Balanced Eyes See Stereopsis More Quickly, but Not More Finely

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PURPOSE. To quantify ocular sensory dominance and investigate its relationship to stereopsis.

METHOD. A total of 69 subjects participated in the study. Ocular dominance was measured by a continuous flashing technique, with the tested eye viewing a Gabor patch increasing in contrast, and the fellow eye viewing a Mondrian noise decreasing in contrast. In each trial, the log ratio of Mondrian to Gabor's contrasts was recorded as a subject first detected the Gabor. We collected 50 trials for each eye and an interocular difference was analyzed with a rank-sum test. The z-value was used as the ocular dominance index (ODI) to quantify the degree of ocular dominance. A subject with ODI ≥ 2 was categorized as having a clear ocular dominance, and a subject with ODI < 2 was considered as having balanced eyes (unclear dominance). The stereoacuity was measured with random dot patterns with durations varying from 50 to 1000 ms. The best achievable stereoacuity (D_{min}) and the integration time needed to acquire that (T_{min}) were calculated.

RESULTS. A total of 30 subjects had balanced eyes and 39 had clear ocular dominance. T_{min} was significantly longer in subjects with clear ocular dominance than in subjects with balanced eyes (180.18 vs. 121.17 ms, $P < 0.01$). T_{min} was positively correlated with ODI ($P < 0.01$). However, D_{min} in subjects with clear dominance was not different from that in subjects with balanced eyes (40.60 vs. 35.73 arcsec, $P = 0.18$).

CONCLUSIONS. Ocular dominance is not associated with how fine the stereoacuity is, but rather how quickly the best stereoacuity is acquired.

Keywords: ocular sensory dominance, stereopsis, integration time

Ocular dominance refers to the tendency for a person to prefer visual input from one eye to the other.[1,2] The preferred eye is defined as the dominant eye, which is used with ease or by habit to perform tasks. Traditionally, three types of ocular dominance have been reported: sighting, motor, and sensory dominance. Sighting dominance means that one eye is preferred over the other when fixating on a target.[3–5] Motor dominance refers to the eye that is better at maintaining fixation at the near point of convergence.[3–5] Sensory dominance happens when one eye dominates the other eye in a competition for the perceptual dominance when two distinguishable figures are viewed in a stereoscope.[3–5]

At the highest level of binocular vision, there is stereopsis through which the relative depth information is extracted from the slight difference of the two retina images.[6,7] During the process, signals from the two eyes must reach the visual cortex for comparison.[6–8] It is natural to think that the disparity extraction process would be easier if two equally strong signals were compared, and much more difficult if a very strong signal is compared to a weak signal.[9] It is also known that an unequal blur of the images in the two eyes deteriorates stereoacuity more than when there are equally blurred images in the two eyes.[10–15] This may be, in part, due to unequal contrast of the images in the two eyes.[16–19] Unequal neural sensitivity of the two eyes could also contribute to the reduced stereoacuity. Theoretically, when compared to a person with clear ocular dominance, those with two balanced eyes should be able to detect finer disparities and accomplish the task in a shorter amount of time.

However, this hypothesis has not been previously tested, likely due to methodologic limitations of the traditional ocular dominance tests. In the hole-in-the-card test to test sighting dominance,[20] 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 eye is nondominant and the open one is the dominant eye.[21] In the near-point-of-convergence test (NPC) to test motor dominance,[22] a subject is asked to fixate on an object that is moving toward the nose. The eye that deviates first is the nondominant eye. Both of these methods are qualitative and only identify the dominant eye without determination of the extent of the dominance. Neither method directly measures the relative sensitivity of the visual part of the brain to visual signals from the two eyes.[23,24]

In the current study, we measured ocular sensory dominance and quantified it with the ocular dominance index for each subject, and subsequently identified the dominant eye. The aim of this study is to provide a quantitative assessment of
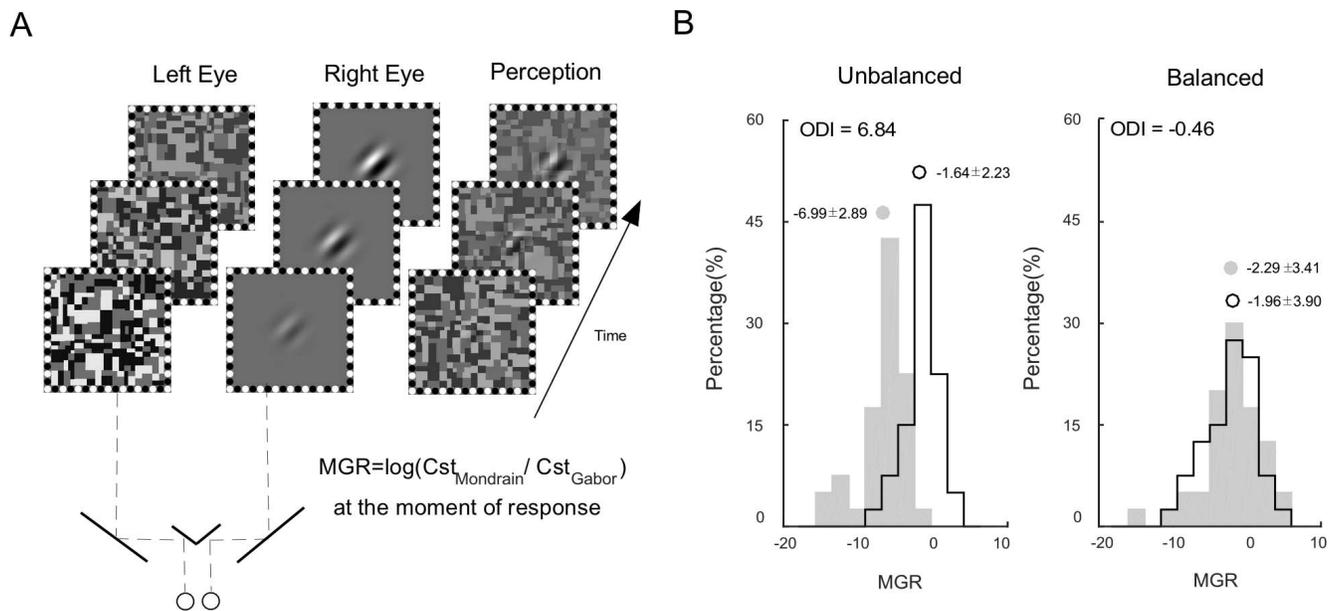
A

Left Eye   Right Eye   Perception

Time

$$MGR = \log(Cst_{Mondrain} / Cst_{Gabor})$$
at the moment of response

B

Unbalanced

ODI = 6.84

○ -1.64±2.23

● -6.99±2.89

Balanced

ODI = -0.46

● -2.29 ±3.41

○ -1.96±3.90

FIGURE 1. Method to quantify ocular dominance. (**A**) The MGR was calculated at the moment of response for each trial, and each eye was tested 50 times. ODI was calculated as the normalized difference between the left and right eyes' MGRs. (**B**) *Left*: An example of a subject with clear ocular dominance. *Right*: An example of a subject with two balanced eyes. *Open* and *filled bars* represent right and left eyes, respectively. The *circle* represents mean value.

the relationship between ocular sensory dominance and stereopsis and overcome limitations of previous studies.

MATERIALS AND METHODS

Subjects

A total of 69 subjects were recruited from the NOVA Southeastern University campus, and they completed the testing. The subjects were aged between 20 to 40 years with a mean age of 28.1 ± 4.9 years. There were 31 males and 38 females. To be included in the study, the subjects were required to have a best corrected visual acuity (BCVA) of 20/20 or better at distance for each eye. Subjects were excluded from the study if they had a prior history of any of the following ocular diseases: strabismus or ptosis, any ocular surgery, amblyopia, keratoconus, glaucoma, retinal diseases, optic disc abnormalities, phoria greater than 6 prism diopters at near, optic neuropathy, or other diseases that might affect BCVA. Written informed consent was obtained from the subjects 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.

Ocular Dominance Measurement

Ocular dominance was determined with the continuous flashing technique.[25] The visual stimuli were presented in the center of a cathode ray tube (CRT) screen (1024 × 768 resolution; 100 Hz; Gamma corrected for linearity; Richardson Electronics, LaFox, IL, USA) against a uniform background (mean luminance 50 cd/m²) and viewed at a distance of 60 cm with a chin rest. One eye viewed the dynamic Mondrian patterns, which subtended 4.3° × 4.3° with individual elements extending to 0.154°. The other eye viewed the testing target, which was a Gabor patch tilted 45° toward either the right or the left (SF = 1 c/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 was counterbalanced and randomized across trials. The experiment was programmed in commercial software using a computational environment (MATLAB, version 2012Rb; MathWorks, Natick, MA, USA).

At the beginning of a trial, one eye viewed a Mondrian pattern with 100% contrast and the other eye viewed the target Gabor patch at 0% contrast. During the 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 perceived the Mondrian pattern only. When the contrast of the Mondrian was reduced and the contrast of the 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 versus right) by pressing one of two response keys (Fig. 1A). After each trial, the ocular strength value was calculated as the log ratio of Mondrian to Gabor's contrasts (MGR) at that moment. The higher the ratio, the greater the quantitative measure of the sensory dominance for that eye.

Subjects performed 10 practice trials for orientation and training, prior to starting 50 experimental trials. The trials in which a subject did not respond when the stimulus presentation duration expired were excluded from the analysis. To accommodate the potential distortion to the distribution and different numbers of samples in the two eyes, Wilcoxon rank-sum test was used to compare the MGRs collected from each eye. The approximated z-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. A positive value of ODI indicated the right eye was stronger and a negative value of ODI
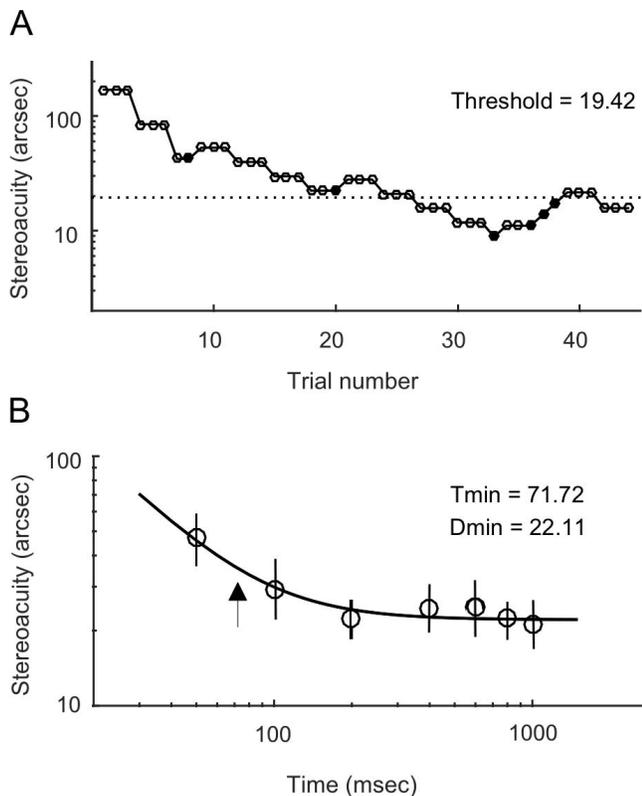
A

Threshold = 19.42

B

Tmin = 71.72
Dmin = 22.11

FIGURE 2. Method used to measure stereopsis. (**A**) For each stimulus presenting duration, the stereo threshold was measured with a staircase procedure. *Open* and *closed circles* represent correct and incorrect responses, respectively. (**B**) An example result showing how stereoacuity changed with different stimulus presenting durations. The best stereoacuity (D_{min}) and the time to achieve it (T_{min}) were derived from the fitted function. The *black arrow* indicates the location of the T_{min}.

indicated the left eye was stronger. An ODI with absolute value of 2, which corresponded to a *P* value of 0.05 for a sample size of 50, was selected as the significance level. A subject with absolute value of ODI larger than 2 was regarded as having clear ocular dominance (Fig. 1B, left panel). On the other hand, a subject with absolute value of ODI less than 2 is regarded as having balanced eyes (unclear sensory dominance; Fig. 1B, right panel).

Stereopsis Measurement

Stereopsis was measured with random dots (RD) on the same CRT monitor used for ocular dominance test. Each eye viewed a pattern of random dots, which subtended $3.3° \times 3.3°$. The monitor has a horizontal width of 34.5 cm viewed at a distance of 115 cm. At this distance, each pixel of the monitor distends approximately 60 arcsec. To achieve subpixel disparity, each half-image of the RD was first decomposed by discrete Fourier transformation into a set of sinusoidal spatial frequency components.

Then an appropriate interocular phase disparity, which can vary continuously without being limited by the size of the pixel, was introduced between the corresponding Fourier components.[26] Afterward, each half-image was reconstructed from its Fourier components by inverse Fourier transformation.[26] The method's validity was not tested directly given it is in the public domain.

Through double stereoscope (the mirrors in Fig. 1A), the subjects' left and right eye looked at fixation marks in the centers of the left and right half of the screen, where the half-images of the RD would be presented. The fixation marks for the two eyes were an upward and downward pointing T. The subjects adjusted the mirrors to fuse the two T's into a cross. The subjects were instructed to make a judgment regarding whether the central square ($1° \times 1°$), known as the object, was standing in front of the background or falling behind the background by pushing either the up or down button. The amount of disparity contained in the half-images was varied in each trial. For one stimulus presentation duration, the threshold to detect disparity was measured using a 3-down-1-up staircase algorithm, in which the disparity between the half-images became smaller after three correct responses and became larger after one wrong response (Fig. 2A). Each staircase ended when it reached six reversals and the values from the last four reversals were averaged as the final stereo threshold.

Stereoacuity was measured with different stimulus presentation durations, which included 50, 100, 200, 400, 600, 800, and 1000 ms. The obtained stereoacuities were plotted against the stimulus presentation durations and were further fitted into an empirical model of quadratic summation.[27] The model takes the form: $th = D_{max} (t^{-2} + T_{min}^{-2})^{0.5}$, where th was the stereoacuity at a given viewing duration (t) and D_{max} was the constant that determined the overall vertical position of the function. T_{min} was critical time constant at which the stereoacuity became independent of duration. According to the model (Fig. 2B), stereo threshold decreases as the stimulus presentation duration becomes longer and stabilizes into a plateau, D_{min}, eventually.

Data Analyses and Statistics

Statistical analyses were performed with the R programming package (version 3.3.1). Mean, median, and standard deviation were used for descriptive comparison of each subject's ODI value, T_{min}, and D_{min}, which all followed normal distribution. *T*-test was used for comparison of D_{min} and T_{min} between subjects with balanced eyes and subjects with unbalanced eyes. Linear regression was performed to assess the relationship between T_{min} and D_{min} versus the absolute value of ODI. A *P* value less than 0.05 was considered statistically significant.

RESULTS

We first calculated the distribution of ODI in all subjects tested; 43.48% of the subjects ($n = 30$) had two balanced eyes with ODI located with the range from −2 to 2, and 56.52% of the subjects ($n = 39$) had clear dominance. The median value of ODI was 1.38 (Fig. 3).

For stereopsis, we calculated the distribution of D_{min} in all subjects tested (Fig. 4A). The median value of D_{min} was 39.41 arcsec (mean ± SD: 55.01 ± 45.00 arcsec). For T_{min} in all subjects tested (Fig. 4B), the median value was 150.32 ms (mean ± SD: 177.71 ± 105.72 ms).

To see whether stereopsis measurements, T_{min} and D_{min}, were different between the subjects with balanced eyes and those with unbalanced eyes, we calculated the statistics on population data. Subjects with clear ocular dominance had significantly higher T_{min} values (median = 180.18 ms, mean ± SD: 215.63 ± 118.37 ms) than the subjects with balanced eyes (median = 121.17 ms, mean ± SD: 128.43 ± 58.30 ms, $t = -3.70$, $df = 67$, $P < 0.01$). However, subjects with clear ocular dominance (median = 40.60 arcsec, mean ± SD: 61.35 ± 52.24 arcsec) had similar D_{min} values to those with balanced
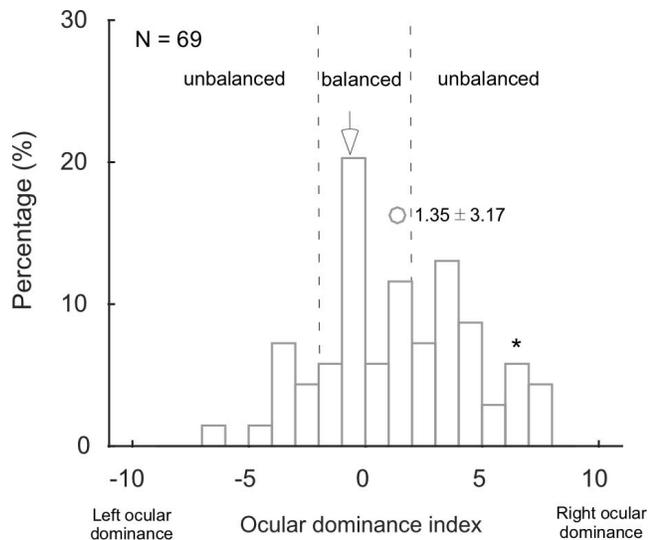
Figure 3. Histogram showing the distribution of ocular dominance index in all subjects. The *circle* represents the mean value. The *asterisk* represents the first example and the *arrowhead* represents the second example in Figure 1B.

eyes (median = 35.73 arcsec, mean ± SD: 46.77 ± 32.37 arcsec, $t = -1.34$, $df = 67$, $P = 0.18$).

Figure 5 displays the data collected across all participants for D_{min} (Fig. 5A) and T_{min} (Fig. 5B) as a function of the absolute values of ODI. D_{min} values were not statistically significantly correlated with the absolute values of ODI ($R = 0.20$, $t = 1.75$, $P = 0.09$). However, T_{min} was moderately correlated with the absolute values of ODI ($R = 0.49$, $t = 4.61$, $P < 0.01$). It should be noticed that T_{min} was only correlated to the absolute values of ODI, which represents the difference of ocular strength between the two eyes. T_{min} was not correlated with each eye ocular strength value, indicated by the MGR value. Linear regression revealed no significant correlation in the right eye (Fig. 5C, top panel, $R = 0.03$, $t = 0.66$, $P = 0.51$) or the left eye (Fig. 5C, bottom panel, $R = 0.17$, $t = 1.74$, $P = 0.08$). It is also worth noticing that T_{min} was not correlated with D_{min} ($R = 0.20$, $t = 1.63$, $P = 0.11$).

DISCUSSION

This study shows that subjects with two balanced eyes can achieve best stereoscopic vision in a shorter period of time, and those subjects with unbalanced eyes need a longer interval to do so. However, the best stereoacuity, once achieved, is not different between the two groups.

On Comparison With Previous Studies

In previous studies, the hole-in-card method or near-point-of-convergence was often used to determine the eye dominance. However, to investigate the relationship between ocular dominance and stereopsis, neither method appears appropriate. The hole-in-card method measures sighting dominance, but according to some studies, may play a role in the judgment of visual direction.[20,25,28] The near-point-of-convergence method measures the relative strength in keeping fixation on the target approaching close to the observer.[29,30] Stereopsis is directly related to how the visual cortex processes the interocular image disparity. Therefore, it is more relevant to study ocular sensory dominance. The other advantage of sensory dominance over sighting and motor dominance is its
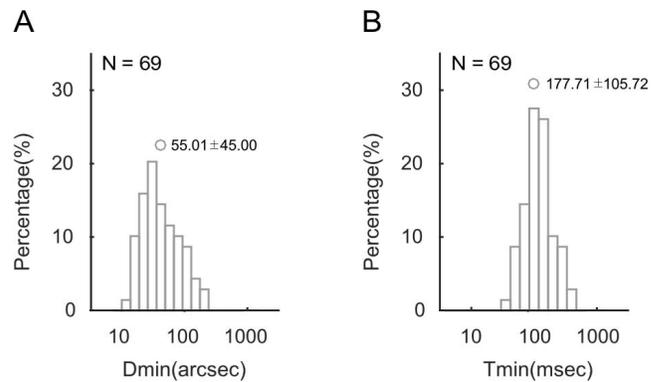

Figure 4. Histogram showing the distribution of D_{min} (A) and T_{min} (B) in all subjects. *Circles* represent the mean values.

capability to quantify the degree of ocular dominance. By calculating the ODI, it is possible to explore the quantitative relationship between stereopsis and ocular dominance. This quantification of dominance was not possible with sighting or motor dominance tests.

Dynamic Process of Stereopsis

Instead of settling on a selected stimulus presentation duration and measuring the stereoacuity, a series of stimulus presentation durations was applied to explore the dynamic process of stereoscopic vision. Previous studies have often overlooked the dynamic process. Our data confirmed earlier study's finding[27] that stereoacuity improves with stimulus presentation duration, up to a certain point. T_{min} represents the turning point when best achievable stereoacuity (D_{min}) no longer depends on stimulus presentation time. Our results showed that T_{min} is significantly linearly related to ODI and D_{min} is not. The results of this study show that despite the slow stereo vision integration those with clear dominance, their stereo vision integration is relatively slow, once integration is completed, they can achieve excellent stereoacuity. In this way, this study describes the two different aspects of stereoscopic vision.

Speculation on the Relationship Between D_{min} and T_{min}

Our results revealed that the integration rate of stereopsis is directly related to the relative strength difference between the eyes. It might take less time for the signal to arrive at the visual cortex from the dominant eye than signals from the nondominant eye. When the stimulus presentation duration is short, given the different arrival timing of the signal, the effective time for signal integration is very limited. Therefore, performance in stereoacuity deteriorates. With the longer presentation duration, there is more time for signals from both eyes to arrive, and for the visual cortex to integrate the signal. We speculate that there is a threshold for disparity information to be fully extracted. Once the stimulus presentation time is longer than the threshold value, the best stereoacuity could be achieved (D_{min}) and is not dependent on the degree of ocular dominance. Even a person with very unbalanced eyes can achieve an excellent level of stereoacuity. How fast one can do this might depend on the speed of binocular signal combination and integration, and how finely one sees stereoacuity might be determined by the efficiency of the cortical neurons to extract the relative disparity from the integrated signals. Ocular dominance mainly affects the first mechanism, and has little to do with the latter one. Since extraction of relative
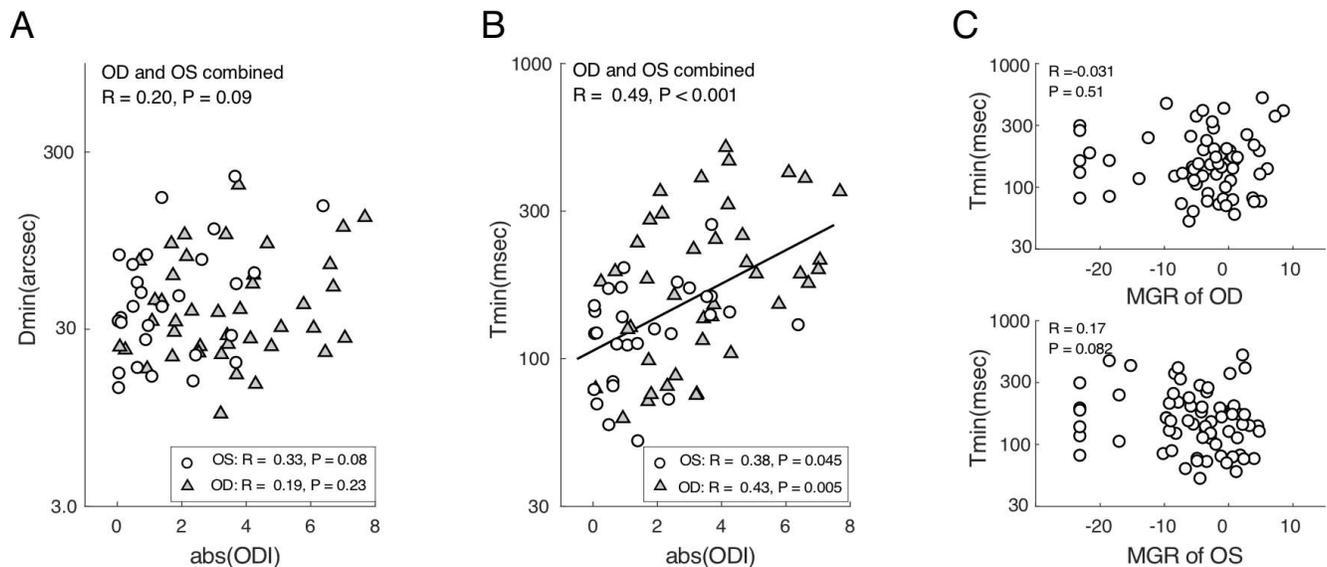
FIGURE 5. The relationship between ocular sensory dominance and stereopsis. (A) D_{min} is not significantly correlated with the absolute value of ODI. *Triangle* represents right eye dominance and *open circle* represents left eye dominance. (B) T_{min} is significantly correlated with the absolute value of ODI. The *drawn line* represents a linear regression. Symbols are the same as in (A). (C) T_{min} is not correlated with either the right or left eye's MGR (*top* and *bottom*, respectively).

interocular disparity happens in visual cortical area 2 (V2) and beyond,[31,32] it seems that ocular dominance may possibly work in V1, where binocular signals converge and integrate.[33–35] One study has reported that the signal conduction speed is relatively faster in the dominant eye.[36] Whether that is the case in sensory dominant eyes remains a case to be explored.

Clinical Implications

Accurate determination of ocular dominance is useful in clinical decision-making, as it relates to monovision management of presbyopia[37–39] with intraocular lens implant in cataract surgery,[40,41] contact lenses,[39,42] or LASIK.[43,44] The determination of ocular dominance has mainly been based on sighting dominance, which takes little time to perform. The key assumption in monovision is that the blur is suppressed more easily in the nondominant eye. There are different opinions on whether the dominant eye should be corrected for distance or near vision.[45–48] Correction for distance would allow for better binocular summation at middle distances and near stereoacuity since the signals from the eyes are roughly equally blurred.[49] This study's results further indicate that ocular dominance has a greater effect on the integration time needed to achieve best stereoacuity. In some professions, such as tennis and baseball players, the ability to correctly judge the depth in a limited time window is critical. In athletes undergoing visual training with dynamic stereo tests, the reaction time, instead of stereoacuity only, is of better predictive value for perceiving the depth.[50] Therefore, the results from this study would lend support to correct the dominant eye for distance.

CONCLUSIONS

This study shows ocular sensory dominance is moderately correlated with integration time for stereopsis processing. Persons with unbalanced eyes need more time to achieve best stereoacuity than those with balanced eyes. However, the best stereoacuity achieved is not related to ocular sensory dominance. With balanced eyes or not, persons can achieve a similar best stereoacuity.

References

1. Mapp AP, Ono H, Barbeito R. What does the dominant eye dominate? A brief and somewhat contentious review. *Percept Psychophys*. 2003;65:310–317.

2. Porac C, Coren S. The dominant eye. *Psychol Bull*. 1976;83:880–897.

3. Cheng C-Y, Yen M-Y, Lin H-Y, Hsia W-W, Hsu W-M. Association of ocular dominance and anisometropic myopia. *Invest Ophthalmol Vis Sci*. 2004;45:2856–2860.

4. 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.

5. Reiss M, Reiss G. Ocular dominance: some family data. *Laterality*. 1997;2:7–16.

6. Livingstone MS, Nori S, Freeman DC, Hubel DH. Stereopsis and binocularity in the squirrel monkey. *Vision Res*. 1995;35:345–354.

7. Weinman J, Cooke V. Eye dominance and stereopsis. *Perception*. 1982;11:207–210.

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

9. Lappin JS. What is binocular disparity? *Front Psychol*. 2014;5:870

10. Wood IC. Stereopsis with spatially-degraded images. *Ophthalmic Physiol Opt*. 1983;3:337–340.

11. Westheimer G, Mckee SP. Stereoscopic acuity with defocused and spatially filtered retinal images. *J Opt Soc Am*. 1980;70:772–778.

12. Schmidt PP. Sensitivity of random dot stereoacuity and Snellen acuity to optical blur. *Optom Vis Sci*. 1994;71:466–471.

13. Patel SS, Bedell HE, Sampat P. Pooling signals from vertically and non-vertically orientation-tuned disparity mechanisms in human stereopsis. *Vision Res*. 2006;46:1–13.

14. Lit A. Presentation of experimental data. *J Am Optom Assoc*. 1968;39:1098–1099.

15. Hess RF, Liu CH, Wang YZ. Differential binocular input and local stereopsis. *Vision Res*. 2003;43:2303–2313.

16. Stevenson SB, Cormack LK. A contrast paradox in stereopsis, motion detection, and vernier acuity. *Vision Res*. 2000;40:2881–2884.

17. Schor C, Heckmann T. Interocular differences in contrast and spatial frequency: effects on stereopsis and fusion. *Vision Res*. 1989;29:837–847.

18. Legge GE, Gu YC. Stereopsis and contrast. *Vision Res*. 1989;29:989–1004.

19. Cormack LK, Stevenson SB, Landers DD. Interactions of spatial frequency and unequal monocular contrasts in stereopsis. *Perception*. 1997;26:1121–1136.

20. Durand A, Gould GM. A method of determining ocular dominance. *JAMA*. 1910;55:369–370.

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

22. Seijas O, de Liaño PG, de Liaño RG, Roberts CJ, Piedrahita E, Diaz E. Ocular dominance diagnosis and its influence in monovision. *Am J Ophthalmol*. 2007;144:209–216.e1.

23. Li J, Lam CS, Yu M, 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.

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

25. Jiang F, Chen Z, Bi H, et al. Association between ocular sensory dominance and refractive error asymmetry. *PLoS One*. 2015;10:e0136222.

26. Patel SS, Ukwade MT, Bedell HE, Sampath V. Near stereothresholds measured with random-dot stereograms using phase disparities. *Optometry*. 2003;74:453–462.

27. Harwerth RS, Fredenburg PM, Smith EL III. Temporal integration for stereoscopic vision. *Vision Res*. 2003;43:505–517.

28. 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.

29. Kawata H, Ohtsuka K. Dynamic asymmetries in convergence eye movements under natural viewing conditions. *Jpn J Ophthalmol*. 2001;45:437–444.

30. Horng JL, Semmlow JL, Hung GK, Ciuffreda KJ. Dynamic asymmetries in disparity convergence eye movements. *Vision Res*. 1998;38:2761–2768.

31. Thomas OM, Cumming BG, Parker AJ. A specialization for relative disparity in V2. *Nat Neurosci*. 2002;5:472–478.

32. Cumming BG, Parker AJ. Binocular neurons in V1 of awake monkeys are selective for absolute, not relative, disparity. *J Neurosci*. 1999;19:5602.

33. Shatz CJ, Stryker MP. Ocular dominance in layer IV of the cat's visual cortex and the effects of monocular deprivation. *J Physiol*. 1978;281:267–283.

34. LeVay S, Hubel DH, Wiesel TN. The pattern of ocular dominance columns in macaque visual cortex revealed by a reduced silver stain. *J Comp Neurol*. 1975;159:559–576.

35. Hubel DH, Wiesel TN, LeVay S. Plasticity of ocular dominance columns in monkey striate cortex. *Philos Trans R Soc Lond B Biol Sci*. 1977;278:377–409.

36. Wang Q, Wu Y, Liu W, Gao L. Dominant eye and visual evoked potential of patients with myopic anisometropia. *BioMed Res Int*. 2016;2016:5064892.

37. Handa T, Mukuno K, Uozato H, et al. Ocular dominance and patient satisfaction after monovision induced by intraocular lens implantation. *J Cataract Refract Surg*. 2004;30:769–774.

38. Evans BJ. Monovision: a review. *Ophthalmic Physiol Opt*. 2007;27:417–439.

39. Gupta N, Naroo SA, Wolffsohn JS. Visual comparison of multifocal contact lens to monovision. *Optom Vis Sci*. 2009;86:E98–E105.

40. Greenbaum S. Monovision pseudophakia. *J Cataract Refract Surg*. 2002;28:1439–1443.

41. Zhang F, Sugar A, Jacobsen G, Collins M. Visual function and spectacle independence after cataract surgery: bilateral diffractive multifocal intraocular lenses versus monovision pseudophakia. *J Cataract Refract Surg*. 2011;37:853–858.

42. Morgan PB, Efron N, Toshida H, Nichols JJ. An international analysis of contact lens compliance. *Cont Lens Anterior Eye*. 2011;34:223–228.

43. Hom M. Monovision and LASIK. *J Am Optom Assoc*. 1999;70:117–122.

44. Braun EH, Lee J, Steinert RF. Monovision in LASIK. *Ophthalmology*. 2008;115:1196–1202.

45. Jain S, Ou R, Azar DT. Monovision outcomes in presbyopic individuals after refractive surgery. *Ophthalmology*. 2001;108:1430–1433.

46. Ito M, Shimizu K, Amano R, Handa T. Assessment of visual performance in pseudophakic monovision. *J Cataract Refract Surg*. 2009;35:710–714.

47. Handa T, Mukuno K, Uozato H, et al. Ocular dominance and patient satisfaction after monovision induced by intraocular lens implantation. *J Cataract Refract Surg*. 2004;30:769–774.

48. Braun EH, Lee J, Steinert RF. Monovision in LASIK. *Ophthalmology*. 2008;115:1196–1202.

49. Nitta M, Shimizu K, Niida T. 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.

50. Schoemann MD, Lochmann M, Paulus J, Michelson G. Repetitive dynamic stereo test improved processing time in young athletes. *Restor Neurol Neurosci*. 2017;35:413–421.

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