Virtual Reality [VR] as a tool to assess the effects of asymmetric vision loss on visual search performance

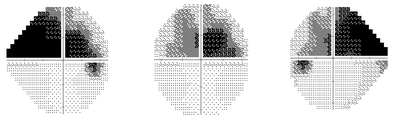
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Background

Glaucoma is a progressive blinding eye-disease that affects 1 person in 50 aged 40+ years. It can be managed but not reversed, yet even in developed countries, it is estimated that over 50% of cases are undiagnosed [1]. This is commonly thought to be because initial vision loss is often restricted to the peripheral vision of one eye, and the better eye is able to 'compensate', meaning that day-to-day function is not affected. This is made explicit in the notion of the 'integrated visual field' [2] [Fig 1], in which visual function is thought to be determined by the better eye. If this is true, then performance on an everyday visual task would be unchanged if the vision in one eye only was degraded (unilateral loss).

[Fig. 1] Example of Integrated Visual Field map showing the current belief that visual ability is determined purely by the better eye



Left Eye | Integrated Visual Field | Right Eye

Aims of this Study

How does asymmetric vision loss affect performance on real world tasks? In the present work, we used virtual reality to simulate vision loss in one or both eyes, and measured performance (response latency) on a common everyday task: locating a household object (mobile phone) in various simulated domestic environments.

Methods

Participants wore a FOVE0 Eye-Tracking VR headset [Fig. 2]. Search environments [Fig 3] were simulated using Unity 3D v5.5.2 (Screen: 70 Hz, Eye-tracker: 120 Hz). Impairments were simulated by using OpenGL mip-mapping to apply a variable amount of gaze-contingent blur to the visual scene [3] [Fig. 4]. For more info regarding the simulator see: https://tinyurl.com/PJ-VRsim2018

"Where Is My Phone?" – The Game

Participants: 11 healthy adults (divided in 2 groups: uniform whole-field (n = 6), peripheral blur (n = 5)).

Procedure: Participants were asked to find a smartphone in a naturalistic environment (3D virtual house) within 45 seconds, while either uniform, or peripheral blur of varying magnitude (5 levels of blur) was simulated. N trials = 250,10 trials per condition.

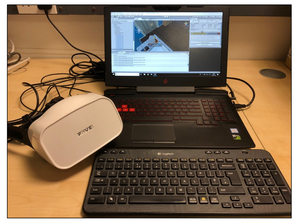
Texture-in-Texture Search Task

Participants: 6 healthy adults.

Procedure: Participants were asked to find a 3D textured-bump in an artificial environment (3D texture-matched sphere) within 60 seconds, while uniform blur of varying magnitude was simulated (5 levels of blur). N trials = 250,10 trials per condition.

[Fig. 2] Virtual Reality Set-Up

Participants wore the headset (white box), and pressed the 'space' key on a keyboard to give their answer. The laptop allowed us to monitor the calibration and check the eye-tracking.



[Fig. 3] Example of simulated rooms

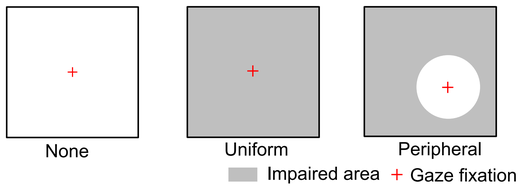
We simulated N = 18 rooms, and in each room the phone was randomly located at one of ten locations.



← Target (phone)

[Fig. 4] Schemas of Visual Field Loss Filters

The peripheral blur is gaze-contingent and has a radius of 9 degrees VA, which corresponds approximately to the macula.



Results

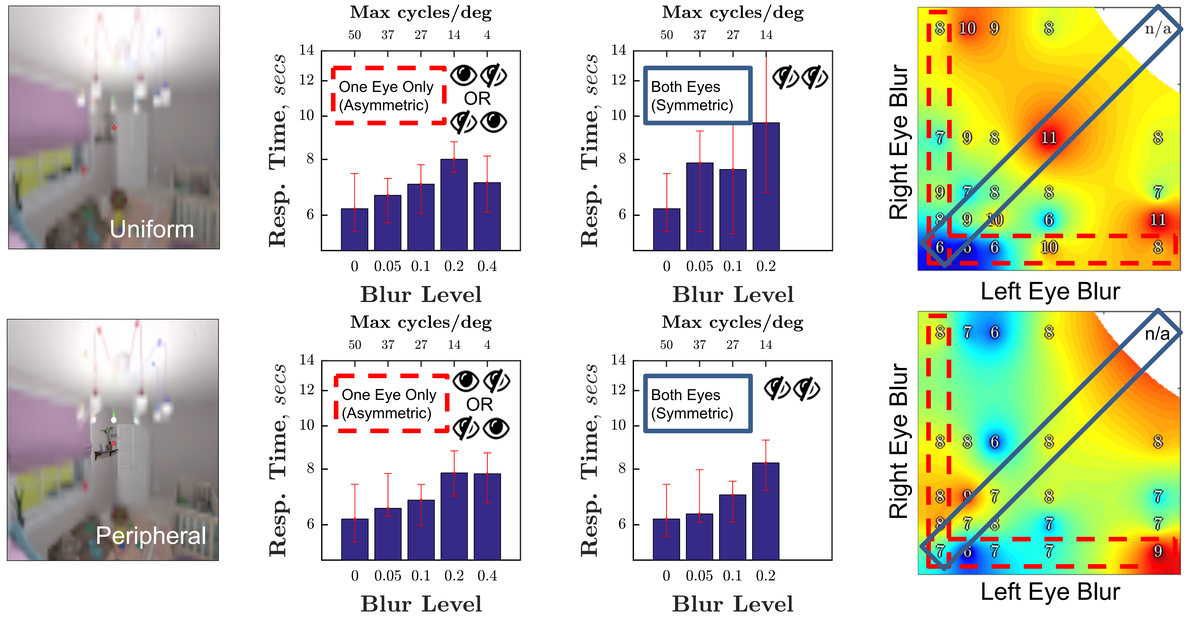
Response latencies increased even when blur was applied monocularly, though at a slower rate than in binocular conditions.

This pattern was observed in both the uniform condition [Fig. 5, top] and in the peripheral loss condition [Fig. 5, bottom].

The same pattern was also observed in the uniform texture-in-texture condition [Fig 6], and here the pattern was even more consistent.

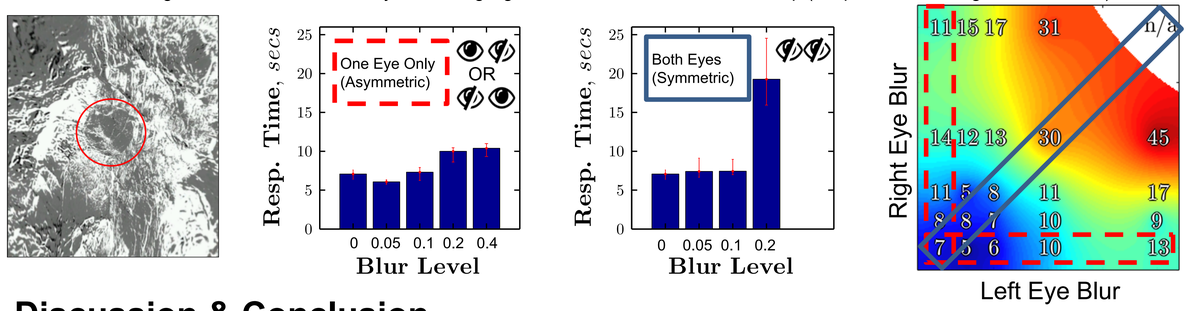
[Fig. 5] The "Where is my phone?" Game: How do people perform in a real-world task?

The bar plots represent the mean response time in function of blur level. Error-bars represent bootstrapped 95% confidence interval. The heat map is a 5x5 matrix representation of mean response times (blue: low RT, red: high RT). The asymmetric and symmetric conditions are represented by the red dotted and the blue boxes, respectively. Results show an increase of the mean response times when increasing the level of blur. Participants were not able to perform the task at the highest level of blur. Non-impaired eye: 👁 // Impaired eye: 👁‍🗨



[Fig. 6] Texture-In-Texture Visual Search Task

Same format as Figure 5. The red circle is only here to highlight the location of the textured-bump (not presented during the actual task).



Discussion & Conclusion

Asymmetric vision-loss affects performance on real-world visual search tasks (partial compensation by better eye). These preliminary results indicate that:

- It is wrong to simply use the sensitivity of 'the better eye' when constructing summary measures of visual ability [Fig 1].
- Even patients with early/unilateral field loss may exhibit measurable impairments in real-world tasks (possible implications for health-and-safety, in particular: patients' right to drive)
- VR simulations of real-world tasks could potentially be used as a biomarker of common eye diseases, such as glaucoma.
- VR simulations could help us to understand how different types/patterns of vision loss affect performance in common real-life scenarios.

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