Advancing Eye Dominance Testing: Comparing Traditional Methods with an In-HMD Approach for AR/VR Applications

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(a) Miles-Test [14] (b) Hole-in-card test [19]. (c) Point-Test [19]. (d) In-HMD test [19].

Figure 1: a)–c): Traditional eye dominance tests. d) Our virtual hole-in-card eye-dominance test. A card with a hole is attached to a controller and the participant has to look through the card at the target. This is only possible with one eye — the dominant eye.

Abstract

Eye dominance, the subconscious preference for one eye, is an increasingly critical factor in optimizing user experiences in virtual and augmented reality (AR/VR) applications. However, traditional methods for determining eye dominance often produce inconsistent results, creating challenges for calibration and the development of reliable eye-dominance-based technologies. To address this, we investigated eye dominance by comparing three traditional tests with a novel in-HMD test, designed specifically for immersive AR/VR settings. Our findings revealed that while traditional methods often produced inconsistent results, the in-HMD test demonstrated greater alignment with established methods. Based on these results, we provide recommendations on testing eye dominance in future research to improve reliability. Furthermore, the in-HMD test demonstrates strong potential as a practical and valid alternative for AR/VR applications, offering a streamlined approach for calibration and advancing the development of eye-dominance-based technologies.

Index Terms: eye dominance, eye-tracking, AR, VR

1 Introduction

Eye dominance is the subconscious preference of one eye over the other [18]. While being studied widely in psychology and vision science [1, 10, 2], it has only recently acquired attention in HCI and augmented and virtual reality (AR/VR). For example, results of Prummer et al. [20] suggest that eye dominance behaviour is similar in VR and non-VR experiments. Similarly, researchers see the potential of exploiting eye dominance to improve (foveated) rendering [13], pointing [12], and content presentation [22]. Each of these studies determine participants' dominant eye and integrate this information into their techniques. For example, to improve the efficiency of foveated rendering, the image for the non-dominant eye is rendered in lower quality than the image for the dominant eye — without the user noticing.

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To exploit the dominant eye, researchers need to know which eye is dominant. Thus, participants' dominant eye must be determined before or during studies. Here, psychology and vision science proposed several testing methods that can be performed to determine which is the dominant sighting eye. Among others, the Miles test, the hole-in-card test, and the point test are prominent. While all of them have the same objective, determining the dominant eye, they differ in how this is achieved. Some tests rely on the participant reporting their dominant eye [2], and some rely on the experimenter observing [15].

However, prior research critiques these tests, suggesting that they do not always agree [23, 6]. Comparing these methods is crucial for improving their consistency and identifying the most reliable approach. A standardized testing method appears to be lacking in extended reality (XR) work, leading researchers to adopt various available tests. While this is fine for research and laboratory studies, requiring a dedicated step outside the head-mounted display (HMD) potentially degrades the onboarding experience, making it challenging to test and deploy eye-dominance-based technologies at scale. Here, a method determining the dominant eye in the HMD within the eye tracking calibration process would streamline this process.

In this work, we compare three traditional eye dominance tests to see how much they agree with their outcome. In addition, we propose an in-HMD eye dominance test (Virtual Hole-in-Card Test) and contrast its results with the traditional tests. Our results show that traditional tests do not always agree with each other, with the point test deviating from the norm most often. Our results also show that our in-HMD method agrees almost always with the Miles and Hole-in-Card test and, most of the time, with the majority consensus of the three traditional tests. We conclude with the recommendation that it is necessary to use multiple tests to build up a consensus about the dominant eye and that an in-VR hole-in-card test seems to be a valid alternative

These results are valuable for guiding researchers and practitioners working with eye dominance in selecting which tests to use and introducing an in-HMD alternative. This facilitates the development of eye-dominance-based rendering, interaction, and content presentation techniques.

2 Eye Dominance Testing Methods

The following briefly describes the three most prominent traditional eye dominance tests and our in-HMD testing method.

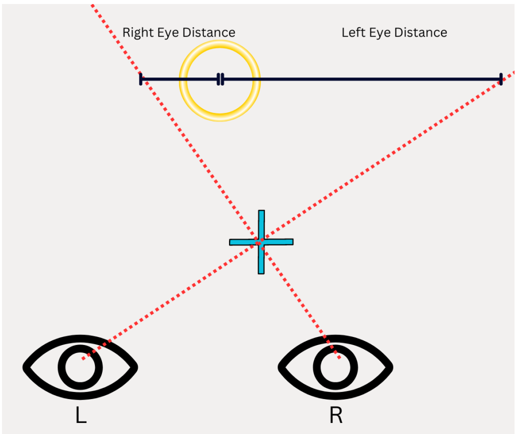

Figure 2: Schematic of distance-based eye dominance classification in VR. Participants aligned a virtual hole-in-card cursor (+) with a distant virtual target (◯).

2.1 Traditional Testing Methods

Which eye is dominant is reported to depend on the test method used [6, 16]. Many methods measure or determine the dominant eye, yet these can differ greatly in procedure and outcome [23]. The commonly utilized methods are the hole-in-card test (also known as the Dolman test) [1], pointing test (referred to as the Porta test or near-far-alignment test) [11], and the Miles-test [15]. Given the nature of these testing methods, sighting eye dominance is measured in monocular situations, requiring a conscious or subconscious choice between the two eyes [4].

2.1.1 Miles-Test

1a shows participants performing a variation of the Miles-Test [15]. Generally, participants are instructed to look at the experimenter through a small hole. The hole can be an object (e.g., a cone as illustrated in the picture) or, alleviating the need for external objects, a triangle shaped with their hands. Through the hole created, participants are instructed to focus on the experimenter's nose, who stands a few meters before them. The experimenter then observes which eye the participant aligns with the hole and records that eye as the dominant one. Thus, it is not the participant who indicates what they see, but rather the experimenter who determines which eye the participant tends to use to align with the stimulus.

2.1.2 Hole-in-Card

The hole-in-card is also known as Dolman test and is completed using a card with a central hole (cf. 1b [5]). Participants typically hold the card with both hands reached out in front of them. Through the hole, subjects view a distant target. Participants are then instructed to alternate the closing of one eye and indicate whenever the target is no longer seen through the hole in the card. The open eye, in which the target is still visible through the hole, is dominant. Here, the participant reports the outcome.

2.1.3 Point Test

The point test (see 1c), also known as the Porta test, follows a similar method to the hole-in-card test [19]. Instead of holding a card, participants point at a distant target. Then, they alternate closing one eye and indicate whenever the target is no longer pointed at. The eye with which participants still point at the target is determined as dominant. Again, the participant reports the result.

2.2 Proposed: Automatic Virtual Hole-in-Card Test

Based on previous work by Prummer et al. [20], we developed an automatic geometric classification method for eye dominance in VR.

In VR, participants are required to align a virtual cursor and a target with their line of sight. The dominant eye is determined using the target position, the cursor position, and the position of the eyes. Figure 2 illustrates determining eye dominance with this approach. The cross represents the VR cursor position (centre of a hole-in-card), while the ring marks the target's centre. Red lines depict (invisible) rays from each eye passing through the cursor's centre. To identify the dominant eye, we measure the distances between the target's centre and each red line along a line that extends through the target and runs parallel to both eyes, assigning dominance to the eye with the shorter distance. The dominant eye is then determined after an alignment period of 100 frames.

In our implementation, a virtual round target (3.2423°) and a rectangular card (10×10 cm) with a dynamically adjustable central hole (3.2423° in size) were attached to the controller. This setup emulated the traditional hole-in-card technique. Participants viewed the target through the hole while aligning the target, cursor, and one eye. The card enforced precise alignment of one eye with the target, reducing parallax and double vision effects. Khan and Crawford [9] positioned targets 0.53 cm away from participants with a 3 cm diameter. In contrast, we placed targets at a 2 m distance to induce a noticeable parallax effect and ensure they remained out of reach. The target's angular size of 3.2423° corresponded to a 3 cm perceived size in the visual field. Alignment was automatically verified after maintaining successful alignment for 100 consecutive frames. If alignment was interrupted, the counter reset. Figure 3 shows the left and right eye's view of a participant after successful alignment. Code for the calculation is open-source and free to use, available at https://removed-for-review.

2.3 Summary of testing methods

In both the hole-in-card and point test, the test results depend on the participant indicating alignment with a distant target. Ideally, participants can make a clear distinction between both eyes in these tests. Nevertheless, a limitation of these two methods is their subjective nature. Ambiguous results may occur when participants indicate the target is well-aligned with either eye. Here, it is possible that they either adjust their posture to re-align the finger or card with the target. In turn, the Miles test relies on the experimenter, who can note with which eye a participant has aligned the target. Again, small shifts in posture and anatomy, such as small IPD, can make determining the dominant eye cumbersome. With the in-HMD method, such small postural adjustments in posture are prevented by participants being required to keep the eye, cursor, and target aligned. It also does not require any intervention from an experimenter (or manual reporting in general). Thus, this method could be added as an additional (even invisible) step during the eye tracking calibration or on-boarding. For example, a dwell-based confirmation could start or end the eye-tracking calibration.

3 Study

As part of a larger study, we tested participants' eye dominance using the three most commonly used tests: Miles-, hole-in-card- and point test. Each participant completed each test once. All tests, except for the in-HMD method, were performed using both hands to eliminate any potential hand bias in the results. Since it is uncommon to hold a VR controller with both hands, we opted to test it with one hand at a time. To examine the effects of handedness, each participant completed the test twice — once using the left hand and once using the right hand.

Figure 3: Left and Right Eye View for the virtual Hole-in-Card Test: This figure shows the participant's view during the task. The left panel displays the left eye's -, and the right panel shows the right eye's view of the yellow target. The grey card is attached to the cursor held by the participant. In this instance, the participant used their right eye to align the cursor with the target, indicating right-eye dominance during the trial.

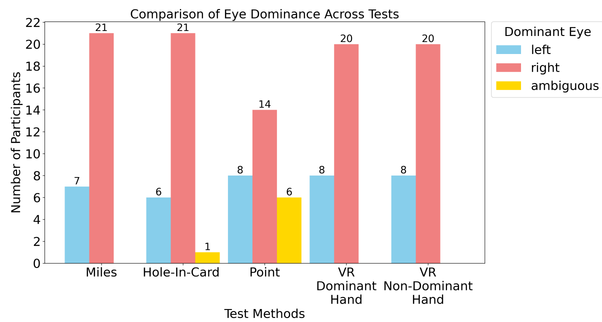

Figure 4: Number of participants classified as left dominant, right dominant, or ambiguous across five eye dominance testing methods. The results demonstrate variability in classifications, highlighting potential inconsistencies between test methods.

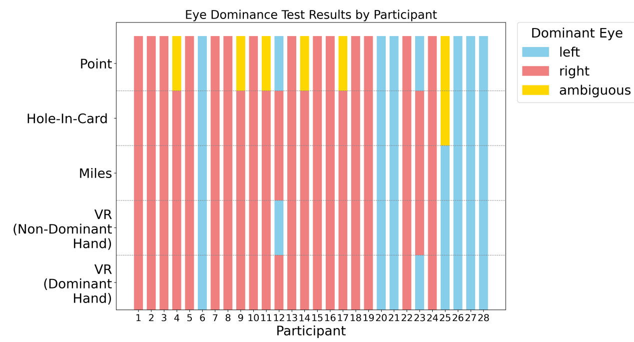

Figure 5: Eye dominance test results per participant of five eye dominance testing methods. The point test shows most inconsistencies due to many classifications as "ambiguous". Note: Participant 3 is left-handed, and participant 10 is ambidextrous.

3.1 Procedure

Before participation, subjects signed informed consent and completed a demographics questionnaire. A *Edinburgh Handedness Inventory* [17] test was completed by each participant at the end of the study. The questionnaire determines the strength of handedness, allowing for a more defined understanding of participants' handedness. Then, subjects completed each eye dominance test as instructed. Participants completed the three traditional tests in order (Miles, hole-in-card, p point test). First, eye dominance was tested with the *Miles-test*, using a triangle with both thumbs and index fingers. The *hole-in-card test* was conducted using a 10×10cm card containing a 2.5cm diameter hole in the centre. While aligning the card at head height, subjects then viewed a 3m distant target through the hole of the card. For the *Point test*, participants pointed at a 3m distant target with both index fingers, shaping their hands like a gun (hands clasped). Finally, as part of the main experiment (reported elsewhere), participants aligned the virtual card with a virtual target.

3.2 Participants

The study involved 28 participants (11 female, 16 male, 1 non-binary; M = 29.12 years, SD = 8.02; age range: 20–48) recruited from our local university. Seventeen participants reported normal vision, while 11 had corrected-to-normal vision (using contact lenses to avoid discomfort with large eyeglass frames in the HMD). Most participants (26) were right-handed, with one left-handed and one ambidextrous, as determined by the Edinburgh Handedness Inventory. Participants received £10 as compensation. The university's ethics committee approved the study.

4 Results

Figure 4 illustrates the cumulative sum of all tests. Overall, the eye dominance testing methods yielded inconsistent results, as indicated by the different amount of people classified as left-eye dominant, right-eye dominant, and ambiguous per test. While general trends exist (more right than left eye dominant participants), only the hole-in-card test and the point test led to participants being classified as ambiguous (note this happened when it was unclear which eye was used for alignment, e.g., due to participant repeatedly shifting posture). Looking at all results, no two tests agree (or disagree), except the two in-VR tests. The point test is a strong outlier, having 6 participants classified as ambiguous.

Looking at test results per participant, Figure 5 shows the distribution of left-, right-eye dominant and ambiguous participants Only participants 12, 23, and 25 displayed true disagreements, with more than two tests disagreeing. For all other non-agreeing tests, only one test does not agree (Participants 4, 9, 11, 14, and 17). For two participants (12 and 23), the in-VR tests disagree (one says left- and the other says right-eye dominant). These two participants are also the only two where the Point test disagrees with the majority and does not say ambiguous but left-eye dominant. For all other tests, the in-VR tests agree with each other and the majority value of the traditional tests.

5 Discussion

Our results reveal inconsistencies across eye dominance tests, with varying classifications as left-eye dominant, right-eye dominant, or ambiguous. Our findings indicate that traditional tests frequently disagree (9 out of 28 cases), with the point test being the most divergent (8 out of 9 cases). In contrast, our in-HMD method shows a high level of agreement with both the Miles test (26 out of 28 cases) and the Hole-in-Card test (25 out of 28 cases) and aligns with the majority consensus of the three traditional tests in most instances (25 out of 28 cases). The two in-VR tests almost always agreed with each other (26 out of 28 cases) and most traditional test outcomes. The hole-in-card and point tests were the only methods to classify participants as ambiguous, often due to unclear alignment. Notably, two participants (12, 23) disagreed within the in-VR tests (dominant- vs non-dominant hand), highlighting potential issues with traditional and point-based methods while supporting the reliability of in-VR testing.

5.1 Possible Reasons for Inconsistencies

The point test requires participants to point themselves and alternately close one eye. Participants might subconsciously adjust their fingers or upper body to align with the target while keeping one eye closed. In addition, different anatomies (e.g., IPD, arm length) might prevent a correct singular alignment (as in: the target is close to being aligned with both eyes). The point test is also the only test that does not require participants to look "through" something (hole in a card, triangle formed by hands), thus making it more susceptible to the parallax effect (double images). This could have irritated participants but also led to them aligning the target "between the two ghost images". While the parallax effect could also influence the results of the Miles test or the hole-in-card test, the material surrounding the hole participants look through minimizes this effect. Despite thorough explanations, the point tests appear inherently susceptible to inaccuracies, as indicated by the high number of ambiguous cases.

Interestingly, all traditional tests are bi-manual and, thus, do not integrate the influence of the hand used for alignment into their results. However, previous research has suggested that the hand used for interaction can influence which eye is dominant [8, 7, 3]. This might be the cause for the disagreement between the in-VR tests.

5.2 Recommendations & Future Work

Generally, tests where people look "through" an object seem to lead to more agreement, as they avoid the parallax effect. However, they are removed from the reality of 3D user interaction as there, the parallax effect is indeed an issue [21].

To ensure accurate results in controlled experiments, we recommended using **multiple eye dominance tests** rather than relying on a single method, which may lead to incorrect or inconsistent outcomes. Combining tests and determining a majority consensus provides a more stable classification while reducing the likelihood of ambiguous results. Utilizing various methods, such as the hole-in-card, Miles, and in-HMD VR tests, ensures a comprehensive evaluation and minimizes instances where no definitive value can be determined. Our **automatic testing in HMD** offers significant advantages for applications and calibration procedures. Our VR eye dominance testing method eliminates the need for participants to close an eye or verbally indicate their observations, as the system automatically tracks and determines eye dominance.

Eye dominance test protocols should be carried out with clear and standardized instructions to ensure consistency and avoid ambiguity or misinterpretation. It is crucial to emphasize that participants must avoid any additional hand movements or postural adjustments when pointing, as these can introduce variability in the results. When conducting the Miles test, it is ideal to use participants who are naïve to the testing purpose to minimize the risk of subconscious pre-selection of their dominant eye. Additionally, eye dominance is best to be assessed ain the same environment where it will be applied, as contextual factors may influence the results.

A need for **multi-point testing** may arise from the dynamic nature of eye dominance observed in prior research [20, 9]. While many systems and tests perform a one-off calibration at 0°, it remains unclear how changes in eye dominance, influenced by factors such as horizontal viewing angles [9, 20] or handedness [10], affect system performance. This raises the question of whether single-point testing is sufficient or if multi-point testing procedures are necessary to account for variations in dominance across different contexts and ensure reliable system behaviour. Further investigations are required to determine whether dynamic recalibration can improve performance in scenarios where eye dominance shifts. .

6 Conclusion

This study investigated eye dominance in AR/VR by comparing three traditional tests and introducing an in-HMD test, the Virtual Hole-in-Card Test. Our results showed that traditional tests often disagreed, with the point test deviating the most. In contrast, the in-HMD test demonstrated strong alignment with the Miles and Hole-in-Card tests, and generally agreed with the majority consensus of the traditional methods. These findings emphasize the need for multiple tests to establish eye dominance and suggest the in-HMD test as a valid alternative for AR/VR applications. This work provides practical insights for researchers and practitioners by streamlining eye-dominance testing, simplifying the calibration process, and supporting the development of eye-dominance-based technologies. Future research should explore the in-HMD method's reliability across diverse contexts and investigate dynamic factors affecting eye dominance to establish standardized procedures for XR applications.

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References

[1] K. Akabalieva, V. Kotetarov, and A. Beshkov. A better approach of assessing lalerality by using combined foot and eye dominance scale in mentally healthy subjects. 50(2):33–41, 2023. doi: 10.2478/amb-2023-0017 1, 2

[2] M. Almasi, A. Mirzajani, J. Abolghasemi, and S. Rahmani. Examining the relationship between the dominant eye and the dominant hand. 6(1):0–0, 2023. Publisher: Function and Disability Journal. doi: 10.32598/fdj.6.233.1 1

[3] D. P. Carey and C. V. Hutchinson. Looking at eye dominance from a different angle: Is sighting strength related to hand preference? 49(9):2542–2552, 2013. doi: 10.1016/j.cortex.2012.11.011 4

[4] B. Clark and N. Warren. A consideration of the use of the term ocular dominance. 1938. doi: 10.1097/00006324-193811000-00003 2

[5] A. L. Combs. Patterns of lateral preference: Hand, eye, thumb and clapping. 57(3):847–850, 1983. Publisher: SAGE Publications Inc. doi: 10.2466/pms.1983.57.3.847 2

[6] S. Coren and C. Porac. Monocular asymmetries in visual latency as a function of sighting dominance. 59(12):987, 1982. 1, 2

[7] J. Crawford, D. Henriques, W. Medendorp, and A. Khan. Ocular kinematics and eye-hand coordination. 11(1):33–47, 2003. doi: 10.1076/stra.11.1.33.14094 4

[8] B. Crider. A battery of tests for the dominant eye. 31(2), 1944. doi: 10.1080/00221309.1944.10543187 4

[9] A. Z. Khan and J. D. Crawford. Ocular dominance reverses as a function of horizontal gaze angle. 41(14):1743–1748, 2001. doi: 10.1016/S0042-6989(01)00079-7 2, 4

[10] A. Z. Khan and J. Douglas Crawford. Coordinating one hand with two eyes: optimizing for field of view in a pointing task. 43(4):409–417, 2003. doi: 10.1016/S0042-6989(02)00569-2 1, 4

[11] J. Lederer. Brainedness, handedness and eyedness: The meaning of ocular dominance*. 53(11):323–347, 1970. doi: 10.1111/j.1444-0938.1970.tb01054.x 2

[12] J. H. Lee and S.-H. Bae. Binocular cursor: Enabling selection on transparent displays troubled by binocular parallax. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*,

CHI '13, p. 3169–3172. Association for Computing Machinery, New York, NY, USA, 2013. doi: 10.1145/2470654.2466433 1

[13] X. Meng, R. Du, and A. Varshney. Eye-dominance-guided foveated rendering. *IEEE Transactions on Visualization and Computer Graphics*, 26(5):1972–1980, 2020. doi: 10.1109/TVCG.2020.2973442 1

[14] W. R. Miles. Ocular dominance demonstrated by unconscious sighting. 12(2):113–126, 1929. Place: US Publisher: Psychological Review Company. doi: 10.1037/h0075694 1

[15] W. R. Miles. Ocular dominance in human adults. 3:412–430, 1930. Place: US Publisher: Heldref Publications. doi: 10.1080/00221309.1930.9918218 1, 2

[16] P. K. Minucci and M. M. Connors. Reaction time under three viewing conditions: Binocular, dominant eye, and nondominant eye. 67(3):268–275, 1964. Place: US Publisher: American Psychological Association. doi: 10.1037/h0039953 2

[17] R. C. Oldfield. The assessment and analysis of handedness: The edinburgh inventory. 9(1):97–113. doi: 10.1016/0028-3932(71)90067-4 3

[18] C. Porac and S. Coren. The dominant eye. *Psychological bulletin*, 83:880, 1976. doi: 10.1037/0033-2909.83.5.880 1

[19] N. Pradham, G. White, N. Mehta, and A. Forgione. Mandibular deviations in TMD and non-TMD groups related to eye dominance and head posture. 25(2):147–155, 2001. doi: 10.17796/jcpd.25.2.j7171238p2413611 1, 2

[20] F. Prummer, L. Sidenmark, and H. Gellersen. Dynamics of eye dominance behavior in virtual reality. *Journal of Eye Movement Research*, 17(3), 2024. doi: 10.16910/jemr.17.3.2 1, 2, 4

[21] U. Wagner, M. N. Lystbæk, P. Manakhov, J. E. S. Grønbæk, K. Pfeuffer, and H. Gellersen. A fitts' law study of gaze-hand alignment for selection in 3d user interfaces. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23. Association for Computing Machinery, New York, NY, USA, 2023. doi: 10.1145/3544548.3581423 4

[22] S.-F. Yang-Mao, Y.-T. Lin, M.-H. Lin, W.-J. Zeng, and Y.-l. Wang. Evaluation of Mono/Binocular Depth Perception Using Virtual Image Display. In M. Kurosu, ed., *Human-Computer Interaction. Towards Intelligent and Implicit Interaction*, pp. 483–490. Springer, Berlin, Heidelberg, 2013. doi: 10.1007/978-3-642-39342-6_53 1

[23] F. Zeri, M. De Luca, D. Spinelli, and P. Zoccolotti. Ocular dominance stability and reading skill: A controversial relationship. 88(11):1353, 2011. doi: 10.1097/OPX.0b013e318229635a 1, 2