A Comparison Between Two Ocular Dominance Tests: Letter Dominance and Binocular Rivalry

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Abstract

Purpose
Ocular dominance can be measured by a variety of tests, which may not yield the same results. This study compared the repeatability and agreement for two ocular dominance tests, a newer letter dominance test and a well-established binocular rivalry test.

Methods
Thirty-nine adults (28 females and 11 males) with normal vision completed three sessions involving letter dominance and the binocular rivalry tests. An additional seven participants completed only one session. Within-test repeatability was assessed through intraclass correlation and standard deviation. Between-tests agreement was assessed through a Bland-Altman test, intraclass correlation, and ocular dominance directions.

Results
Within-test analysis indicated that the letter dominance test had better repeatability than the grating rivalry test (intraclass correlation coefficient: letter dominance 0.829, rivalry 0.790; standard deviation: letter dominance 0.015 [median], rivalry 0.023 [median], $P = .015$). Between-test analysis indicated that the two tests had moderate to good agreement (intraclass correlation coefficient 0.712) and identified the same eye as dominant for most participants, although not all (39 consistent across tests, seven inconsistent when a strict measure of equidominance was adopted).

Conclusion
These analyses indicate that the letter dominance test is a more repeatable measure of ocular dominance than the grating rivalry test, and that ocular dominance magnitude metrics do vary across tests.

Keywords
eye dominance, binocular vision, psychophysical tests, binocular rivalry test, letter dominance test

Suggested citation

Chen X, Chakraborty A, Bobier W, Thompson B. A comparison between two ocular dominance tests: Letter dominance and binocular rivalry. *Can J Optom.* 2025;87(4):27-37. doi:10.15353/cjo.v87i4.6125

Normal binocular vision requires the balance between the suppressive actions of each eye on the other eye.[1–3] This balance can be disturbed by factors such as strabismus and amblyopia, with one eye becoming more dominant.[3,4] However, unequal weightings of ocular dominance can be found in patients without recognized binocular anomalies.[5,6] Dominance patterns have been studied in patients being considered for monovision treatment for presbyopia.[7–11] This has led to various ocular dominance assessments in binocular normal being prescribed monovision.

Initially eye dominance were measured using sighting (eye alignment), such as hole-in-the-card Miles and Porta tests.[12–15] Research has found these tests to be highly variable and dependent on specific conditions.[16,17] For example, better results for monovision are found with tests of dominance using blur suppression.[18] Numerous such tests of sensory eye dominance have been developed. Here the relative contribution of each eye is assessed in response to a cyclopean image viewed under dichoptic conditions. The Worth 4-Dot test[19] is a common and longstanding early example. Through the subsequent development of more quantitative and sensitive sensory tests involving dichoptic motion coherence threshold test,[5,20] binocular phase combination,[21–23] binocular orientation combination,[24,25] and binocular rivalry,[26–32] the strength of sensory ocular dominance has been found to vary from weak (balanced contribution from both eyes to the binocular percept) to strong (significantly greater contribution from one eye) in individuals with normal monocular and binocular vision.[5,6]

Agreement across these tests has been reported to be moderate to poor due to the different visual mechanisms involved.[17,33–35] More importantly, the precision of different ocular dominance tests varies.[36,37] If changes in dominance are to be used to monitor clinical improvement, such tests must be robust enough to not only track subtle changes but also be easily applied in clinical settings.

In 2018, an ocular dominance test was developed that was comprised of letters with opposite contrast polarities.[37] The forced choice psychophysical judgment required parallels that of the subjective component of a standard refraction. Instead of the choice being “which letter appears clearer” the judgment becomes “which letter appears brighter.” Through comparison with other tests of binocular combination and binocular rivalry, the authors concluded that this new ocular dominance test demonstrated the best reliability.[37]

In this article, we provide further evidence indicating that this letter dominance test is suitable for ocular dominance measurement when compared with another commonly used binocular rivalry test that involves dichoptic presentation of gratings with orthogonal orientations (the grating rivalry test).[26–32]

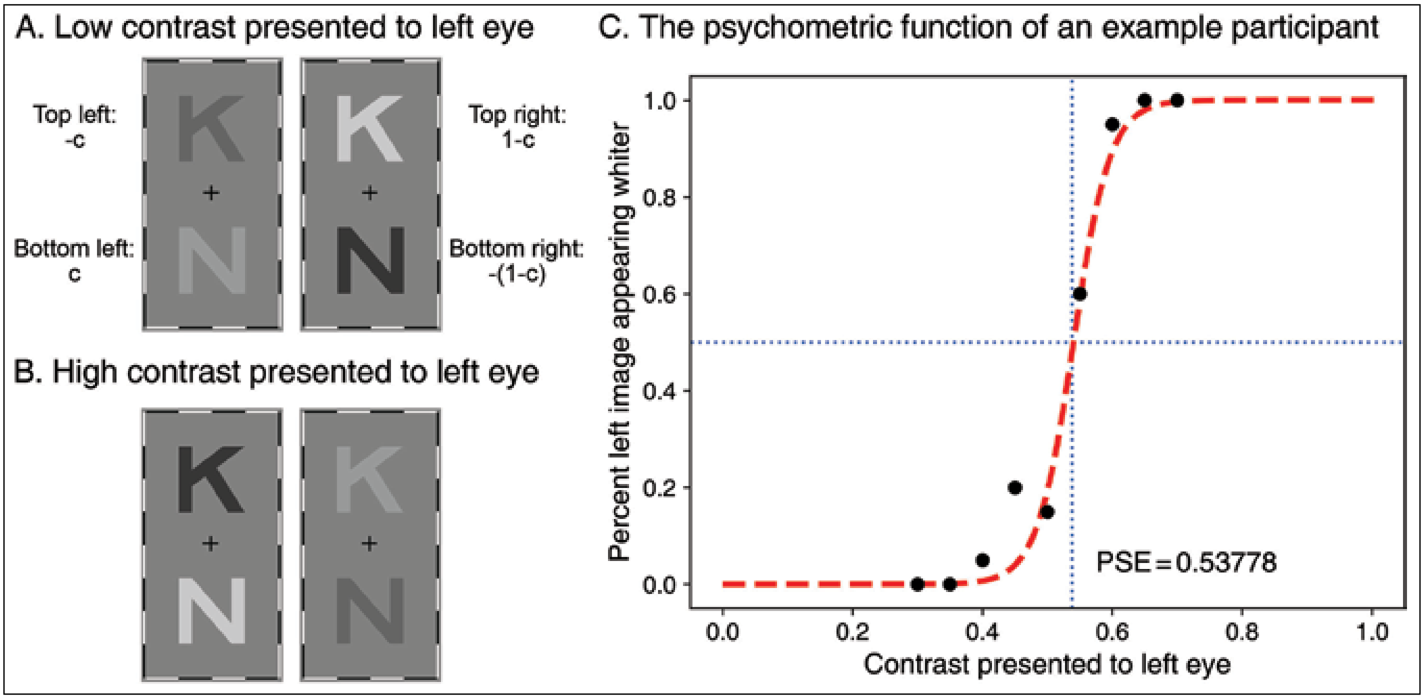
Methods

Baseline sensory ocular dominance data from our two previous non-invasive brain stimulation studies[38,39] were combined and reanalyzed retrospectively. In the first experiment,[38] all participants had aided visual acuity ≤ 0.0 logMAR in each eye. Stereoacuity was not recorded for participants in this experiment. In the second experiment,[39] stricter criteria were adopted where participants had aided visual acuity ≤ 0.0 logMAR in each eye, stereoacuity ≤ 40 seconds of arc, and baseline ocular dominance in the range of 0.5 ± 0.2. The last criterion was to ensure no extreme ocular dominance in our participants so as not to mask the interventional effect in that experiment.

This resulted in 46 participants with at least one measurement for each test was available (age: mean 24.63 ± SD 2.41 years, 30 females and 16 males). Among them, 39 completed three separate sessions of ocular dominance measurements for each test (age: 24.49 ± 2.38 years, 28 females and 11 males). All 46 datasets were independent. The complete datasets are included in Supplementary Table 1. The first experiment was approved by the Ethics Committee of Midwestern University, and the second experiment was approved by the Office of Research Ethics at the University of Waterloo. Both experiments adhered to the *Declaration of Helsinki*, and all participants provided written consent to respective experiments.

In both experiments, participants had both tests in each of three visits, with visits scheduled at least two days apart. In the first experiment, participants always took the grating rivalry test first. In the second experiment, the sequence of both tests was randomized across individuals and visits. Letter dominance stimuli were generated in Python 3.6.6 using the PsychoPy module. In the first experiment,[38] grating rivalry stimuli were generated in MATLAB R2019a (MathWorks, Natick, MA, USA) using Psychtoolbox 3.0.15. Both stimuli were presented on an ROG PG278QR monitor (60 Hz refresh rate, 1920×1080 resolution, gamma-corrected) at 108 cm, (luminance of a medium grey background was 48 cd/m^2). In the second experiment,[39] grating rivalry stimuli were generated in MATLAB R2018a using Psychtoolbox 3.0.18. Both stimuli were presented on an Asus VG279 monitor (60 Hz refresh rate, 1920×1080 resolution, gamma-corrected) at 86 cm (luminance of a medium grey background was 53 cd/m^2). Chin rests were provided to maintain participants’ head position.

Figure 1. Letter contrasts in the letter dominance test



For each trial, two letters were randomly selected from 10 Sloan letters.

(A) On each side, the contrasts of top and bottom letters summed up to zero. On each diagonal, the contrasts of two letters summed up to ±1. A contrast of zero represents no luminance difference from the background (i.e., medium grey). ±1 represents the strongest contrast relative to the background (i.e., +1 fully white, -1 fully black). The contrast value c (always assigned to the left eye, but randomly on the top or bottom) can range from 0 to 1. Positive and negative contrasts were randomly assigned to the top and bottom letters across trials. In this example, a lower contrast (i.e., c < 0.5) was presented to the left eye. Participants were more likely to perceive the top letter (the "K" presented to the right eye) as whiter than the bottom letter.

(B) When a higher contrast (i.e., c > 0.5) was presented to the left eye, participants were more likely to perceive the bottom letter (the "N" presented to the left eye) was whiter than the top letter.

(C) Test results and a psychometric function for an example participant. Because we anticipated participants with normal vision to have a balanced eye dominance (i.e., anticipated point of subjective equality [PSE] = 0.5), to reduce test time, we only tested contrasts from 0.3 to 0.7, instead of the full range 0 to 1. The psychometric function (marked in red) was fitted by a logistic function. The PSE was used as the ocular dominance in this test.

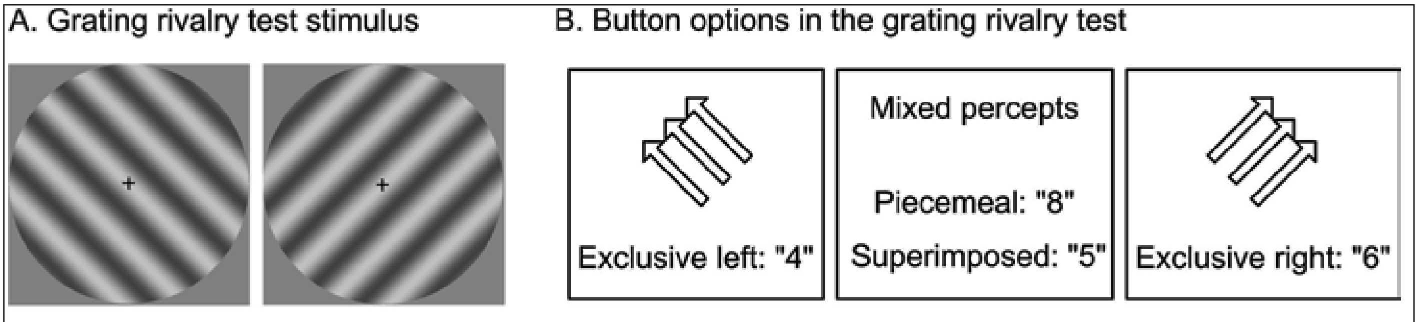
Letter Dominance Test

This test was designed by Bossi et al.[37] Two letters were randomly selected from 10 Sloan letters (C, D, H, K, N, O, R, S, V, Z) in each trial. These letters were placed at 2.75° eccentricity vertically from the fixation cross and presented dichoptically (Figure 1). Each letter subtended 2.75° of visual angle (equivalent to 1.52 logMAR or 6/198 in Snellen). Through a mirror stereoscope, participants fused the fusional borders and saw one letter on the top and one on the bottom. They were asked to report which one of the two letters appeared whiter by clicking the up or down arrow key. Each trial was presented until participants made a choice, up to a maximum of 4.5 seconds. The Weber contrast of letters was manipulated in a conjugal manner so that

1. the top and bottom letters had opposite contrasts and
2. diagonal letters had contrasts that added up to ±1

(Figure 1A). The contrast value varied from 0.3 to 0.7, in steps of 0.05 (9 contrast levels in total). With

Figure 2. Visual stimuli (A) and button options (B) used in the grating rivalry test



$$\text{Ocular dominance} = \frac{\text{DurationRight} + \frac{\text{DurationMixed}}{2}}{\text{DurationLeft} + \text{DurationRight} + \text{Duration Mixed}}$$

Participants used four buttons on the numeric pad to indicate their percepts throughout the test. The ocular dominance equation incorporated both the duration of exclusive right and half of the duration of mixed percepts. This was done to include the contribution of the right eye during mixed percepts. It is mathematically equivalent to the "ocular dominance index" calculated by Min et al.[36]

a smaller value, left letters had lower contrasts but right letters had higher contrasts, and vice versa with a larger contrast value. Positive and negative contrasts were randomized between the top and bottom letters. A positive contrast indicated a lighter grey (higher luminance) than the background colour, whereas a negative contrast indicated a darker grey (lower luminance) than the background. Each of the nine contrast levels was tested 20 times, providing a total of 180 trials.

A logistic function was used to fit the data. The point of subjective equality (PSE), where participants had equal probability of responding top whiter vs bottom whiter (i.e., the contrast balance point), was calculated and used as the ocular dominance metric in this test. A PSE smaller than 0.5 indicated greater dominance by the left eye, and a PSE larger than 0.5 indicated greater dominance by the right eye.

Grating Rivalry Test

In this test, two stationary, orthogonally oriented (±45°) circular gratings were presented, one to each eye (Figure 2). The gratings had a diameter of 2°, a spatial frequency of two cycles per degree (c/deg),[29,30,40–42] and a Michelson contrast of 100%. Participants used one of four buttons to indicate their perception (i.e., exclusive left, exclusive right, piecemeal, and superimposed) and were asked to hold the button while their perception lasted. Each trial lasted one minute, and there were six trials in total. To calculate ocular dominance, piecemeal and superimposed durations were combined into a mixed percept duration. Contribution of the right eye was calculated as the sum duration of exclusive right percepts and half of mixed durations divided by the total duration (equation in Figure 2B). This percentage was used as the ocular dominance measure for this test. As in the letter dominance test, an ocular dominance less than 0.5 indicated greater dominance by the left eye, and an ocular dominance greater than 0.5 indicated greater dominance by the right eye.

Data Analysis

Within-test repeatability analyses were conducted on data where three baseline measurements were available (n = 39). Intraclass correlation coefficient (ICC) estimates and their 95% confident interval (CI) was computed based on a single-rating (k = 1), absolute-agreement, two-way mixed-effects model.[43,44] Additionally, standard deviations were calculated for each individual to assess the variability of each test. Tests of normality were performed with a Shapiro-Wilk test. Standard deviations were compared using a paired-samples t test or, in the case of deviation from a normal distribution, a Wilcoxon signed-rank test.

Table 1. ICC for within-test repeatability and between-test agreement

Test	ICC estimate	95% CI
Letter-polarity	0.829	0.730-0.899
Grating rivalry	0.790	0.674-0.875
Between-test	0.712	0.535-0.829

As recommended by Koo & Li,[43] an ICC value of <0.5 indicates poor reliability, 0.5-0.75 moderate, 0.75-0.9 good, and >0.9 excellent.

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient.

Between-test agreement was examined using the first visit data from all datasets (n = 46). A Bland-Altman test was used to illustrate the spread of the datasets.[45] The Bland-Altman 95% limits of agreement (LoA) were determined as $\bar{d} \pm 1.96s$, where $\bar{d}$ was the mean difference (letter-polarity minus grating rivalry) and s was the standard deviation of the differences. The LoA provides an estimate of the range in which 95% of population differences are expected to fall.[45,46] A linear regression was applied to investigate whether there was a proportional bias;[47] outliers were identified using the interquartile range (IQR) method (values of more than 1.5 × IQR outside the IQR) and were removed from this regression analysis. ICC estimates and their 95% CI based on a single-rating (k = 1), absolute-agreement, two-way mixed-effects model were also used to illustrate the between-test agreement. Finally, an agreement in ocular dominance directions between tests was assessed. To exclude instances of very weak ocular dominance, where the ocular dominance result could fall randomly in either direction, a criterion of inter-test difference was set at 0.04 (0.02 on either side). Opposite directions with a between-test difference of > 0.04 were considered a disagreement in ocular dominance directions. Note that this criterion was arbitrary and was strict compared to other proposed equidominance measures.[48]

ICC was calculated in SPSS (IBM Corp., Armonk, NY, USA). All other statistical analyses were completed in JASP.

Results

Within-Test Repeatability

Repeatability within each ocular dominance test was assessed using ICC. The 95% CI of the ICC estimate (Table 1) indicates that the level of repeatability was moderate to good for both the letter-polarity test (0.730-0.899) and the grating rivalry test (0.674-0.875).

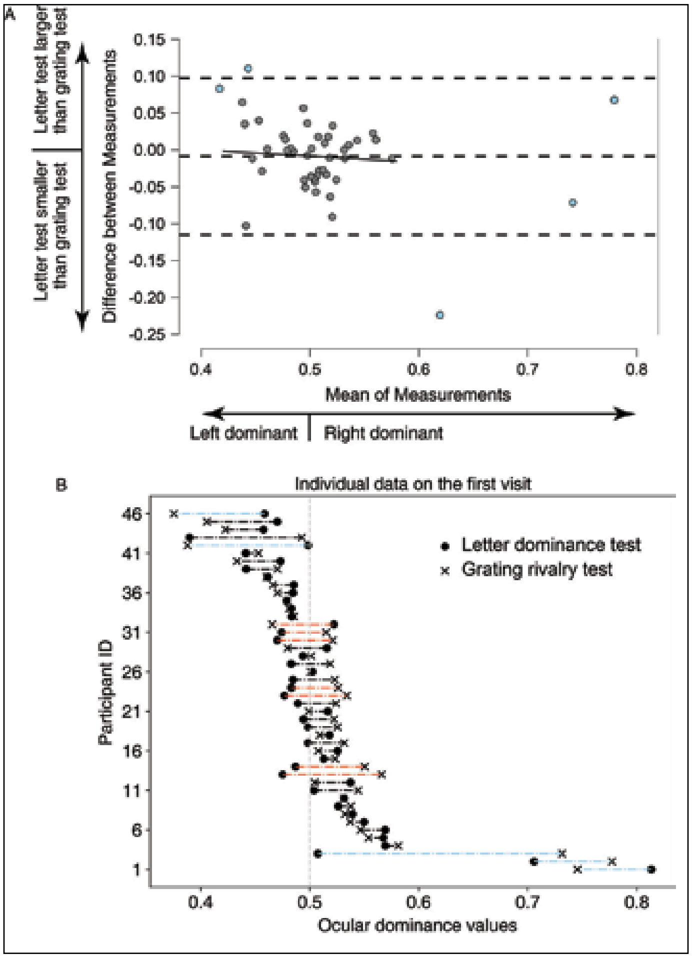
Individual standard deviations from each test were also calculated to assess their variability. The data were not normally distributed (W = 0.908, P = .004). Comparison indicated that the letter-polarity test had significantly lower standard deviations (median 0.015, quartiles 0.009-0.019) than the grating rivalry test (median 0.023, quartiles 0.012-0.034) (W = 563, Z = 2.414, P = .015).

Between-Test Agreement

The difference between both tests was first illustrated through a Bland-Altman analysis for the first-session data (Figure 3A). As recommended by Ludbrook,[47] we performed a linear regression analysis to examine any proportional bias. Assumptions of this analysis were initially validated with the entire dataset (n = 46). After the removal of five outliers (n = 41), the linear regression model was fitted as $\hat{y} = 0.034 - 0.085\,x$ (Figure 3A). The slope did not significantly deviate from zero (t = -0.478, p = 0.635), indicating no proportional bias. (An additional linear regression analysis including the outliers still indicated no proportional bias between both tests [slope = -0.191, t = -1.586, p = 0.120].) Hence, the classical determination of LoA was adopted (i.e., $\bar{d} \pm 1.96s$). The mean difference between tests was -0.009, suggesting that there was only a negligible difference between tests on average. As indicated by the LoA, 95% of the population differences were estimated to be between -0.115 and 0.097. While this spread was larger than expected, most of the data points (37 out of 46, 80.43%) were in the ±0.06 range.

An additional Blant-Altman analysis removing two outliers (i.e., removing the topmost and bottommost data points in Figure 3A, n = 44) showed that the mean difference between tests was -0.007. As indicated by the LoA, 95% of the population differences were estimated to be between -0.086 and 0.073. Hence, the original large LoA was caused by these two outliers. Outliers here were determined using the

Figure 3. Individual data from the first visit



(A) A Bland-Altman plot showing the mean ocular dominance measured by both tests (x axis) against the difference in ocular dominance between tests (y axis). An x value <0.5 indicates greater dominance by the left eye and >0.5 indicates greater dominance by the right eye. A positive y value indicates that the letter-polarity value was greater than the grating rivalry test. The dashed lines show the mean of differences (-0.009) and the upper (0.097) and lower (-0.115) boundaries of the limits of agreement. The solid line represents a regression fitted to the mean of both tests and their differences, with outliers (depicted as blue data points around 0.10 difference between measures and more than 0.6 mean of measures) removed.

(B) Ocular dominance data from each individual as measured by both tests. Data were ordered from top to bottom by their means. Red dashed lines show instances of disagreement in ocular dominance directions according to the predefined criterion.

Blue dots in panel A and blue dashed lines in panel B show outliers that needed to be removed from the regression analysis. The x axes of both panels are aligned for direct comparison. Note that for the letter dominance test, two instances where ocular dominance magnitude of >0.7 were extrapolated point of subjective equality from the logistic curve as our sampling range was 0.3-0.7 (Figure 1C).

same IQR method as the five outliers determined for the linear regression, except that here they were obtained based on the difference between measurements alone. To further illustrate the spread of data, 34 out of 46 (73.91%) of data points was in the ±0.05 range and 31 out of 46 (67.39%) was in the ±0.04 range. Thus, ocular dominance magnitude from both tests was not the same, but the difference was not large for most participants.

The agreement between two tests was also assessed using ICC. The 95% CI of the ICC estimate (Table 1) indicates that the level of agreement was moderate to good (0.535-0.829).

With a criterion of 0.04 for between-test differences, most datasets (39 out of 46, 84.78%) exhibited good agreement in ocular dominance directions, with only seven datasets out of 46 (15.22%) showing disagreement (Figure 3B).

Discussion

Collectively, our within-test analysis indicated that both tests had moderate to good repeatability; however, the letter dominance test exhibited significantly less variability than the grating rivalry test. Our between-test analyses indicated that the two ocular dominance tests had moderate to good agreement. While the estimated 95% LoA for the two tests were wider than expected, and the difference between tests was not large for most individuals.

Our data showed that a small percentage of participants had stronger ocular dominance. This was expected.[5,6] It has been reported that sensory ocular dominance may be influenced by factors such as individual refractive errors and stimulus sizes.[16,49,50] For instance, higher refractive error and higher astigmatism were found associated with the non-dominant eye.[49,50] Due to the retrospective nature of our analysis, we did not record participants' refractive errors or perform a comprehensive evaluation of their binocular visual functions. While stereoacuity was reported not to correlate with ocular dominance,[51] a sampling bias might derive from the fact that only participants with normal vision were tested in this previous experiment.[51] Similarly, we recruited only adults with normal vision. (In one experiment, we only recruited individuals with a stereoacuity of at least 40 seconds of arc, although in the other experiment, stereoacuity was not measured). Therefore, we do not know the reason behind the strong ocular dominance observed in some individuals, nor can we confirm whether they had completely normal binocular vision (not just stereoacuity). In this sample, most of our participants exhibited an ocular dominance of about 0.5 (as shown in Figure 3B), which is a limitation of our dataset. A larger sample including people with stronger ocular dominance, such as individuals with unilateral amblyopia, would be ideal to fully establish the repeatability of both tests.

The dynamics of binocular rivalry have been reported to vary by stimulus size and spatial frequency.[52–55] As Blake et al.[54] proposed, small, discrete spatial zones on the retina are separately dominated by the left or right eye input. When viewing a rivalrous stimulus, the aggregate of multiple zones results in an exclusive or mixed percept at a behavioural level. Therefore, a large stimulus that involves more spatial zones is likely to induce more mixed percepts.[52–54] On the other hand, O'Shea et al.[55] reported a reversed U shape where, for a given spatial frequency, the most exclusive percepts occur under a particular stimulus size, for instance, 2° at 2 c/deg. Incidentally, this was the same as our grating rivalry stimulus. Regardless, it is conceivable that a different stimulus leads to changes in rivalry percepts, which subsequently alters the calculated ocular dominance. In addition, the letter dominance test also involves binocular rivalry due to the use of opposite luminance (i.e., light and dark) between eyes.[37] The large letter size (2.75°) chosen by Bossi et al.[37] presumably induces less rivalry and may therefore help reduce participant errors when they were asked to select the whiter letter. It is unclear whether this difference in stimulus size could have played a role in the repeatability difference between our two tests.

It has been a common finding that ocular dominance results vary across tests and measurements.[8,17,33,34] This may be because these tests involve different underlying mechanisms and may be caused by variations in the testing environment.[7]

While clinicians might like to use the hole-in-card test to determine the dominant eye because of its simplicity, this test is not ideal for ocular dominance measurement since it does not involve binocular vision[16] and does not quantify the degree of ocular dominance.

The newly proposed psychophysical blur preference test[18] provides a quantitative measure of ocular dominance with high repeatability. However, this test takes 14 minutes for both far and near vision[18] and is still under development.

The letter dominance test takes 1.8-4.3 minutes (average 3.1 minutes), and the grating rivalry test is typically 3 minutes.[26,28–32] Therefore, both tests can be done quickly and are worth considering for use in clinical settings. In addition, some quantitative tests have been found to demonstrate more reliability than others.[36,37] Although commonly used in research for ocular dominance measurement,[26,28–32] the grating rivalry test was not ranked among the most reliable tests.[36] Aligning with such observation, our comparison suggests that the letter dominance test may offer better repeatability than the grating rivalry test. Our grating rivalry results were averaged over 6 minutes, despite the literature commonly administering this test only for 3 minutes. Therefore, the variability is unlikely to be due to a lack of data. The superiority of the letter dominance test may be attributed to its intuitive nature and the two-alternative forced choice design.[37] Nevertheless, the grating rivalry test is still useful in studying perceptual alternations over time.

The letter dominance test offers better repeatability than the grating rivalry test and is a suitable choice for the assessment of sensory ocular dominance. Our results support the view that different tests do not measure ocular dominance magnitude equally.

Disclosures

Contributors: Xiaoxin Chen contributed to the conceptualization, methodology, data analysis, visualization, writing (original draft and writing), and reviewing and editing for this study. Arijit Chakraborty contributed to supervision, writing (review and editing), and funding acquisition. William Bobier contributed to supervision, writing (review and editing), and funding acquisition. Benjamin

Thompson contributed to conceptualization, methodology, supervision, writing (review and editing), and funding acquisition. All authors read and approved the final manuscript.

Funding: This work was supported by Natural Sciences and Engineering Research Council [RGPIN-04404 to WB, RGPIN-05394 and RGPAS-477166 to BT], Canadian Foundation for Innovation (34095 to BT), and Midwestern University (Faculty Start-Up Seed Grant to AC). BT was also supported by the Hong Kong Special Administrative Region Government and InnoHK. The funders had no role in the design nor conduction of the experiments nor in the writing of this manuscript.

Competing interests: All authors have completed the International Committee of Medical Journal Editors uniform disclosure form and declare no conflict of interest.

Ethical approval: Informed written consent was obtained from all participants. The research ethics boards at Midwestern University (IRB# IL-20066) and the University of Waterloo (REB # 43953) approved the study.

AI Statement: ChatGPT was used in this manuscript for editing purposes only.

Data: All data analyzed in this study are included in Supplementary Table 1.

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Supplementary Table 1. Individual baseline ocular dominance measurements

Participant	LDT Visit 1	LDT Visit 2	LDT Visit 3	GRT Visit 1	GRT Visit 2	GRT Visit 3
A01	0.53	0.49	0.50	0.51	0.44	0.48
A02	0.52	0.49	0.47	0.47	0.36	0.32
A03	0.48	0.51	0.50	0.49	0.63	0.47
A04	0.52	0.49	0.49	0.48	0.46	0.46
A05	0.48	0.49	0.52	0.53	0.57	0.54
A06	0.44	0.50	0.53	0.45	0.54	0.51
A07	0.50	0.53	0.54	0.53	0.54	0.56
A08	0.50	0.53	0.53	0.54	0.54	0.56
A09	0.49	0.51	0.50	0.52	0.44	0.54
A10	0.50	0.47	0.46	0.39	0.44	0.48
A11	0.71	0.71	0.65	0.78	0.75	0.72
A12	0.57	0.53	0.56	0.58	0.56	0.57
A13	0.47	0.46	0.42	0.41	0.35	0.38
A14	0.48	—	—	0.57	—	—
A15	0.81	—	—	0.75	—	—
A16	0.57	—	—	0.55	—	—
A17	0.47	—	—	0.43	—	—
A18	0.46	—	—	0.42	—	—
A19	0.57	—	—	0.55	—	—
A20	0.51	—	—	0.73	—	—
B01	0.47	0.50	0.47	0.52	0.52	0.51
B02	0.52	0.52	0.51	0.51	0.48	0.47
B03	0.49	0.47	0.47	0.47	0.51	0.50
B04	0.49	0.48	0.50	0.50	0.43	0.45
B05	0.49	0.57	0.53	0.55	0.59	0.51
B06	0.46	0.42	0.44	0.38	0.37	0.35
B07	0.49	0.52	0.51	0.52	0.54	0.54
B08	0.48	0.47	0.51	0.48	0.50	0.49
B09	0.53	0.52	0.52	0.53	0.55	0.58
B10	0.39	0.40	0.43	0.49	0.48	0.49
B11	0.50	0.50	0.50	0.50	0.53	0.53
B12	0.51	0.49	0.51	0.52	0.52	0.52
B13	0.54	0.54	0.54	0.50	0.48	0.51
B14	0.46	0.46	0.47	0.46	0.47	0.47
B15	0.48	0.49	0.49	0.48	0.46	0.54
B16	0.53	0.53	0.55	0.54	0.50	0.50
B17	0.44	0.46	0.45	0.47	0.47	0.48
C01	0.48	0.49	0.50	0.52	0.52	0.50
C02	0.48	0.48	0.50	0.53	0.53	0.48
C03	0.48	0.52	0.49	0.47	0.51	0.47
C04	0.52	0.54	0.53	0.50	0.54	0.50
C05	0.48	0.47	0.47	0.52	0.51	0.50
C06	0.47	0.48	0.50	0.52	0.50	0.48
C07	0.54	0.49	0.51	0.53	0.52	0.52
C08	0.55	0.52	0.52	0.54	0.49	0.54
C09	0.50	0.51	0.52	0.53	0.57	0.50

Abbreviations: LDT, letter dominance test; GRT, grating rivalry test; —, data not available.

Participant numbers starting with A are from Chen et al., 2022.[38] Participant numbers starting with B and C are from Experiment 1 and Experiment 2, respectively, in Chen et al., 2023.[39]

Values > 0.50 indicate greater dominance by the right eye. Data have been rounded to two decimal places.