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The Relationship Between Ocular Sensory Dominance and Stereopsis

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A thesis submitted to the College of Optometry
Of
Nova Southeastern University
In partial fulfillment of the requirements
For the Degree of
Master of Science in Clinical Vision Research

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Abstract

Purpose: It is unknown whether individuals with two balanced eyes show quicker response and lower threshold in fine stereoscopic detection. Previous methods to measure ocular dominance were primarily qualitative, which do not quantify the degree of dominance and show limitation in identifying the dominant eye. In this study, we aimed at quantifying the difference of ocular strength between the two eyes with ocular dominance index (ODI) and studying the association of ocular balance between the two eyes with stereoscopic detection.

Methods: Stereoscopic threshold was measured in thirty-three subjects. Stereopsis was measured with random dot stimuli. The minimal detectable disparity (D_{min}) and the minimal time needed to acquire the best stereoacuity (T_{min}) were quantified. Ocular dominance was measured by a continuous flashing technique with the tested eye viewing a titled Gabor patch increasing in contrast and the fellow non-tested eye viewing a Mondrian noise decreasing in contrast. The log ratio of Mondrian to Gabor's contrasts was recorded when a subject just detected the tilting direction of the Gabor during each trial. The t-value derived from a t-test of the 50 values obtained in each eye was used to determine a subject's ODI (ocular dominance index) to quantify the degree of ocular dominance. A subject with ODI ≥ 2 ($p < 0.05$) was defined to have clear dominance and the eye with larger mean ratio was the dominant eye.

Results: The D_{min} (55.40 arcsec) in subjects with two balanced eyes were not significantly different from the D_{min} (43.29 arcsec) in subjects with clear ocular dominance ($p = 0.87$). Subjects with two balanced eyes had significantly ($p = 0.01$) shorter reaction times on average (T_{min} = 138.28 msec) compared to subjects with clear dominance (T_{min} = 1229.02 msec). T_{min}

values were highly correlated with ocular dominance (p = 0.0004).

Conclusion: Subjects with two relatively balanced eyes take shorter reaction time to achieve optimal level of stereoacuity.

Keywords: Ocular Dominance, Local Stereopsis, Binocular, Balanced Eyes, Anisometropia

Chapter 1: Background

1.1 *Binocular Vision*

Binocular vision involves the use of two eyes to focus on an object or point simultaneously to perceive a single image. Depth perception problems and trouble with effectively judging distances can occur if the two eyes are unable to coordinate together [5-6]. There are three levels of binocular visual processing which are simultaneous perception, fusion, and stereopsis. Efficient binocular vision can be achieved through the benefits of the three visual processing levels, which is unlikely to obtain with monocular viewing only [9]. With binocular vision, a greater visual field, compensating for blind spots, and easing mobility can be achieved [9]. Among the three levels of binocular vision, stereopsis allows the ability to detect size, distances, and speed more precisely [1-3]. Conversely, simultaneous perception gives the ability to view two images from two eyes at the same time [38]. Although each level has separate neurophysiologic phenomena, they work together during cortical processing when images are simultaneously projected onto each retina [25].

1.2 *Simultaneous Perception*

The first level of binocular vision is simultaneous perception where two dissimilar images are simultaneously formed on each retina. For normal binocular vision, each image has to be formed at the same time on the fovea of that retina and both images must be superimposed [38]. This process is known as the lowest level of sensory fusion [36-37]. In order to test for simultaneous perception, different images are presented to the right and left eye. If one of the images is difficult to see or perceive interchangeably, then simultaneous perception is absent.

Also, if seeing out of both eyes is challenging, then double images will appear and this is a sign of low sensory fusion.

1.3 *Fusion*

The second level of binocular vision, fusion allows objects projecting onto the corresponding retinal points, with their two images linked at the level of the central nervous system (CNS) into one perception [36-37]. The two types are motor fusion and sensory fusion that are central processes occurring in the visual cortex. During motor fusion, the two eyes become aligned to sight the same direction. During sensory fusion, the two retina images are fused and perceived as one [36-37]. In order for the eyes to fuse on an object at a distance, they must diverge, or turn outward. If the object is up close, the eyes must converge, or turn inward. A weakness that can prevent the eyes from simultaneously moving together to view the object can be caused by tension present in the muscles of either eye or many other causes [36-37].

The presence of sensory fusion requires more than just having the images located on the specific retinal areas. It is important for the images to be alike in size, brightness, and sharp to permit sensory to occur [36-37]. Only then can sensory fusion allow two similar images to be appreciated as one. In order to maintain sensory fusion, the function of motor fusion must be present. If an object is moving towards a subject, the subject's eyes must converge. If the subject's eyes do not have motor fusion to converge towards the object, then sensory fusion of the object will stop, and will cause double vision. Hence, the presence of good motor fusion normally means that there is good sensory fusion [36-37].

The function of motor fusion is known to have substantial benefits. Without alignment of the eyes, it would be difficult to enjoy the benefits of sensory fusion or depth perception. The mechanism of motor fusion allows coordinated eye movements to occur by adjusting the position of the eye and maintaining alignment [36-37]. Therefore, the eyes remain aligned on the visual target and prevent wandering off the target. Binocular foveal alignment maintained by the correctional eye movements is defined as fusional vergence movements [28]. In clinical settings, subjects who are incapable of a subjective response are more easily tested by motor fusion to gather quantifiable and measurable data [36-37].

1.4 *Stereopsis*

At the highest level, there is stereopsis, through which the relative depth information is extracted from the slight difference of the two retina images [6-7]. During the stereopsis process, signals from the two eyes must reach the visual cortex for comparison [5-7]. Stereopsis is grouped into two categories called local and global. Local stereopsis is primarily dependent on central vision and global stereopsis depends on long viewing distances and smaller viewing angles [6-7].

Local stereopsis is known as the horizontal retinal disparity analysis process that disregards association to other retinal fields [6-7]. If the disparity is processed in one location of the visual field without association to the other disparities in various other locations, then it is defined as the local disparity range [28]. The global disparity range requires interactions amongst local disparity processing mechanisms. The process of global stereopsis means that if contours are absent, then form perception is impossible until the horizontal retinal disparities are linked across a large area [5-7]. Form perception occurs after global stereopsis.

The range of measured stereopsis is classified as coarse stereopsis and fine stereopsis. The difference between the two is that they provide depth information of distinctive degree of spatial and temporal accuracy [3]. Coarse stereopsis is used to identify stereoscopic motion in the periphery and is referred to as qualitative stereopsis [3]. Fine stereopsis is based on static differences and is most important to determine depth of objects in the central visual area

(Panum's fusional area) and is called quantitative stereopsis [1-3]. Fine stereopsis can only occur in subjects with two balanced eyes, which means that sensitivity of the two eyes allows equal eye growth [1-3]. Without balanced eyes it would be difficult to view similar images since they would appear double. The difference between fine and coarse stereopsis is that, fine stereopsis includes higher spatial frequency, stationary targets, images with similar size and shape, and smaller retinal disparities [1-3]. Coarse stereopsis includes lower spatial frequency, moving targets, periphery, larger retinal disparities, and images do not necessarily have to be similar [3].

Contour stereogram tests are used to measure local stereopsis and random-dot stereogram tests are used to measure global stereopsis. The random-dot technique helps provide an explanation on how stereo vision is processed by the human brain [39]. There are monocularly visible contours in the contour stereogram tests that trigger the fusion mechanism, which reduces the importance of precise motor control [39]. In this study, we used global stereopsis in association with fine stereopsis because the random-dot stereogram test included a way to identify a disparity-defined form and provided a higher stereoacuity. This stereopsis process was important in this study since it helped quantify the quickness of the subjects response by obtaining the minimum time needed to achieve the best stereoacuity.

1.5 *Ocular Dominance*

Ocular dominance refers to the tendency for a person to prefer visual input from one eye to the other [10-11]. The preferred eye is defined as the dominant eye, which is used with ease or by habit to perform tasks. In normal binocular vision, the dominant eye is usually the one that is most relied on for activities such as sports that require aim [14]. The three different types of ocular dominance are sighting, motor, and sensory dominance. Sighting dominance means that one is preferred over the other eye when fixating on a target [22-24]. Motor dominance refers to the dominant eye that is strong in fixating at the near point of convergence and the work of the extraocular muscles play a role [22-24]. Sensory dominance happens when one eye is presented with a stimulus and it dominates the other eye in a competition between dominance of right and left retinal images, when two distinguishable figures are viewed in a stereoscope [22-24].

1.6 *Binocular Disparity*

Binocular disparity is known as the main binocular cue for depth. Since two eyes look at objects from slightly different angles, they get slightly different views [4]. This difference between the two views is called disparity. The visual system merges the two images into one perception and translates the disparity between the two images into depth perception [4]. The disparity between images is larger when an object is closer. The sensitivity of stereopsis may be quantified by stereoacuity, the minimal detectable disparity (D_{min}), and the quickness of the response is quantifiable by recording the minimal time needed to achieve the best stereoacuity (T_{min}) [1-4]. Stereoacuity is measured in seconds of arc (arcsec) to capture the smallest angle and convert it into an angle of binocular disparity.

It is natural to think that the disparity extraction process would be easier if two equally strong signals were compared, and the disparity extraction process would be much more difficult if a very strong signal is compared to a weak signal [4]. Therefore, detection of fine stereopsis (i.e., detection of stereopsis with small D_{min} and short T_{min}), theoretically, should show better performance in subjects with two balanced eyes. However,-this hypothesis has not been previously tested, likely due to methodological limitations of the traditional ocular dominance tests.

1.7 *Purpose*

Traditional methods to measure ocular dominance are qualitative, as they can only identify the dominant eye without measuring the degree of dominance. In the hole-in-the-card test [12], a subject is asked to hold the cardboard with both hands and to view a target through the hole with both eyes open. Then one of the eyes is occluded. If the target remains in view, the occluded one is non-dominant eye and the open one is the dominant eye [13]. In the convergence near-point test (CNP) [14], a subject is asked to fixate on an object that is moving toward the nose. The eye that deviates first is the non-dominant eye. Both of these methods are qualitative, which only identifies the dominant eye without determination of the extent of the dominance. In the current study, we measured ocular sensory dominance and quantified it with ocular dominance index (ODI) for each subject and subsequently identified the dominant eye. Although traditional qualitative ocular dominance tests were previously considered valid, neither method directly measured the relative sensitivity of the visual brain to visual signals from the two eyes [15-16]. The aim of this study is to provide a quantitative assessment of the relationship between ocular sensory dominance and stereopsis and overcome limitations of previous studies.

Chapter 2: Material and Methods

2.1 *Subjects*

A total of 33 subjects (11 males and 22 females, 18-38 years old, mean = 25 years old) were recruited from the NOVA Southeastern University campus and they completed the testing. The planned recruitment goal was to have a sufficient sample size, age group, and no prior history of ocular disease. The sample size of 33 subjects was sufficient to cover the range of variance in stereopsis. Subjects were excluded from the study if they had prior history of any of the following ocular diseases: glaucoma, retinal detachment, or macular degeneration. Written informed consent was obtained after explanation of the nature and possible consequences of the study. The protocol for the study was approved by the Institutional Review Board (IRB) of Nova Southeastern University and followed the tenets of the Declaration of Helsinki.

To be included in the study, the subjects were required to have best corrected visual acuity (BCVA) of 20/20 or better at distance for each eye and be willing to complete the study. Each subject took part in 2 one-hour sessions. Objective refraction measurements were acquired using an autorefractor. The head and chin rests on the autorefractor were used to ensure the subject's did not move during the experiment. To ensure subjects were not incorrectly refracted, visual acuities were obtained using a Snellen chart.

2.2 *Stereopsis measurement*

Stereopsis was measured with random dots in this study (Fig 1A). The amount of disparity contained in the half-images was varied in each trial as the images were presented to the right and left eye. The subjects were instructed to make a judgment regarding whether the pacman symbol, known as the object, was standing in front of the background or falling behind the background by pushing either the up or down button. Across a single stimulus presentation time, responses to a series of stimuli with different amounts of disparity were measured to determine the threshold for a particular stimulus duration using a modified staircase algorithm (Fig 1B). The method of limits is also known as the up-down method or staircase method.

The stimulus duration times we evaluated were 25ms, 50ms, 100ms, 200ms, and 400ms. The functions for stereothresholds versus viewing durations were analyzed using an empirical model of quadratic summation, in the form of $th = D_{min} (t^{-2} + T_{min}^{-2})$^0.5 where th was the stereothreshold at a given viewing duration (t), T_{min} was the constant that determined the horizontal position of the function, which was related to the time at which the stereothreshold became independent of duration (critical duration). D_{min} was the constant that determined the vertical position of the function and was equal to the stereothreshold when t = T_{min}.

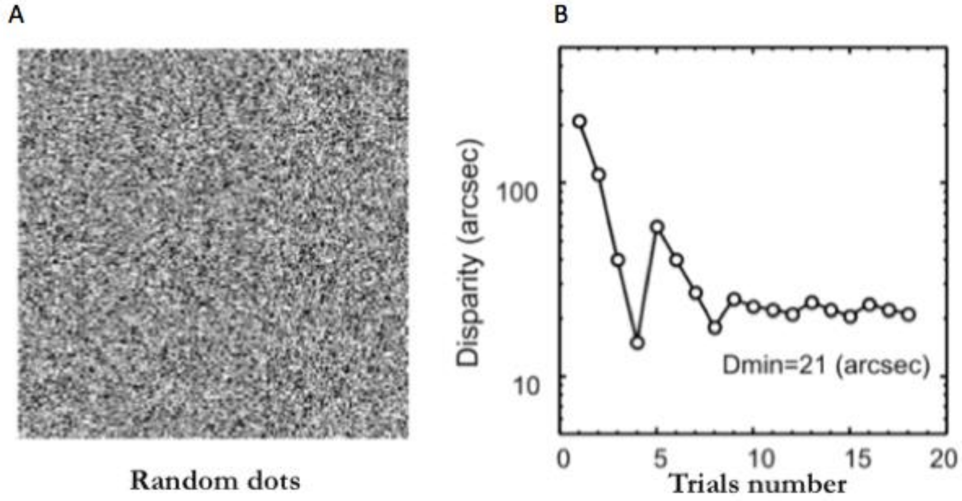

Fig 1. The method to measure Stereopsis. (A) Stimuli. (B) Example of the result from one subject with one test of stereopsis. The threshold of stereopsis was measured with random dots presented for a variety of duration times. The best stereoacuity (D_{min}) and the time to achieve it (T_{min}) was recorded.

2.3 *Ocular Dominance Measurement*

Ocular dominance was determined by the continuous flashing technique [19] and ocular dominance index (ODI). The test stimuli were presented in the center of a CRT screen (1024 x 768 resolution; 100 Hz; Gamma corrected for linearity, Richardson Electronics) against a uniform background (mean luminance 50 cd/m^2) and viewed at a distance of 6 meters with a chin rest. The dynamic Mondrian patterns subtended 4.3° x 4.3°, with individual elements extending to 0.154°. The target stimulus was a Gabor patch tilted 45 degrees toward either the right or the left (SF = 1c/d, spatial extension 1.9°). The black and white strokes that framed the Mondrian and Gabor were 0.33° in width and were used to help achieve binocular fusion. Mirrors were used to present the Mondrian and target stimuli dichoptically. The subjects were instructed to exclusively view one of the two stimuli during a given trial. The eyes' view of the dynamic Mondrian and target stimuli were counterbalanced and randomized across trials. The experiment was programmed in commercial software using Matlab Version 2012 Rb.

At the beginning of the trial, one eye viewed a 100% contrast Mondrian pattern and the other eye viewed the target Gabor patch at 0% contrast. During a trial, the contrast of the Gabor patch linearly increased by 1% every 100 ms, and the contrast of Mondrian patterns linearly decreased at the same rate. At high contrast, the subject saw Mondrian patterns only. When contrast of Mondrian was reduced and the contrast of Gabor was increased, the subject was able to see the Gabor patch. Subjects were instructed to respond immediately once they detected the tilting direction of the Gabor patch (left vs. right) by pressing one of two response keys. After each trial, the ocular strength value was calculated as the ratio of Mondrian to Gabor's contrasts (unit db) at that moment (Figure 2A). The higher the ratio, the greater the quantitative measure of the sensory dominance for that eye. A high ratio implied that that the contrast detection threshold of the oriented Gabor patch needed to overcome the suppression imposed by the Mondrian stimulus to the other eye. In other words, the eye with low contrast detection threshold for overcoming Mondrian suppression had high sensitivity. Subjects performed 10 practice trials for orientation and training, prior to starting 50 experimental trials. The eye with the higher ocular strength value was considered the stronger eye and the one with smaller value was considered the weaker eye. It took about 15 minutes on average to complete the test for each subject.

A t-test was used to compare the 50 values collected for each eye. T-value, which was the interocular difference in mean values normalized by the standard deviations of values from both eyes, was used as the ocular dominance index (ODI) to quantify a subject's overall degree of ocular dominance. An ODI value of 2, which corresponded to a p value of 0.05 for a sample size of 33, was selected as the significance level. An ODI < 2 was regarded as having an unclear dominance. An example of a subject with unclear dominance is shown in the left panel of Figure 2B. On the other hand, a subject with an ODI ≥ 2 is regarded as having clear sensory dominance. An example of a subject with clear sensory dominance is shown in the right panel of Fig 2B, in which the right eye was the dominant eye.

2.4 *Data analyses and statistics*

Statistical analyses were performed with Matlab 2012b software. Mean, median, and standard deviation were used for descriptive comparison of each subject's ODI value, T_{min}, and best D_{min}. We assessed for possible correlations between T_{min} and best D_{min} versus ODI using Pearson's R; the significance of R was tested according to the following formula: $t = R*sqrt((N-2)/(1-R*R))$ where R was Pearson's R and N was sample size.

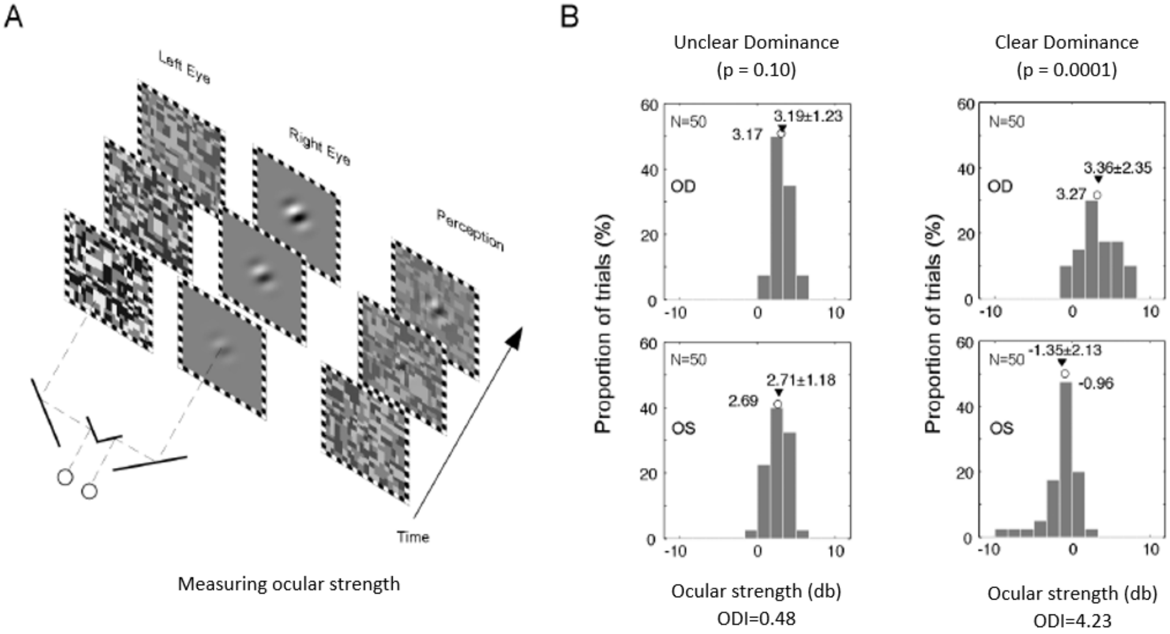

Fig 2. The method to measure ocular dominance index (ODI). (A) The ratio of Mondrian to Gabor's contrasts (measuring ocular strength) was calculated for each response after each trial and each eye was tested 50 times. (B) A t-test was used to compare the log ratios collected from the two eyes and the t-value was used as the ODI. Examples of a subject with unclear dominance (ODI < 2, left panel, p = 0.10) and another subject with clear dominance (ODI ≥ 2, right panel, p = 0.0001) are shown here. Circles and triangles represent median and mean values of the log ratios, respectively.

Chapter 3: Results

3.1 *Examples*

Figure 3 shows the data from a subject with two balanced eyes (Figure 3A) and another subject with clear ocular dominance (Figure 3B). Stereopsis thresholds were plotted as a function of the duration of stimulus presentation. In both cases, the stereothresholds declined with increasing viewing duration until a constant, lowest stereothreshold was achieved, providing evidence for a critical duration for temporal summation of binocular disparity. The D_{min} in the subject with two balanced eyes was 55.40 arcsec and was 43.29 arcsec in the subject with clear ocular dominance. Although those two values were quite similar, the T_{min} in the subject with balanced eyes was 138.8 msec, which was dramatically different from the value of 1229.02 msec in the subject with clear ocular dominance.

Thus, the data from those two examples indicated that subjects with balanced eyes may have shorter processing time to reach optimal stereopsis and subjects with strong ocular dominance need longer time to reach optimal stereopsis. However, once the optimal stereopsis was achieved, the stereoacuity thresholds were quite similar for both subjects with balanced eyes and those with strong ocular dominance.

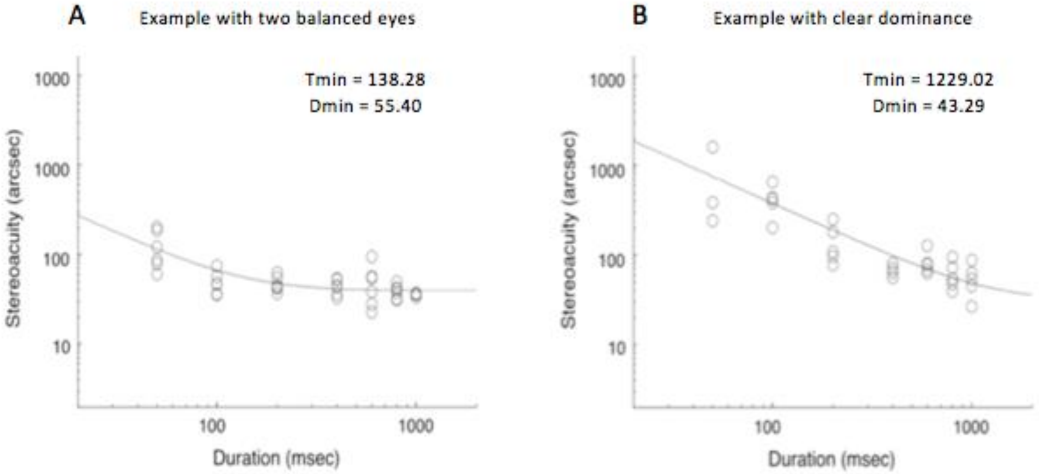

Fig 3. The threshold of stereoacuity for two examples with different viewing durations. (A) Scatterplot with an example of data from two balanced eyes. (B) Scatterplot with an example of data in a case of clear dominance. The stereoscopic stimuli were Gabor patterns with spatial frequency and contrast parameters designated in each graph. The solid line superimposed on each set of data represents a quadratic summation model that was fit to the data.

3.2 *Population data*

Figure 4 displays the data collected across all 33 participants for T_{min} (Fig 4A) and D_{min} (Fig 4B) as a function of ocular dominance strength. T_{min} was highly correlated with ocular dominance strength. Subjects with clear ocular dominance had significantly higher T_{min} values (mean 479.9 msec ± SD 380.9) than the subjects with unclear ocular dominance (179.9 ± 100.7, $t = 2.66$, $p = 0.01$). The correlation between T_{min} and ocular dominance strength was statistically significant ($R = 0.58$, $t = 3.96$, $p = 0.0004$, $p < 0.05$).

However, D_{min} values were not statistically significantly correlated with ocular dominance strength. Subjects with clear ocular dominance (73.1 ± 57.8) had similar D_{min} values to those with unclear dominance (102.4 ± 174.3) ($R = 0.03$, $t = 0.16$, $p = 0.87$).

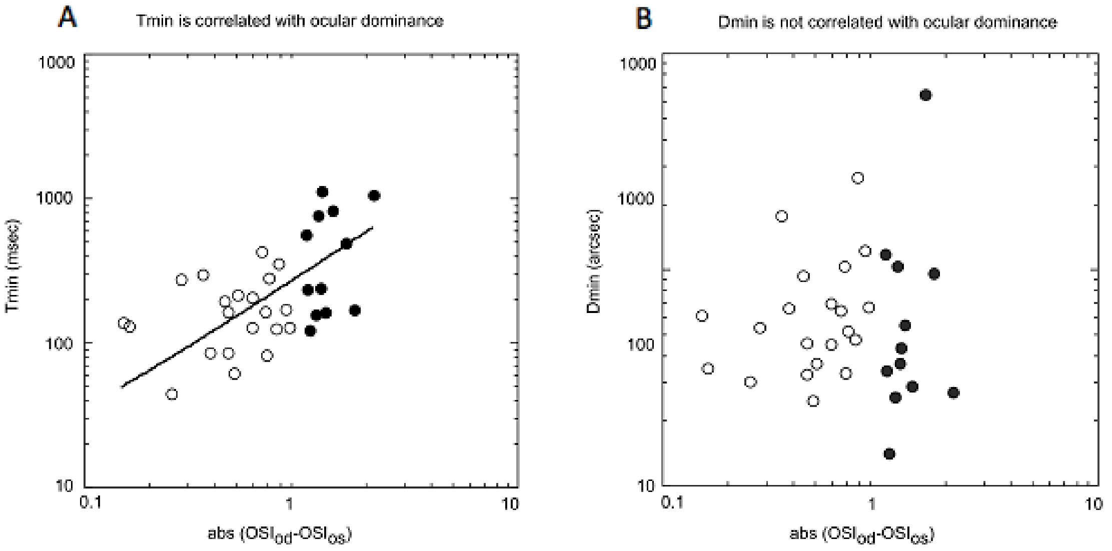

Fig 4. The correlation between stereopsis and ocular sensory dominance. (A) Time needed to achieve best stereoacuity with ocular dominance. (B) Minimal detectable disparity not correlated with ocular dominance. The drawn line represents a linear regression, each circle represents a single subject, filled circles represent subjects with strong binocular imbalance (one of the two eyes is strongly dominant), and open circles represent subjects with two balanced eyes.

Chapter 4: Discussion/Conclusion

One important feature of our study was the separation of the subjects with clear dominance from those with unclear dominance (i.e., balanced eyes). In sighting dominance based on the hole-in-the card test, a subject was rarely labeled as showing unclear dominance. In our study, for every subject, the log ratio of Mondrian to Gabor's contrasts at response was measured 50 times for each eye and ocular sensory dominance was determined based on the statistical comparison of values from each eye. This allowed us to confidently group the subjects according to whether they displayed clear dominance or unclear dominance. The findings enabled us to show that people with balanced eyes can achieve the optimal level of stereoacuity with a much shorter time.

The assessment of eye dominance is used by eye care practitioners in clinical decision-making to determine monovision. It is important in monovision to indicate one eye as the dominant for distance vision and the non-dominant for near vision. This idea is based on the assumption that the dominant eye will be less easily suppressed by the moderately blurred image in the other eye. Traditional tests may be used in practice to measure dominance that include motor factors contributing to sighting or by sensory factors contributing to the eye that sees better on sensory tests like acuity [15-16]. However, the findings in this study contribute to previous work by raising the concern that visual acuities or measures of spatial vision simply are not sufficient indicators of determining ocular dominance. The method derived in this study was advantageous because it not only helped determine the dominant eye, but it also helped quantify the strength of ocular dominance. This enabled us to explore the correlation between T_{min}/D_{min} and the ocular strength dominance.

Previous studies used ocular dominance tests such as the hole-in-the-card test and convergence near-point (CNP) test to separate groups by presence or absence of ocular dominance without reference to the relative strength of dominance [15-16]. However, neither of these methods directly described the relative sensitivity of the visual brain to visual signals from the two eyes. Also in previous studies, the hole-in-the-card test was used to determine the sighting direction and the CNP test was related to motor fusion [15-16]. Yet, neither of these tests truly measured the sensory dominance. Thus, a quantitative method was developed through psychophysical methods in this study to address those limitations.

The major finding of this study was that the method helped quantify the latency of the subject's response by obtaining the minimum time needed to achieve optimal stereoacuity. Subjects with balanced eyes had significantly ($p = 0.01$) shorter reaction times on average ($T_{min} = 138.28$ msec) compared to subjects with clear dominance ($T_{min} = 1229.02$ msec). The data represents that subjects with balanced eyes may have shorter processing time to reach optimal stereopsis and subjects with strong ocular dominance need longer time to reach optimal stereopsis. The findings in this study sheds light on the influence of fine stereopsis associated with response time and stereothreshold in individuals with balanced eyes. The mechanism underlying this finding can be explained by refractive development in both eyes, linkage to the retina, and communication to the visual areas of the brain where binocular information is processed [4].

Ocular dominance is measured by the signals sent from both eyes to the visual areas of the brain. The eye considered dominant has greater access to the visual brain versus the non-dominant eye. One possible speculation explaining this phenomenon could be that the dominant eye has greater visual impact and therefore, has a greater growth rate [10]. For a subject with unclear dominance, equal eye growth is possible with the understanding that both eyes have similar sensitivity. Conversely, for a subject with clear dominance, the dominant eye would have higher sensitivity and it has been suggested that growth is much faster than the non-dominant eye [10]. Our findings suggest that the perception of depth formed in the brain from the visual stimuli is perceived much more rapidly with balanced eyes.

Further development of the ODI test may be helpful to determine candidacy for permanent monocular devices, such as the implantable miniature telescope (IMT) for age-related macular degeneration (AMD) [40]. This requires patients' ability to alternate suppression between eyes to make use of either the central magnification with the IMT or the peripheral vision in the fellow eye for mobility [40]. Clinically, it is difficult to assess whether patients with clear ocular dominance are not good candidates for the IMT. AMD patients would have very poor stereopsis so the method in this study would not be suitable for testing. However, the method could potentially be modified to accommodate the patients' level of reduced stereopsis. The modified version of the ODI test could possibly be used for individuals with severe vision loss to determine if it may be helpful in distinguishing patients' candidacy for the IMT.

Other potential uses for the ODI may be to help determine candidacy for monovision contact lenses or LASIK surgery [41]. Correcting the dominant eye for far vision allows for better binocular summation at middle distances and near stereoacuity [41]. However, it is important to determine, which eye to allocate as the dominant and non-dominant for either contact lens fitting or refractive surgery. In a clinical setting, eye care practitioners would be able to fit contact lenses more efficiently by determining the dominant eye. For monovision patients, the dominant eye is fitted with the contact lens that is used to focus on objects at a distance. Similarly, with LASIK surgeries, commonly referred to as a laser eye surgery to correction vision, the distance vision is linked with the dominant eye. Above all, better determination of ocular dominance could translate into better clinical decision making for the benefit of patients.

References

[1] Richards W, Kaye MG. Local versus global stereopsis: Two mechanisms? Vision Res. 1974;14:1345–1347.

[2] Harwerth RS, Fredenburg PM, Smith EL III. Temporal integration for stereoscopic vision. Vision Res. 2003;43:505-517.

[3] Wilcox LM, Allison RS. Coarse-fine dichotomies in human stereopsis. Vision Res. 2009;49:2653-2665.

[4] Lappin JS. What is binocular disparity? Front Psychol. 2014;12:870.

[5] Anzai A, Ohzawa I, Freeman RD. Neural mechanisms for processing binocular information. I. Simple cells. J Neurophysiol. 1999;82:891–908.

[6] Livingstone MS, Nori S, Freeman DC, Hubel DH. Stereopsis and binocularity in the squirrel monkey. Vision Res. 1995;35:345-54.

[7] Weinman J, Cooke V. Eye dominance and stereopsis. Perception. 1982;11:207-210.

[8] Walls GL. A theory of ocular dominance. AMA Arch Ophthalmol.1951;45:387– 412.

[9] Berner GE, Berner DE. Relation of ocular dominance, handedness, and the controlling eye in binocular vision. AMA Arch Ophthalmol.1953;50:603– 608.

[10] Porac C. The dominant eye. Psychol Bull. 1976;83:880-897.

[11] Mapp AP, Ono H, Barbeito R. What does the dominant eye dominate?—a brief and somewhat contentious review. Percept Psychophys. 2003;65:310-317.

[12] Gould G. A method of determining ocular dominance. JAMA. 1910;55:369-370.

[13] Barbeito R. Sighting dominance: an explanation based on the processing of visual direction in tests of sighting dominance. Vision Res. 1981;21:855-860.

[14] Seijas O, Gomez de Liano P, Gomez de Liano R, Roberts CJ, Piedrahita E, Diaz E. Ocular dominance diagnosis and its influence in monovision. Am J Ophthalmol. 2007;144:209-216.

[15] Li J, Lam CS, Yu M, Hess RF, Chan LY, Maebara G, et al. Quantifying sensory eye dominance in the normal visual system: a new technique and insights into variation across traditional tests. Invest Ophthalmol Vis Sci. 2010;51:6875-6881.

[16] Yang E, Blake R, McDonald JE. A new interocular suppression technique for measuring sensory eye dominance. Invest Ophthalmol Vis Sci. 2010;51:588-593.

[17] Menon RS, Ogawa S, Strupp JP, Ugurbil K. Ocular dominance in human V1 demonstrated by functional magnetic resonance imaging. J Neurophysiol.1997;77:2780-2787.

[18] Ronald SH, Patricia MF, Earl LS III. Temporal integration for stereoscopic vision. Vision Res. 2003;43:505-517.

[19] Jiang F, Chen Z, Bi H, Ekure E, Su B, Wu H, et al. Association between Ocular Sensory Dominance and Refractive Error Asymmetry. PLoS ONE 2015;10. doi:10.1371/journal. pone.013622

[20] Suleman, R., Yang, T., Paige, J., Chauvin, S., Alleyn, J., Brewer, M., Hoxsey, R. J. Hand-Eye Dominance and Depth Perception Effects in Performance on a Basic Laparoscopic Skills Set. JSLS : Journal of the Society of Laparoendoscopic Surgeons. 2010;14:35-40.

[21] Chaurasia BD, Mathur BB. “Eyedness”. Acta Anat (Basel). 1976;96:301-305

[22] Cheng CY, Yen MY, Lin HY, Hsia WW, Hsu WM. Association of ocular dominance and anisometropic myopia. Invest Ophthalmol Vis Sci. 2004;45:2856–2860. pmid:15277513 doi: 10.1167/iovs.03-0878

[23] Ito M, Shimizu K, Kawamorita T, Ishikawa H, Sunaga K, Komatsu M. Association between ocular dominance and refractive asymmetry. J Refract Surg. 2013; 29:716–720. doi: 10.3928/1081597X-20130813-02. pmid:23952844

[24] Reiss M. Ocular dominance: some family data. Laterality. 1997; 2:7–16. pmid:15513049 doi: 10.1080/135765097397602

[25] Sridhar D,Bedell HE. Relative contributions of the two eyes to perceived egocentric visual direction in normal binocular vision. Vision Res. 2011; 51:1075–1085. doi: 10.1016/j.visres.2011.02.023. pmid:21371491

[26] Ehrenstein WH, Arnold-Schulz-Gahmen BE, Jaschinski W. "Eye preference within the context of binocular functions". Graefes Arch. Clin. Exp. Ophthalmol. 2005;243:926–32.

[27] Aswathappa, Jagadamba, Karthiyanee Kutty, and Nachal Annamalai. "Relationship between handedness and ocular dominance in healthy young adults–A study." Int J Pharm Biomed Res. 2011;76-78.

[28] Dhanraj Vishwanath. "Toward a new theory of stereopsis". Psychological Review. 2014;121:151–178.

[29] M. W. Robboy, I. G. Cox, and P. Erickson, "Effect of sighting and sensory dominance on monovision high and low contrast visual acuity," CLAO Journal. 1990;16:299-301.

[30] T. Handa, K. Mukuno, H. Uozato, T. Niida, N. Shoji, and K. Shimizu, "Effects of dominant and nondominant eyes in binocular rivalry," Optometry and Vision Science. 2004;81:377-382.

[31] E. Shneor and S. Hochstein, "Effects of eye dominance in visual perception," International Congress Series. 2005;1282:719-723.

[32] Berens C, Zerbe J. "A new pinhole test and eye-dominance tester". Am. J. Ophthalmol. 1953;36:980-981.

[33] Kromeier M, Heinrich SP, Bach M, Kommerell G. "Ocular prevalence and stereoacuity". Ophthalmic Physiol Opt. 2006;26:50-60.

[34] Treutwein, Bernhard. Minireview: Adaptive psychophysical procedures. Vision Research. 1995;35:2503-2522.

[35] Fink W. The dominant eye: its clinical significance. Arch Ophthalmol 1938;4:555–582

[36] N. Xiong; P. Svensson. "Multi-sensor management for information fusion: issues and approaches". Information Fusion. Science Direct. 2002;3:163–186.

[37] Fredenburg P., Harwerth RS. The relative sensitivities of sensory and motor fusion to small binocular disparities. Vision Res. 2001;41:1969-1979.

[38] Buckthought A., Mendola J. How simultaneous is the perception of binocular depth and rivalry in plaid stimuli? Iperception. 2012;3:305-315.

[39] O'Toole AJ., Kersten DJ. Learning to see random-dot stereograms. Percecption. 1992;21:227-243.

[40] Implantable miniature telescope: lessons learned. Optometry. 2010;2:86-93.

[41] The influence of ocular dominance on monovision--the interaction between binocular visual functions and the state of dominant eye's correction. Nippon Ganka Gakkai Zasshi. 2007;111:435-440.