the other 36 were divided between testing with the left eye, the right eye, and both eyes. The subjects' score for each set of 12 trials as indicated by Lumosity, the subject's "best board" on all 12 trials, and the total time the subject takes for each set of 12 trials was recorded for this game.

Data Analysis

As there was a non-normal skewing of scores on all tests, box and whisker plots were used to plot the data (Fig. 5A-8B). Boxplots show the median, 25th and 75th percentiles and 5th and 95th percentiles, as well all individual data points. The non-parametric Friedman Repeated Analysis Measures on Ranks was used for inferential testing in all tests in all four games because of the within-subject design and non-normal distribution of scores. An α of 0.05 was used as the criterion for significance. Data was managed in Microsoft Excel, and statistics and graphics computed in Systat Sigmaplot. For complete data see Appendix.

VIII. Results

The purpose of this study was to determine whether there was a relationship between ocular dominance and visual processing. Subjects with ocular dominance (n=19) performed four different games: Raindrops, Disillusion, Chalkboard Challenge, and Memory Matrix which were played under three conditions: left eye closed, right eye closed, and both eyes open. Ocular dominance was split almost equally divided between the subjects with 9 having left eye dominance and 10 having right eye dominance

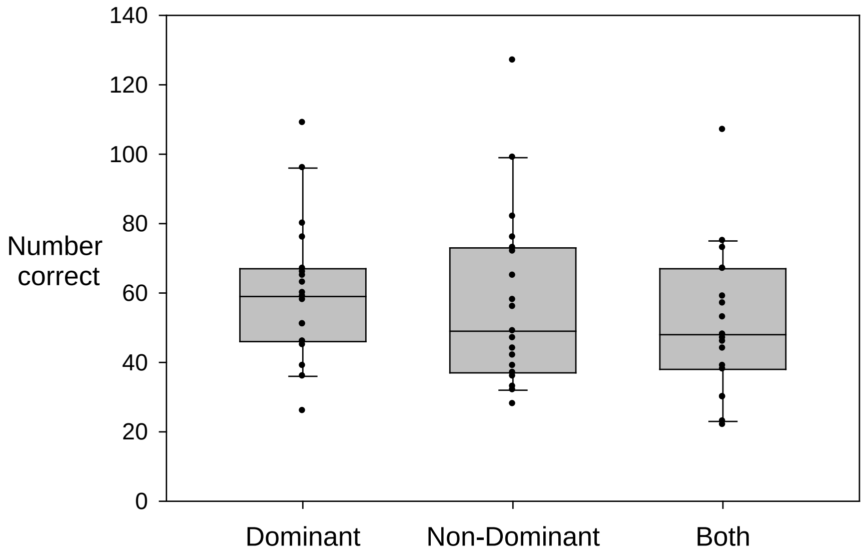
The first game evaluated was Raindrops, which measured the visual arithmetic ability of the subjects. Figure 5A shows that the total number of correct responses was significantly affected by eye group ($P=0.01$, Friedman) and that the scores were greater for the dominant eye compared to the non-dominant eye ($P<0.05$, Tukey) but not both eyes. However, accuracy in the Raindrops game (Figure 5B) was not significantly affected by eye group.

The second game evaluated was Disillusion, which measured the subjects' ability to visually switch tasks. The subjects switched tasks by matching changing puzzle pieces to a board. Figure 6 shows that the number of correctly matched puzzle pieces was not significantly affected by eye group ($P=0.90$, Friedman).

The third game evaluated was Chalkboard Challenge which also measured visual arithmetic ability of the subjects. Figure 7A reveals that the number of correctly identified greater quantities was not affected by eye group ($P=0.99$, Friedman). Figure 7B displays that the accuracy in terms of correctly identified greater quantities was also not affected by eye group ($P=0.85$, Friedman).

The fourth game evaluated was Memory Matrix which measured the subjects' capacity to remember quantities of tiles in various patterns. Figure 8A shows that the subjects' best board, or largest quantity of memorized tiles in a single trial, was not affected by eye group (P=0.17, Friedman). Figure 8B shows that the subjects' scores as indicated by the Lumosity interface was also not affected by eye group (P=0.85, Friedman).

In order to determine whether the sample size was adequate to reveal differences between eye groups, a power analysis was performed for all four games. The powers of the four games were 0.048, 0.048, 0.048 and 0.17, which were less than the typically desired 0.8.



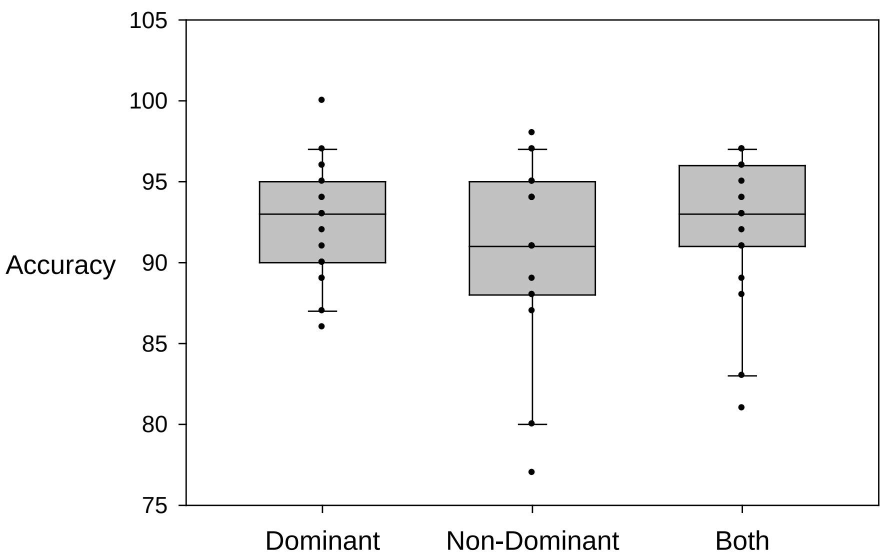


Figure 5. Two box and whisker plots display both the number correct and accuracy for subjects' dominant eyes, non-dominant eyes, and both of their eyes on game 1: Raindrops. Statistical analysis for both number correct (A) and accuracy (B) used a sample size N = 19. The dominant eye yielded a median of 59 correct, a lower quartile of 46 correct, and an upper quartile of 67 correct. The non-dominant eye yielded a median of 49 correct, a lower quartile of 38 correct, and an upper quartile of 73 correct. Data from both eyes yielded a median of 48 correct, a lower quartile of 38 correct, and an upper quartile of 65 correct. The Chi-Squared value = 8.41 with 2 degrees of freedom and P = 0.015 indicated that the differences in the median values among the treatment groups were greater than would be expected by chance. A post-hoc Tukey test revealed that the median score for the dominant eye was greater than for the non-dominant eye ($P<0.05$) but not both eyes. (B) The dominant eye yielded a median of 93%, a lower quartile of 90%, and an upper quartile of 95%. The non-dominant eye yielded a median of 92%, a lower quartile of 87%, and an upper quartile of 95%. The data from both eyes yielded a median of 94%, a lower quartile of 92%, and an upper quartile of 96%. There was no statistically significant difference as P = 0.45. The power of the performed test was 0.049.

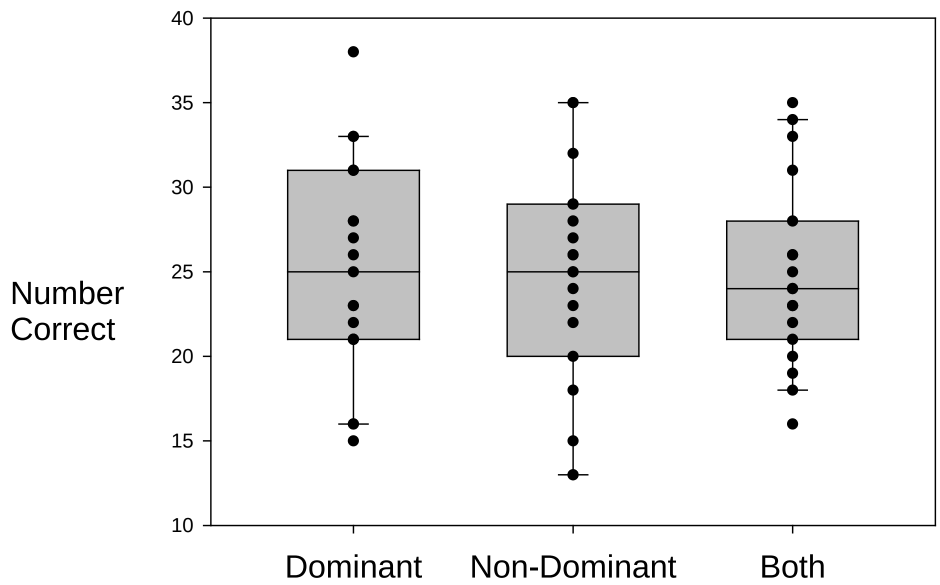


Figure 6. A box and whisker plot of the subjects' number correct in their dominant eye, non-dominant eye, and both of their eyes for game 2: Disillusion. Statistical analysis for the number correct used a sample size of N = 19. The dominant eye yielded a median of 25 correct, a lower quartile of 22 correct, and an upper quartile of 31 correct. The non-dominant eye yielded a median of 25 correct, a lower quartile of 19 correct, and an upper quartile of 28 correct. Data from both eyes yielded a median of 24 correct, a lower quartile of 22 correct, and a upper quartile of 28 correct. There was no statistically significant difference as P = 0.90. The power of the performed test was 0.049.

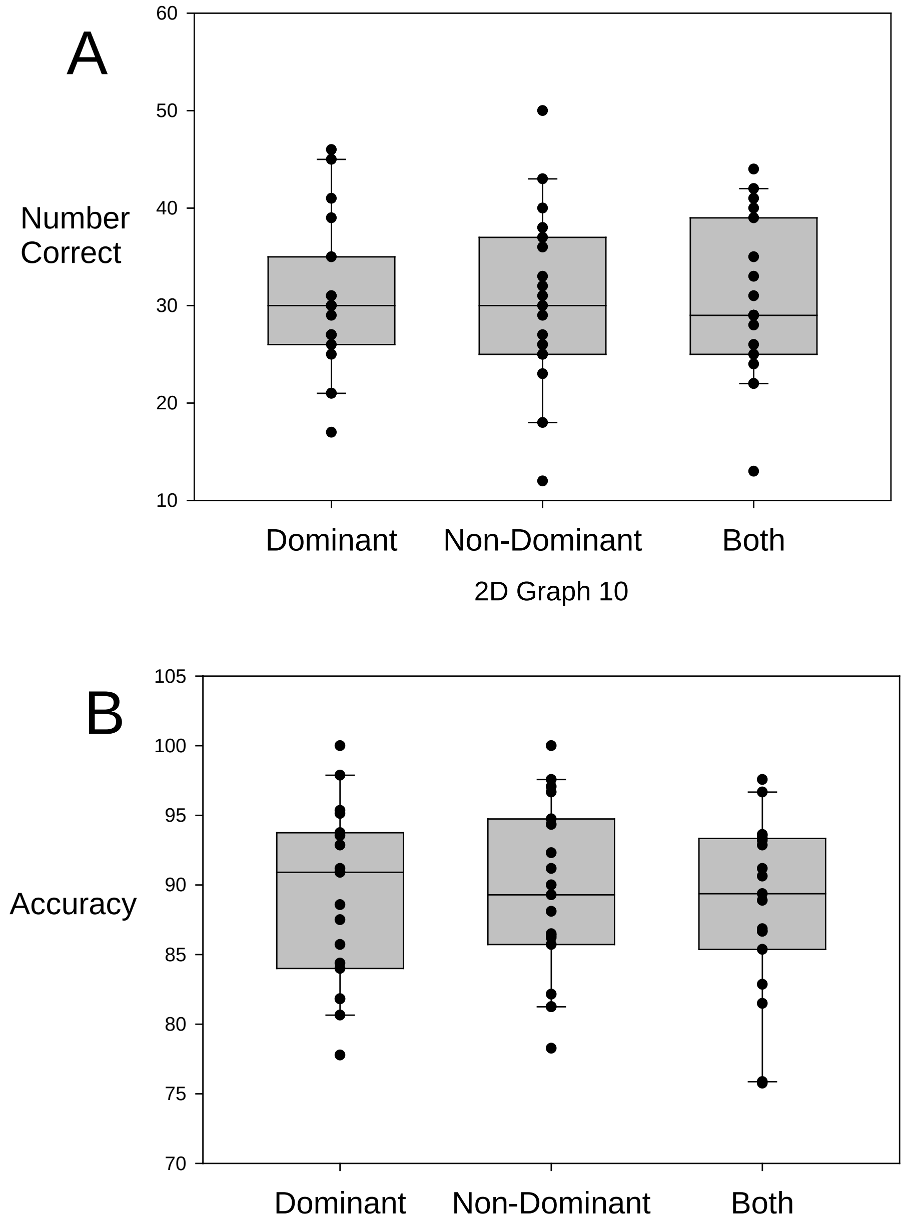


Figure 7. Two box and whisker plots which display both the number correct and accuracy for subjects' dominant eyes, non-dominant eyes, and both of their eyes for game 3: Chalkboard Challenge. Statistical Analysis for both number correct (A) and accuracy (B) used a sample size of N = 19. The dominant eye yielded a median of 30 correct, a lower quartile of 26 correct, and an upper quartile of 35 correct. The non-dominant eye yielded a median of 30 correct, a lower quartile of 25 correct, and an upper quartile of 38 correct. Data from both eyes yielded a median of 28 correct, a lower quartile of 25 correct, and an upper quartile of 40 correct. There was no statistically significant difference as P = 0.99. The power of the performed test was 0.049. (B) The dominant eye yielded median of 91%, a lower quartile of 84%, and an upper quartile of 94%. The non-dominant eye yielded a median of 88%, a lower quartile of 86%, and a upper quartile of 94%. The data from both eyes yielded a median of 88%, a lower quartile of 85%, and an upper quartile of 93%. There was no statistically significant difference as P = 0.85. The power of the performed test was 0.049.

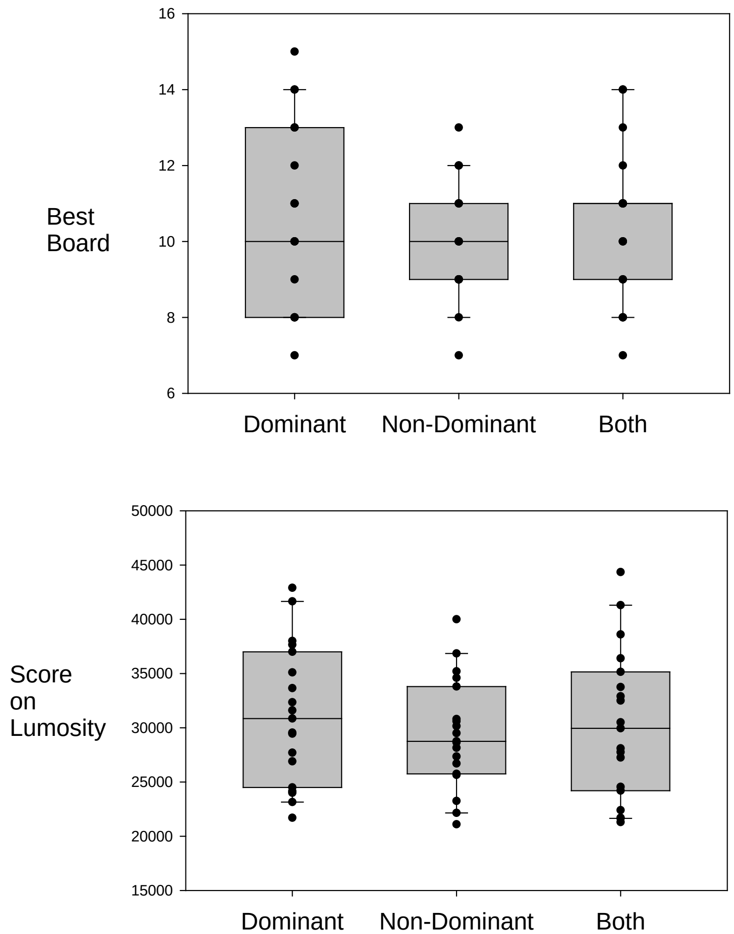


Figure 8. Two box and whisker plots which display both the best board and score on Lumosity for subjects' dominant eyes, non-dominant eyes, and both of their eyes for game 4: Memory Matrix. Statistical analysis for both best board and score on Lumosity used a sample size of N = 19. The average best board for the dominant eyes yielded a median of 10 tiles, a lower quartile of 8 tiles, and an upper quartile of 13 tiles. The non-dominant eye yielded a median of 10 tiles, a lower quartile of 9 tiles, and an upper quartile of 13 tiles. Both eyes yielded a median of 10 tiles, a lower quartile of 9 tiles, and an upper quartile of 13 tiles. There was no statistically significant difference as P = 0.17. The power of the performed test was 0.071. The dominant eyes yielded a median score of 31000, a lower quartile of 24000, and an upper quartile of 37500. The non-dominant eye yielded a median score of 28000, a lower quartile of 26000, and an upper quartile of 33500. Both eyes yielded a median of 30000, a lower quartile of 24500, and an upper quartile of 34500. There was no statistically significant difference as P = 0.32. The power of the performed test was 0.072.

IX. Discussion

Summary

The goal of this project was to determine whether subjects that used only their dominant eye in computer games scored differently than when those same subjects that only used their non-dominant eye or both eyes. Across all four games, in only one game did subjects score better with their dominant eye than with their non-dominant eye. In the Raindrops game, which tested simple arithmetic ability, subjects using their dominant eye scored significantly higher than subjects using their non-dominant eye but the same as subjects using both eyes. In contrast, the type of eye group was not significant in the other three games which tested complex arithmetic ability, task switching and memory. This suggests ocular dominance may preferentially benefit simple arithmetic visual tasks. However, low power suggests a greater sample size may have been needed to detect differences in the other three games.

Comparisons with Previous Studies

Previous studies have shown mixed effects of ocular dominance on performance. While research across sports (Frelich et al. 1995), visual perception and eye movement have revealed effects of eye dominance, other similar studies (Kirschen and Laby, 2011) have shown little evidence of the effect of ocular dominance on their examinations. Similarly, my results, have shown that ocular dominance had little effect on subject's performance on most, but not all, of the Lumosity games.

Interestingly, most previous studies assessed the role of dominance or non-dominance performance indirectly. My studies directly assessed the role of ocular dominance on task performance. One study conducted by Hochstein and Shneor in 2006 did directly test the effects of ocular dominance on performance in a feature search where subjects would be given a visual target to look at and distractor targets designed to distract their visual attention. Better performance was measured by the number of times the subjects detected the distractor stimulus. In their experiment, it was found that dominant eyes detected more distractors than non-dominant eyes. The only test in my experiments comparable with Hochstein and Shneor's experiment was the 2nd game: Disillusion. Disillusion primarily measures the subject's ability to switch tasks but also tests the subjects' ability to search for targets. Similarly, Hochstein and Shneor's experiment focused on the relationship between ocular dominance and target searching specifically. It is likely that the game: Disillusion was too complex a task to measure the effects of ocular dominance as subjects were making decisions in addition to target searching.

Finally, in previous studies (Miles, 1929), right eye dominance was exhibited to be more prevalent than left eye dominance by a ratio of roughly 2:1, respectively. In my study, right eye and left eye dominance ratios was roughly 1:1, however, several of the left eye dominant subjects claimed to have some sort of trauma to their right eye during childhood.

Physiological Mechanisms

My results, for one task, showed the dominant eye scored better than the non-dominant eye. Visual input stays separate through the lateral geniculate primary visual cortex. The ocular dominance column is evidence that two separate paths could receive preferential processing.

Preferential processing may correlate with cerebral lateralization. Many studies insinuated that this was a possible explanation of the outcomes. However, in my experiment there was no evidence that cerebral lateralization can flip for left and right ocular dominant individuals because most games showed no significant difference between groups. One possibility is that dominance correlates to cerebral lateralization (Choi et al. 2016). This is unlikely because the percentage of left eye and right eye dominance individuals was approximately the same.

Even though there is physiological evidence of ocular dominance columns, it did not appear to manifest itself in this visual processing experiment. It is possible that the brain compensates in visual processing experiments for eye dominance. This may be due to the interhemispheric connections of the corpus callosum. The corpus callosum may be responsible for this compensation in tasks between the different eyes. The semi-decussation of the optic chiasm may also play a role in the interhemispheric transfer of information to compensate for the monocular tasks.

X. Literature Cited

Annett M (1999) Eye Dominance in Families Predicted by the Right Shift Theory, Laterality: Asymmetries of Body, Brain and Cognition 4: 167-172.

Augustine GJ, Fitzpatrick D, Purves D (2001) Neuroscience (2nd ed). Sunderland, MA: Sinauer Associates.

Altintas AK, Gundogan NU, Koctekin BS (2016) The relationship between color vision discrimination ability and depth perception among university students. International Eye Science 16: 1412-1418.

Bear MF, Connors BW, Paradiso MA (2016) Neuroscience Exploring the Brain (4th ed). Philadelphia, PA: Wolters Kluwer.

Blouin J, Chamillon R, Guillame A (2014) Eye dominance influences triggering action: The Poffenberger paradigm revisited. Cortex 58: 86-98.

Borod JC, Cytryn F, Vingiano W (1988) The Effects of Emotion And Ocular Dominance on Lateral Eye Movement. Neuropsychologia 26: 213-220.

Brenden B (2016) The Importance and Relevance of Eye Dominance. Optometry Today 56:70-74.

Choi JA, Kim JS, Jeong HJ, Lee JA, Park CK (2016) Ocular dominance is associated with the ganglion cell-inner plexiform layer thickness profile in the macula. PLoS ONE 11: 15-35.

Coren S, Kaplan CP (1973) Patterns of Ocular Dominance. American Journal of Optometry and Archives of American Academy of Optometry 50: 283-292.

Frehlich FG, Steinberg GM, Tennant LK (1995) Dextrality and Eye Position in Putting Performance. Perceptual and Motor Skills 80: 635-640.

Fujikake H, Higuchi T, Kitayama S, Kokubu M (2014) The Relationship Between Spatial Cognition and Walking Trajectory for Passing Through a Doorway: Evident in Individuals with Dominant Right Eye? Experimental Brain Research 233: 797-807.

Gazzaniga MS, Ivry RB, Mangun GR (2002) Cognitive Neuroscience – The Biology of the Mind (2nd ed). New York, NY: Norton & Company.

Kandel ER, Schwartz JH, Jessell TM, Siegelbaum SA and Hudspeth, AJ (eds) (2013) Principles of Neural Science (5th ed). New York, NY: McGraw Hill Medical.

Heilman KM, Lora AN, Roth HL (2002) Effects of monocular viewing and eye dominance on spatial attention. Brain: Journal of Neurobiology 125: 2023-2035.

Hochstein S, Shneor E (2006) Eye dominance effects in feature search. Vision Research 46: 4258-4269.

Keller JB, Miller KD, Stryker MP (1989) Ocular dominance column development: analysis and simulation. Science 245: 605-615.

Kirschen DG, Laby DM (2011) Thoughts On Ocular Dominance-Is It Actually A Preference? Eye and Contact Lens 37: 140-144.

Kolb H (2007) Anatomy and physiology of the retina. In: Webvision, the organization of the retina and visual system (Kolb H, Nelson R, Fernandez E and Jones B, eds). Salt Lake City, UT: University of Utah Health and Sciences Center.

Llaurens V, Raymond M, and Faurie C (2009) Why are some people left handed? An evolutionary perspective. Philosophical Transactions of the Royal Society B 364: 881-894.

Madan L (1980) Comparison of performance on a tracking task utilizing binocular, dominant and non-dominant viewing, pp1-70. Monterey, CA: Naval Postgraduate School Institutional Archive.

Miles, WR (1929) Ocular dominance demonstrated by unconscious sighting. Journal of Experimental Psychology 12:113-126.

Porac C, and Coren S (1976) The dominant eye. Psychological Bulletin 83:880 - 897.

Shneor E and Hochstein S (2006) Eye dominance effects in feature search. Vision Research 46:4258-4269.

Sheedy JE, Bailey IL, Buri M, and Bass E (1986) Binocular vs. monocular task performance. American Journal of Optometry Physiological Optics 63:839-846.

Tagu J, Doré-Mazars K, Lemoine-Lardennois C, and Vergilino-Perez D (2016) How eye dominance strength modulates the influence of a distractor on saccade accuracy.| ARVO Journals 57: 534-543.

XI. Appendix

Table 1. Data for game 1: Raindrops

		left			right			both			
Subject #	Male or Female	# correct	Time (seconds)	Accuracy	# correct	Time (seconds)	Accuracy	# correct	Time (seconds)	Accuracy	Eye Dominance
1	Female	46	114.06	93	44	126	91	30	67.45	88	left
2	Female	45	50.98	93	28	51.9	77	23	47.11	91	left
3	Male	36	131.55	87	32	108.55	88	22	84.35	81	left
4	Female	59	114.35	93	36	88.04	87	57	112.07	93	left
5	Female	46	112.79	90	42	112.87	91	44	98	93	left
6	Male	51	109.62	89	56	109.72	94	39	79.14	91	left
7	Female	26	66.7	86	37	100.52	80	30	92.49	83	left
8	Female	66	106.46	97	49	88.33	98	73	112.43	97	left
9	Female	60	115.9	100	72	143.06	94	38	78.96	95	left
10	Female	58	130.05	89	65	118.52	94	48	109.07	94	left
1	Male	99	126.39	95	109	144.66	94	107	136.59	97	right
2	Male	76	117.05	91	76	112.93	91	59	104.3	89	right
3	Male	39	91.64	88	39	73.42	90	53	106.81	96	right
4	Male	73	174.8	91	80	174.09	96	67	168.54	91	right
5	Male	82	115.48	97	96	141.11	96	67	93.83	94	right
6	Male	33	100.38	89	63	133.73	95	46	95.61	93	right
7	Male	127	25	94	67	27	90	75	31	92	right
8	Female	47	109.39	95	51	131.19	94	47	106.2	97	right
9	Male	58	130.05	97	65	118.52	92	48	109.07	96	right
1	Female	36	84.98	85	50	110.88	89	39	88.45	84	neither

Table 2. Data for game 2: Disillusion

		Left			Right			Both			
Subject #	Male or Female	# correct	Time (seconds)		# correct	Time (seconds)		# correct	Time (seconds)		Eye Dominance
1	Female	28	55.07		25	56.28		19	47		left
2	Male	28	59		29	50.52		34	54.17		left
3	Male	22	57.06		29	56.24		16	60		left
4	Female	33	50.98		28	51.9		23	47.11		left
5	Male	21	53.72		15	39.71		22	60		left
6	Male	33	55		35	57		28	59.96		left
7	Male	23	60		22	60		35	60		left
8	Male	15	57.14		13	60		18	60		left
9	Female	31	60		26	60		26	60		left
10	Female	25	56.8		23	60		23	50.09		left
1	Male	35	60		38	55.58		25	52.16		right
2	Male	25	50.12		27	60		31	60		right
3	Female	13	52.82		16	49.23		24	54.22		right
4	Male	24	52.35		23	58.64		21	48.99		right
5	Female	32	60		21	57.61		33	56.28		right
6	Female	18	42.05		26	57.53		23	60		right
7	Female	20	52.87		16	49.2		20	58.08		right
8	Female	27	58.58		21	47.49		24	60		right
9	Male	26	57.86		31	57.15		26	46.8		right
1	Female	21	53.74		25	60		24	55.64		neither

Table 3. Data for game 3: Chalkboard Challenge

		Left Eye			Right Eye			Both Eyes			
Subject #	Male or Female	# correct	Time (seconds)	Accuracy	# correct	Time (seconds)	Accuracy	# correct	Time (seconds)	Accuracy	Dominance
1	Female	25	85.85	80.6451613	26	73.66	81.25	22	60.39	75.86207	left
2	Female	30	85.5	85.7142857	32	85.81	86.4864865	35	93.01	85.36585	left
3	Male	17	80.05	100	12	67.39	92.3076923	13	64.33	86.66667	left
4	Female	26	84.62	92.8571429	29	93.75	96.6666667	29	93.71	96.66667	left
5	Female	21	68.68	84	25	81.8	89.2857143	29	94.07	93.54839	left
6	Male	27	76.06	81.8181818	25	78.7	86.2068966	42	120.55	89.3617	left
7	Female	30	90.58	90.9090909	18	55.65	78.2608696	22	66.41	81.48148	left
8	Female	39	114.62	95.1219512	43	122.19	100	39	115.67	92.85714	left
9	Female	27	83.16	81.8181818	30	85.98	85.7142857	29	96.56	90.625	left
10	Female	31	94.27	91.1764706	33	103.96	97.0588235	24	81.76	88.88889	left
1	Male	50	134.36	94.3396226	45	125.64	93.75	41	111.87	93.18182	right
2	Male	26	73.15	81.25	27	75.59	84.375	25	58	75.75758	right
3	Male	27	71.66	90	29	94.13	93.5483871	26	73.38	86.66667	right
4	Male	40	117.78	97.5609756	35	95.76	87.5	29	84.67	82.85714	right
5	Male	38	93.43	86.3636364	41	114.93	95.3488372	40	117.22	97.56098	right
6	Male	31	91.56	91.1764706	31	89.61	88.5714286	33	85.78	86.84211	right
7	Male	37	101.87	88.0952381	46	137.4	97.8723404	44	123.7	93.61702	right
8	Female	23	75.85	82.1428571	21	72.74	77.7777778	28	95.55	93.33333	right
9	Male	36	114.98	94.7368421	30	92.22	90.9090909	31	91.79	91.17647	right
1	Female	24	64.52	80	31	96.2	91.1764706	25	72.84	80.64516	neither

Table 4. Data for game 4: Memory Matrix

		Left Eyes			Right Eyes			Both Eyes			
Subject #	Male or Female	Best Board	Score	Time (seconds)	Best Board	Score	Time (seconds)	Best Board	Score	Time (seconds)	Dominance
1	Female	8	24500	120	9	23250	149.85	11	27250	114.26	left
2	Female	14	37650	144.19	12	35200	144.42	11	29950	122.9	left
3	Male	7	23150	164.74	8	22150	165.73	8	21700	171.38	left
4	Female	10	27700	231.96	11	33800	211.21	10	28100	220.46	left
5	Female	11	30850	181.73	9	27350	172.83	11	32900	183.03	left
6	Male	10	29450	157.17	9	28150	159.17	11	32500	136.96	left
7	Female	8	24000	126.48	9	25650	146	8	24200	137.55	left
8	Female	12	35100	183.3	12	36850	172.07	14	41300	178.89	left
9	Female	13	37000	187.46	11	34600	169.74	13	38600	165.31	left
10	Female	8	21700	141.45	7	21100	145.81	9	24550	134.45	left
1	Male	11	30150	126.48	15	42900	161.75	14	44350	158.46	right
2	Male	10	28750	123.62	11	31600	134.96	8	21300	107.36	right
3	Male	9	26700	148.77	9	26900	130.76	7	21650	130.68	right
4	Male	9	29500	150.97	10	32350	153.52	11	35150	149.43	right
5	Male	10	30800	143.95	13	38000	165.27	10	30500	145.78	right
6	Male	9	25750	150.2	8	24150	129.59	9	22400	139.13	right
7	Male	10	30600	161.04	14	41650	158.24	11	33750	169.85	right
8	Female	10	28650	146.08	10	29550	154.45	10	27750	146.62	right
9	Male	13	40000	146.44	11	33650	148.9	12	36400	147.05	right
1	Female	8	24000	121.43	9	25650	146	8	25050	137.55	neither