Virtual Reality: The Future Of Visual Field Testing

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Abstract

One of the most important tests available to assess human vision is the visual field test, or perimetry. While imaging of the fundus and standard tests such as Snellen charts can assess factors such as acuity, and identify damaged parts of the retina, only the visual field test can measure the subjective field of view of perception from the patient side. We introduce a Virtual Reality (VR)-based perimetry test. A systematic test for measuring the visual field function conducted in VR. The VR-based test is precise enough to supersede the standard perimetry test carried out on either a Goldmann or Octopus test machine. Using VR allows for a more comfortable experience and opens up for further development that can potentially be used to map out other deficiencies of the visual field function. It also provides the ability to gamify the test allowing it to be carried out on children. Here we present some of the considerations and implementation details which ensure that our software has the necessary capabilities of producing correct measurements and valid results.

CCS Concepts

• **Human-centered computing** → *Accessibility technologies*; • **Software and its engineering** → *Software prototyping*.

Keywords

vision loss, virtual reality, mixed reality, perimetry test, visual field

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1 Introduction

The perimetry test is a standardised test that is useful for measuring the visual field and detecting conditions such as glaucoma, diabetic retinopathy, and other disorders causing loss of visual field. While there are many tests to assess the health of the retina via imaging, or the quality of vision via acuity, only the visual field test gives a measure of what the testee can and can't actually see in the visual field, i.e. whether any pathologies present are reducing sensitivity, or not. During the standard test, the patient is required to look into a half-dome, and fix their gaze at the central target. Throughout the test small dots appear projected on the inner surface of the half-dome, and the patient clicks a button if they can perceive these dots. The patient cannot move their head during the test and one eye is covered with a patch as the test is performed separately for each eye.

Two of the most popular perimetry tests and machines are the Goldmann and the Octopus. During the Goldmann test, a trained clinician manually moves the dots to map out the visual field, while the Octopus test uses a predefined, fixed pattern of dots. These perimetry tests however present several drawbacks, including the need to keep fixating on a central target, and their long fixation periods. To reduce these periods, researchers have developed diverse test patterns, that allow us to achieve accurate and reliable results with fewer dots [Racette et al. 2016].

Pivoting to a VR-based setup has important advantages, including that testing becomes more accessible. Simply because using consumer level hardware presents the possibility of their presence at every optician's office. In contrast the large Goldmann and Octopus machines are possible only to establish at specialist low vision clinics. Although perimetry testing can be conducted in VR, it is crucial that a clinician sets the test parameters and interprets the results. Recent work employing VR-based solutions has also solved the problem of long fixation periods that place significant demand on patients [Mulvey et al. 2021], and in this short paper, we describe some of the key technical considerations in approaching the implementation of such solutions.

2 Implementation & Results

Our perimetry test is developed in Unity for the Varjo XR3 [VARJO [n. d.]]. We chose Unity because it is well suited for VR-development and permits development for a wide range of VR-based headsets.

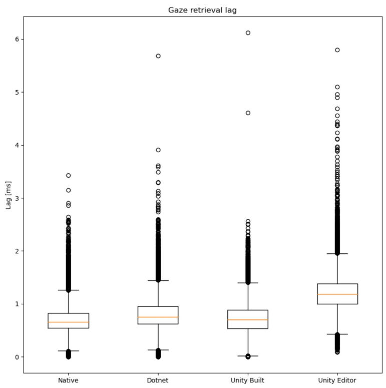

Figure 1: Retrieval time of the latest gaze position in four different implementations. A C++-based, C#-based, and two Unity-based(built and editor mode). Y-axis shows lag in milliseconds. Box plots show average retrieval time and 25 and 75 percent quartiles.

We have at the same time remained cognisant that not building the software from the ground up - may have significant implications for how fast we can request eye-tracking data from the head-mounted display (HMD) [Jensen et al. 2021]. We have conducted an experiment where we measure the time it takes to receive a gaze-position from the headset using Unity. If the delay becomes bigger than the refresh rate of the HMD screen, then we can no longer determine whether or not the patient is fixated on the central target. Figure 1 shows that the average delay from requesting to receiving the gaze position for four different implementations is well below 11.1 milliseconds, which is the time budget per frame on the Varjo XR3.

In our VR-based implementation of the test the clinician views a separate user interface on their computer screen (see Figure 2), through which they both register basic information about the patient, and decide on the pattern, target size and luminance. Once the test starts, all the patient sees is the inside of a virtual half-dome, a fixation point, and those targets appearing in peripheral vision. The clinician on the other hand has access to both a preview of what's presented to the user and additional controls for the test procedure.

Figure 3 illustrates the plot that compares stimuli presented at different angles around the fixation point on the Goldmann perimeter and in VR. These angles can be used to calculate the area of the visual fields that can be tested. VR-based testing of a visual field ranging from 37.56 to 2789.87 degrees^2 demonstrated statistically-significant correlation with the total area of visual field as measured by the Goldmann perimetry *(M = 1778.82, SD = 989.66)*, ranging from 93.09 to 2802.04 degrees^2 ($r(39)= .97$, $r^2 = .94, \alpha < .001$). This indicates that 93.7% of variance is shared between the VR based perimetry and the Goldmann tests.

3 Discussion

Testing children in particular is very challenging, due to the difficulty of communicating the instructions, and keeping their eye fixed, and responding appropriately to targets throughout the long test duration. Pediatric tools and interactive tests can help with solving this problem through gamification, made possible through VR implementations of perimetry testing. The potential gamification of such tests must yet respect the clinical need for valid and reliable results — and so there remains much research to be completed to realise such advantages; as central ambitions of our research agenda.

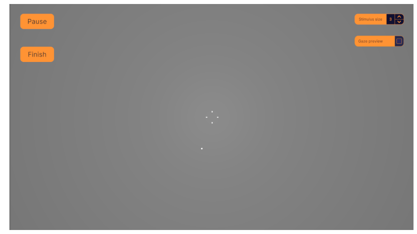

Figure 2: A screenshot of how the perimetry test looks like from the clinician's view, showing the headset view and buttons for in-test interaction.

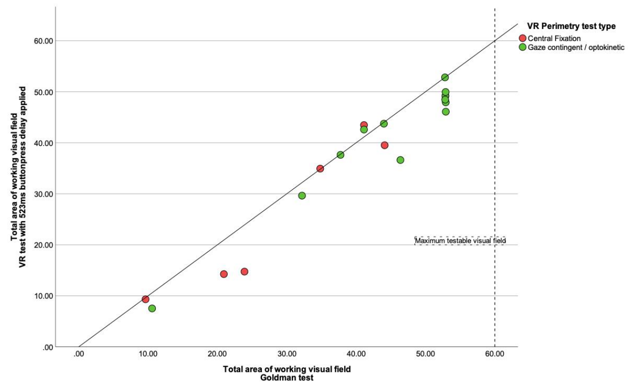

Figure 3: Results of how our perimetry test compares to standard tests, in terms of the size of the measured visual field.

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