Prefrontal Cognitive Workload During Clinical Visual Field Perimetry: A Planned fNIRS Neuroergonomics Study

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Synopsis

Visual field (VF) perimetry is the gold standard for functional assessment of glaucoma, yet its reliance on subjective patient responses introduces significant variability, compromising diagnostic accuracy. Built-in reliability indicators are incorporated, but they do not account for neurocognitive factors which may confound VF accuracy. We describe a plan for a hypothesis-driven study using functional near-infrared spectroscopy (fNIRS) to measure prefrontal cognitive workload during clinical VF testing under parametrically varied cognitive load. Previous literature supports our hypothesis that adding a dual-task working memory load during perimetry degrades VF outcomes even while standard reliability metrics remain clinically acceptable, motivating formal investigation.

Background

Standard automated perimetry (SAP) using the Humphrey Visual Field (VF) Analyzer is standard of care for the diagnosis and management of glaucoma, the leading cause of irreversible blindness worldwide. SAP is cognitively demanding, requiring sustained fixation and repeated detection of stimuli over ~5–15 minutes per eye. This produces high test-retest variability, muddling detection of true disease progression and complicating treatment decisions. Built-in reliability metrics (fixation losses [FL], false positives [FP], false negatives [FN]) provide clinical thresholds for flagging unreliable tests; however, mean deviation (MD), the average vision loss as compared to a healthy age-matched normative database, can vary greatly, even when reliability indices are in the clinically acceptable range (Yohannan et al., 2017). This variability prevents VF forecasting frameworks from predicting MD effectively enough for clinical integration (Abbasi et al., 2025).

Emerging evidence supports a cognitive component to VF variability. Cognitive impairment has been associated with elevated FP and FN rates in glaucoma patients (Ichitani et al., 2023), and concurrent cognitive demand disproportionately degraded VF performance in glaucoma versus controls in a driving simulation study (Gangeddula et al., 2017). Functional near-infrared spectroscopy (fNIRS) has been extensively validated as a prefrontal cortical measure of cognitive workload (Ayaz et al., 2013, with fNIRS accounting for the highest proportion of mental workload variability among six biomedical modalities (Mark et al., 2024).

Despite this convergence, no study has measured real-time neurocognitive workload during clinical VF perimetry. The study described here tests the hypothesis that elevated cognitive workload during VF testing, quantified via fNIRS-derived prefrontal activation, correlates with increased reliability index errors and artificially worsening MD, even when in the acceptable error range.

Methods

For the planned study, we will recruit 20 healthy adults with normal best corrected visual acuity (≥20/25), intraocular pressure (≤21 mmHg), and normal optic nerve structure confirmed by

optical coherence tomography. One randomly selected eye per participant will be tested with the fellow eye patched. Continuous-wave fNIRS (730/850 nm, ≥2 Hz) targeting bilateral dorsolateral prefrontal cortex will be recorded with participants seated in the VF analyzer (**Figure 1**). Heart rate, heart rate variability, and peripheral oxygen saturation (SpO_2) will be recorded via wrist-worn photoplethysmography. fNIRS preprocessing will include motion artifact correction, bandpass filtering, and modified Beer–Lambert Law conversion to ΔHbO and ΔHbR. Experimental blocks will consist of (Block 1) *Baseline*: 5-minute resting state within the VF device; (Blocks 2-3) *Standard VF*: two standard 24-2 SITA Fast VF III tests; (Blocks 4-6) *N-back dual-task*: three VF tests each paired with an auditory n-back at increasing difficulty (0-back, 1-back, 2-back). Auditory stimuli ("rock/paper/scissors") will be delivered at 5-second intervals (~120 trials/test) with participants responding with the corresponding hand gesture using their dominant hand. Tests will be randomized per participant. NASA-TLX questionnaires will be administered after each condition.

Results

This is a planned, hypothesis-driven study with a pilot feasibility component in progress. Preliminary results will be presented at the conference.

Discussion

Growing evidence suggests that adding a graded cognitive load during VF perimetry may induce gradually unreliable VF assessments. These observed trends would imply that the current standard quality parameters may not fully capture the degree to which cognitive burden degrades VF performance. The planned study will, for the first time, test whether fNIRS-derived prefrontal activation correlates with VF outcome degradation beyond what reliability indices alone capture. If confirmed, these findings would support the integration of real-time cognitive workload monitoring into clinical perimetry and motivate larger studies in glaucoma patients, where disease-related cognitive burden may be amplified when compared to healthy controls.

Disclosures

HA has equity in fNIR Devices LLC that licensed IP from Drexel University and manufactures optical brain imaging sensor used in the study.

References

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Figures

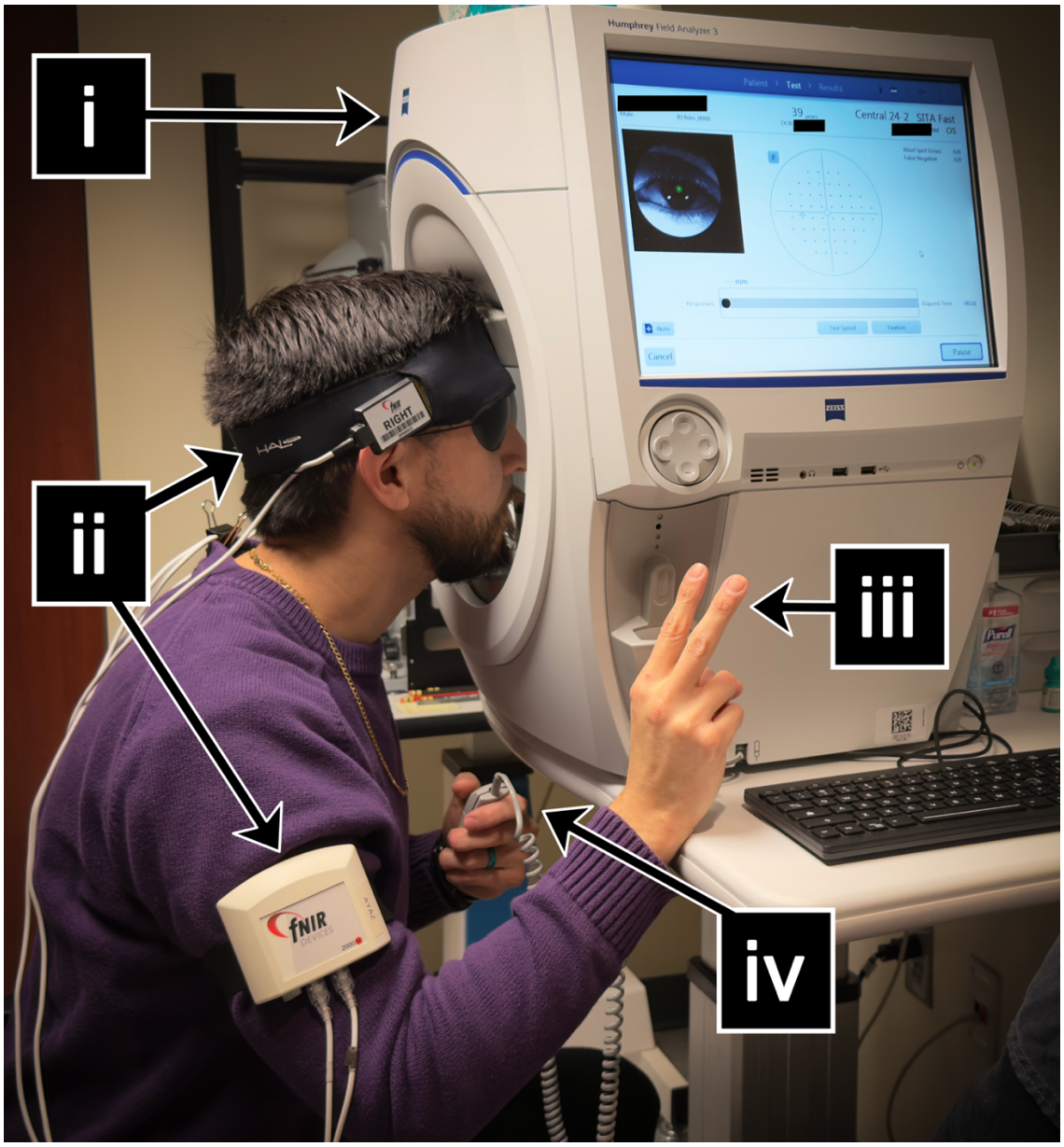

Figure 1. ***Experimental setup.*** *Photograph of a participant seated at the (i)Humphrey Visual Field (VF) Analyzer during dual-task testing. (ii)The fNIRS sensor strip is mounted across the forehead targeting the prefrontal cortex while the mobile receiver is strapped to the arm. The participant's dominant hand (iii) displays a "rock, paper, scissor" gesture as part of the auditory n-back response, while their (iv) non-dominant hand performs the VF stimulus response task.*