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WHICH OCULAR DOMINANCE SHOULD BE CONSIDERED FOR MONOCULAR AUGMENTED REALITY DEVICES?

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A monocular augmented reality device allows the user to see information that is superimposed on the environment. As it does not stimulate both eyes in the same way, it creates a phenomenon known as binocular rivalry. The question therefore arises as to whether monocular information should be displayed to a particular eye and if an ocular dominance test can determine it. This paper contributes to give a better understanding of ocular dominance by comparing nine tests. Our results suggest that ocular dominance can be divided into sighting and sensorial dominance. However, different sensorial dominance tests give different results, suggesting that it is composed of distinct components that are assessed by different tests. There is a need for a comprehensive test that can consider all of these components, in order to identify on which eye monocular information should be directed to when using monocular augmented reality devices.

Augmented reality refers to an interactive virtual interface (in 2D or 3D) combined and superimposed in real time with the environment. Within the semi-transparent displays ('see-through' devices), displays can be divided into three types: binocular (two images are displayed, one to each eye), biocular (the same image is displayed to both eyes), or monocular (one image is displayed to one eye). Monocular devices are, in most cases, adjustable (*i.e.* information can be centered with respect to the observer's pupils), and also the lightest and least expensive system. However, as virtual information is only presented to one eye, the two eyes are not stimulated in the same way. This can lead to a phenomenon known as binocular rivalry, which can cause visual fatigue, headaches, visual suppression, etc. (Hershberger & Guerin, 1975). Monocular augmented reality devices therefore raise the question of which eye should receive monocular information.

Currently, there is no consensus in the literature. On the one hand, Hershberger and Guerin (1975) argue that there are fewer disturbing phenomena when information is fed to the dominant eye. On the other hand, and more recently, Cupero et al. (2009) demonstrated that the eye that information is displayed to has no influence on perception. In these two studies, dominant eye was considered as the sighting eye. However, there is little agreement among the scientific community regarding the definition of ocular dominance. The many definitions go hand-in-hand with the multitude of ways to determine it, which together contribute to a lack of clarity on its determination and its use. As binocular rivalry is a sensorial phenomenon (Coren & Kaplan, 1973; Handa et al., 2004; Li et al., 2010; Seijas et al., 2007), the question arises of whether the sighting eye is relevant to considered in the case of monocular augmented reality and if all dominant eye tests gives consistent results. Only Gronwall and Sampson (1971) have found a positive correlation between various dominance tests, suggesting a unifactorial phenomenon. Other authors identified two (*i.e.* sighting and sensory dominance) (Cohen, 1952) to fives groups (*i.e.* monocular acuity, sighting dominance, orientation dominance, sensory dominance and hemi-retina dominance) (Lederer, 1961).

As with any lateralization of the human body, ocular dominance can be expressed in terms of strength of dominance. Chaumillon (2017) found that patients with less pronounced ocular dominance are thought to have fewer visual constraints leading to better support for monovision. This finding, in turn, raises the question of the impact of the strength of ocular dominance on the use of monocular augmented reality devices.

The aim of the present study is to identify whether different dominant eye tests give consistent results in term of preferred eye and strength of dominance.

Methods

Participants

A total of nineteen participants, ten men and nine women with normal or corrected-to-normal vision (18–60 years; mean 36.9±12.1) were enrolled in the experiment. Three participants were excluded from the analysis because their acuity was worth than 0.05 log or their blink rate meant that fixation could not be maintained during the form rivalry test. All participants gave written informed consent. The study was conducted in accordance with the Helsinki Declaration and met local legal requirements (N IDRCB: 2018-A01331-54).

Tests

We compared nine ocular dominance assessment methods conducted in the same order for each participant: far and near acuity, Near Point Convergence test (NPC), first repetition of the form rivalry test, Bagolini test, Worth test, +1.5δ blur test, hole-in-card test, second repetition of form rivalry test, motion coherence threshold test repeated three times and last repetition of form rivalry test (Table 1.).

Following Blake and Logothetis (2002), form rivalry and motion threshold test were displayed using a mirror stereoscope, for details see Neveu et al. (2012). At 0.5 meter, participants perceived a minimum horizontal visual field of 18.30°, and 21.17° vertically through the device. They could indicate what they saw with a computer keyboard and their position was stabilized via a chin rest, forehead support (Handa et al., 2004) and mouthpiece similar to dental X-ray equipment. Stimuli were generated using the MATLAB Psychophysics Toolbox (The MathWork, Natick, MA, USA).

Form rivalry test was based on Coren and Kaplan (1973) and Handa et al. (2004). Two sinusoidal patterns were presented using the stereoscope: one oriented at 0° for the right eye; and at 90° for the left eye. A spatial frequency of 3.87 cpd was selected to approach the highest spatial frequency used in the form rivalry literature. Contrast was set at 100%. Maximum and minimum target luminance were set at 120 and 0.8cd/m², respectively, and mean luminance of the target and background was 42cd/m². The stimulation was presented for ten seconds, during which participants were asked to avoid blinking (blinking acts as a reset of the visual system (Rainwater & Cogan, 1975), and the frequency could have modified the results). They pressed the ‘space’ key on the keyboard when they only saw horizontal striations, and the ‘enter’ key when they only saw vertical striations. If their perception was mixed, they did not press any key. The task was repeated four times with a three-second break to allow the participant to blink.

Table 1.
Different tests used.

Test	Dominant eye	Reférence
1. Hole-in-card	Eye behind the hole when focusing a Landol rings scale at 5m, 551 lux.	(Li et al., 2010)
2. NPC	First eye to diverge.	(Li et al., 2010)
3. Far acuity	Eye having the best acuity on Landol rings scale.	
4. Near acuity	Eye having the best acuity on Logarithmic morphoscopic scale at 0.5m, 551 lux.	
5. Bagolini	Eye needed the highest filter to suppress (by 0.3 to 1.8 log units) at 0.5m, 20 lux.	(Li et al., 2010)
6. Near Worth	Eye having the colored filter of the color of the bottom point of the test at 0.33m, 20 lux.	(Li et al., 2010)
7. +1.5δ blur	Eye having the highest blur induced by +1.5δ when focusing the Landol rings scale.	(Pointer, 2012)
8. Form rivalry	Eye having the target seen the longest time.	(Coren & Kaplan, 1973) (Handa et al., 2004)
9. Motion threshold	Eye having the lowest threshold of points needed to evaluate movement.	(Li et al., 2010)

Data analysis

The results for each test were coded as −1 if the left eye (LE) was dominant, +1 if the right eye (RE) was dominant or 0 if the test did not detect a dominant eye. To be in accordance with the qualitative analysis of the results, strength of dominance for acuity tests, Bagolini and +1.5δ were evaluated using the formula (Li et al., 2010): (RE results – LE result)/(RE result + LE result) whereas it was determined by: (LE threshold – RE threshold)/(LE threshold + RE threshold) for motion coherence test. Strength of dominance for form rivalry was obtained by: (percentage RE – percentage LE)/100. Z scores were calculated qualitative and quantitative data to compare the tests together. Qualitative and quantitative data were analyzed using a Kendall 2 x 2 rank correlation (Coren & Kaplan, 1973; Li et al., 2010). Next, following Coren and Kaplan (1973), a factor analysis was run to determine if the results could be grouped. All statistical analyses used the STATISTICA® (StatSoft, Tulsa, OK, USA) statistics package, and a p value ≤ 0.05 was considered significant.

Results

Results across the tests are very differents (Table 2). To compare qualitative results correlation coefficients were calculated on Z scores. The best correlation was found between the hole-in-card test and the motion threshold test (τ=0.683). The hole-in-card test was also highly correlated with the near vision acuity test (τ=0.583) and the NPC (τ=0.510). To explore the findings in more detail, we carried out a factorial analysis (Table 2). The first factor grouped four tests which can be considered as assessing sighting or motor dominance. Strength of dominance was only analyzed on the other tests (*i.e.* Bagolini, +1.5δ blur, and form rivalry tests), as the sensorial dominance can be the relevant dominance to considered in the case of monocular augmented reality.

Figure 1 shows the participant distribution of the quantitative data in absolute values – values closer to one indicate greater dominance. This figure highlights that ocular dominance was, in general, weak and that the distribution of strength dominance according each test varies. No correlation between quantitative sensory tests was found.

Table 2.
Percentages of Participants (n=16) Classified with Right, Left, or Uncertain and Factor Loadings on Tests for Ocular Dominance on the three Extracted Factors.

Test	Right	Left	Uncertain	Factor I	Factor II	Factor III
1. Hole-in-card	62.5	37.5	-	0.906*	0.047	0.044
2. NPC	31.3	18.8	50	0.674*	0.205	0.212
3. Far acuity	18.8	50	31.3	0.305	−0.745*	0.003
4. Near acuity	31.3	25	43.8	0.708*	0.018	−0.511
5. Bagolini	43.8	25	31.3	0.006	−0.730*	0.074
6. Near Worth	12.5	31.3	56.3	0.021	−0.365	−0.849*
7. +1.5δ blur	50	43.8	6.3	−0.265	−0.799*	0.212
8. Form rivalry	35.7	64.3	-	−0.396	−0.254	0.006
9. Motion threshold	43.8	56.3	-	0.755*	−0.354	0.337
10. Handedness	75	25	-			

Note. *Values above 0.6 are high enough to be considered statistically reliable.

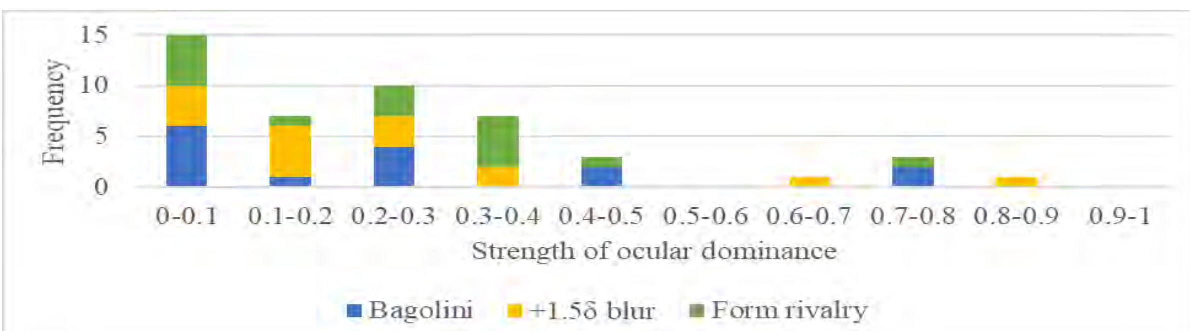

Figure 1.
Distribution of the Population as a Function of Strength of Ocular Dominance.

Discussion

The aim of the present study is to identify whether different dominant eye tests give consistent results in term of preferred eye and strength of dominance. More globally, the goal was to determine whether a particular test is effective in the context of using a monocular augmented reality device.

The analysis of the distribution of ocular dominance shows that it differs according to the test. The results of the hole-in-card test are consistent with Gronwall and Sampson (1971) study.

Like Seijas et al. (2007), we found that the Worth test is unable to classify dominance in a high proportion of subjects, and that the blur test has the lower uncertainty in clinical tests.

Factor analysis distinguished several groups of tests. The first consists of the hole-in-card test, the NPC test, the near vision acuity test, and the motion threshold test. This group of tests mainly takes into account tests identified in the literature as characterizing sighting or motor dominance (*i.e.* hole-in-card and NPC). Correlations between the tests are consistent with this grouping and are consistent with the literature (Coren & Kaplan, 1973; Gronwall & Sampson, 1971; Li et al., 2010, 2010; Pointer, 2012; Seijas et al., 2007). Thereby, the near vision acuity dominance would be more related to the participant's ability to converge than to discriminate details (Pointer, 2012) and it is possible that, despite the central fixation point during the moving threshold test, the moving points generate involuntary ocular eye movement.

The second factor grouped the far vision acuity test, the Bagolini test, and the +1.5δ blur test. However, there were no significant correlations between them. These results suggest that even they may share some common features, they do not give the same results, and they cannot be used interchangeably.

The factorial analysis identified a third factor, mainly based on the near Worth test. The fact that this test is responsible for a factor and does not correlate with other tests suggests that color plays a singular role in sensorial dominance. Our result is consistent with Seijas et al. (2007), who also found that the Worth test was uncorrelated with any other test.

Our results suggest that different sensorial dominance tests give different results. This was confirmed by the analysis of the strength of dominance. Paired correlations highlighted that tests are uncorrelated, as several authors have already noted (Cohen, 1952; Coren & Kaplan, 1973; Li et al., 2010). Our results suggest that sensorial ocular dominance is not unifactorial, but is made up of distinct components. Specifically, each test appears to assess one component of the sensorial ocular dominance. Thereby, Worth test shows which eye is preferred when color challenges binocular vision; the Bagolini test assesses the preferred eye when luminance challenges binocular vision; and the +1.5δ test assesses the preferred eye when blur challenges binocular vision.

Our results suggest that ocular dominance tests fall into two distinct groups: motor and sensory dominance. It suggests that the eye considered by previous studies (Cupero et al., 2009; Hershberger & Guerin, 1975) to explore if information must be displayed in a particular eye when using a monocular augmented reality device is not relevant to considered. While motor tests have similarities, the results of different sensory tests appear to be inconsistent. This latter observation highlights the importance of considering the set of sensory ocular dominance factors to determine the eye on which monocular information should be directed to when using monocular augmented reality devices. As far as we are aware, no test exists to reliably, and whatever the stimulus, determine the sensorial dominance.

References

Blake, R., & Logothetis, N. K. (2002). Visual competition. *Nature Reviews Neuroscience*, *3*(1), 13–21. https://doi.org/10.1038/nrn701

Chaumillon, R., Alahyane, N., Senot, P., Vergne, J., Lemoine-Lardennois, C., Blouin, J., … Vergilino-Perez, D. (2017). Asymmetry in visual information processing depends on the strength of eye dominance. *Neuropsychologia*, *96*, 129–136.

Cohen, J. (1952). Eye-Dominance. *The American Journal of Psychology*, *65*(4), 634. https://doi.org/10.2307/1418050

Coren, S., & Kaplan, C. P. (1973). Patterns of ocular dominance. *Optometry & Vision Science*, *50*(4), 283–292.

Cupero, F., Valimont, B., Wise, J., Best, C., & De Mers, B. (2009). *Head Worn Display System for Equivalent Visual Operations* (No. NASA/CR-2009-215781). Phoenix, AR: Nasa.

Gronwall, D. M. A., & Sampson, H. (1971). Ocular dominance: a test of two hypotheses. *British Journal of Psychology*, *62*(2), 175–185. https://doi.org/10.1111/j.2044-8295.1971.tb02028.x

Handa, T., Mukuno, K., Uozato, H., Niida, T., Shoji, N., & Shimizu, K. (2004). Effects of dominant and nondominant eyes in binocular rivalry. *Optometry & Vision Science*, *81*(5), 377–383. https://doi.org/10.1097/01.opx.0000135085.54136.65

Hershberger, M. L., & Guerin, D. F. (1975). *Binocular rivalry in helmet-mounted display applications* (No. AD-AO13 838) (pp. 1–146). Culver City, CA: Aerospace Medical Research Laboratory.

Lederer, J. (1961). Ocular dominance. *Clinical and Experimental Optometry*, *44*(11), 531–574. https://doi.org/10.1111/j.1444-0938.1961.tb06505.x

Li, J., Lam, C. S. Y., Yu, M., Hess, R. F., Chan, L. Y. L., Maehara, G., … Thompson, B. (2010). Quantifying sensory eye dominance in the normal visual system: a new technique and insights into variation across traditional tests. *Investigative Ophthalmology & Visual Science*, *51*(12), 6875–6881. https://doi.org/10.1167/iovs.10-5549

Neveu, P., Philippe, M., Priot, A.-E., Fuchs, P., & Roumes, C. (2012). Vergence tracking: a tool to assess oculomotor performance in stereoscopic displays. *Journal of Eye Movement Research*, 9. https://doi.org/10.16910/jemr.5.2.1

Pointer, J. S. (2012). Sighting versus sensory ocular dominance. *Journal of Optometry*, *5*(2), 52–55. https://doi.org/10.1016/j.optom.2012.03.001

Rainwater, G., & Cogan, R. (1975). Simultaneous disappearances of both images during binocular rivalry of contours and effect on eye-blink rate. *Perceptual and Motor Skills*, *40*(1), 71–77. https://doi.org/10.2466/pms.1975.40.1.71

Seijas, O., de Liaño, P. G., de Liaño, R. G., Roberts, C. J., Piedrahita, E., & Diaz, E. (2007). Ocular dominance diagnosis and its influence in monovision. *American Journal of Ophthalmology*, *144*(2), 209–216. https://doi.org/10.1016/j.ajo.2007.03.053