B0341

NeuroVEP: Machine Learning Enhanced Portable Objective Visual Field Assessment in Glaucoma

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Purpose & Background

Subjective perimetry remains the clinical standard for glaucoma yet suffers from patient fatigue, fixation losses, and poor utility in advanced disease. NeuroVEP is a head-mounted multifocal (mf) VEP system that captures neuroelectric responses from 36 visual-field sectors in both eyes independently in < 15 min. We tested whether a dual-eye-harmonized Artificial Neural Network (ANN) can transform these signals into objective regional defect probabilities. By leveraging data-augmentation pipelines and deep-learning/AI constrained optimization techniques, we transferred domain knowledge to the machine from human experts rating healthy subjects with artificial defects enabling accurate automated rating of glaucomatous mfVEP responses.

Methods

Participants:

- 4 Healthy subjects with blacked-out artificial defect sectors - **for model training**
- 10 patients with moderate to advanced open-angle glaucoma - **reserved for validation**

System Setup:

- Portable NeuroVEP headset with embedded OLED smartphone display.
- 8 hydrogel scalp electrodes positioned over O1, Oz, and O2 to record cortical visual responses.
- Eye-tracking cameras and photodetector-based timestamping ensure fixation compliance and accurate stimulus synchronization.

mfVEP Testing Protocol:

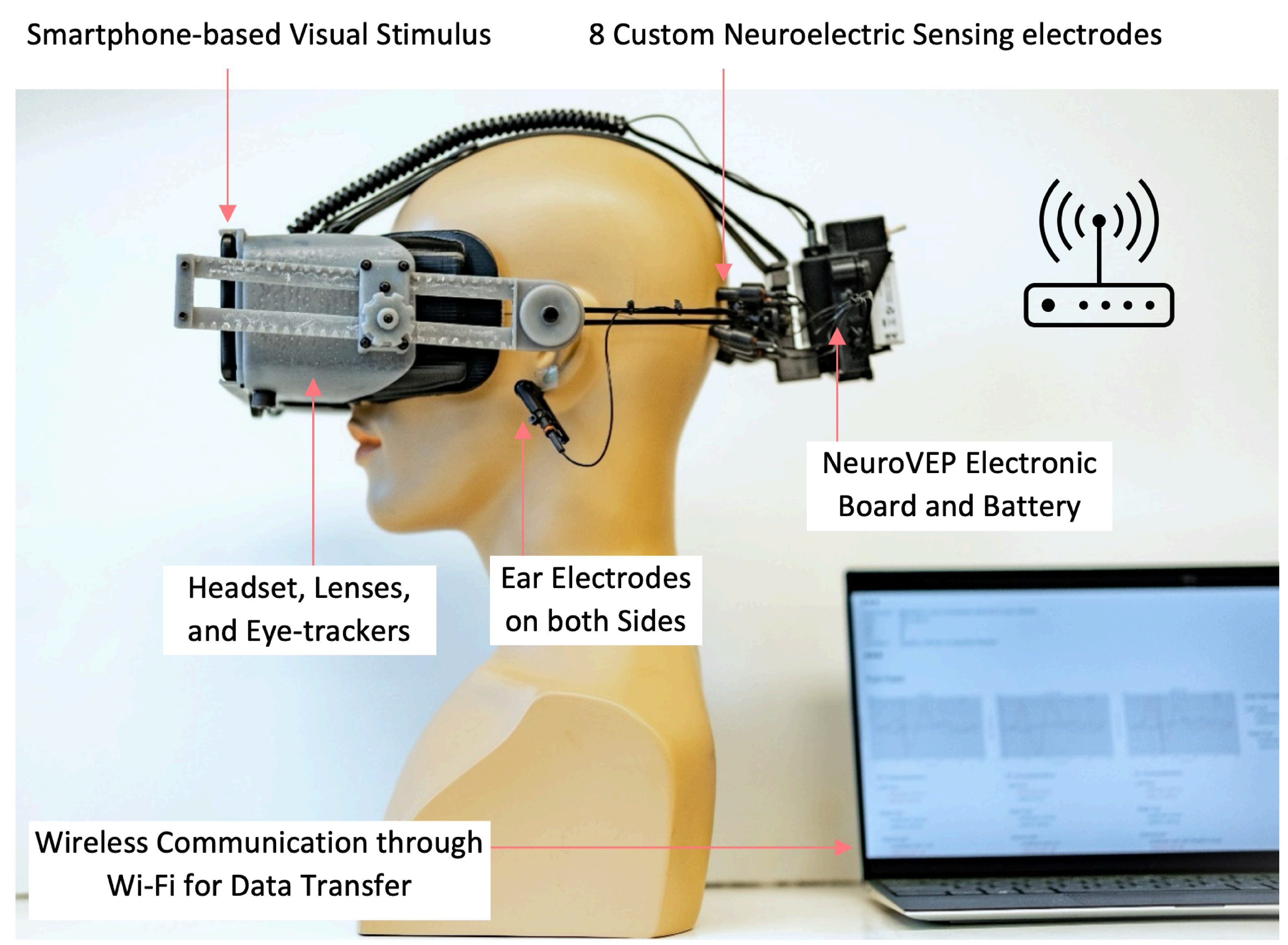
- A 12.5-minute monocular test of both eyes using a black and white 36-sector dartboard pattern reversal stimulus.
- Each sector is modulated by a unique pseudorandom binary sequence (m-sequence), enabling extraction of spatially resolved VEP responses across the visual field.

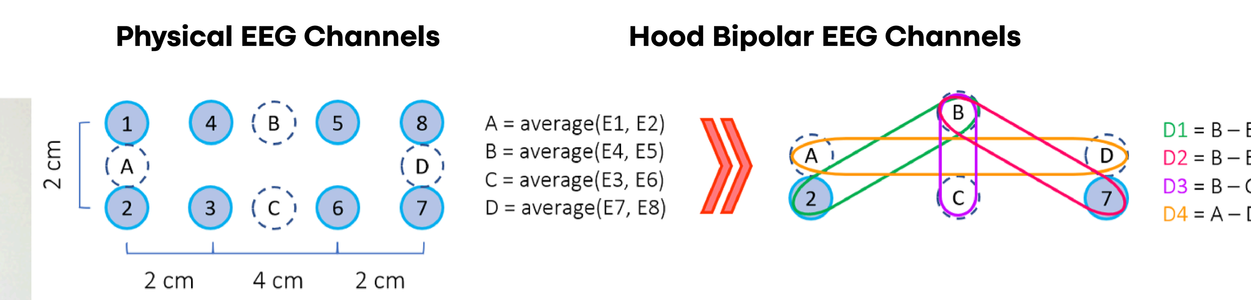
Signal Processing & Machine Learning/AI:

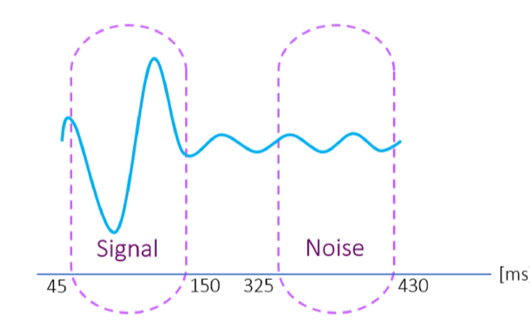
- Raw EEG (8 channels) are filtered and combined to form montage of 1 averaged EEG, 6 bipolar "Hood" EEG, and 3 high-SNR EFEG channels (unique to NeuroVEP)
- A trained ANN classifier assigns a score (0–100) to each sector, with higher scores indicating normal responses.
  - Dual branches (Left/Right) share weights; similarity penalty (MSE, Pearson-ρ, CCC + Fisher-Z) weighted by sector SNR
- Expert-Review GUI: custom Python/Tkinter tool accelerates waveform vetting; ≈5× faster than prior spreadsheet workflow

Take-Home Message

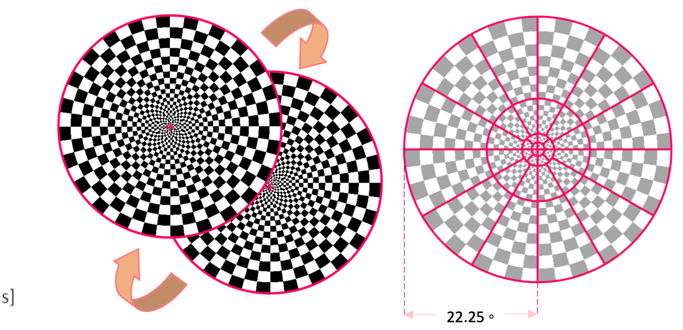
NeuroVEP provides objective, portable, ML-enhanced glaucoma field assessment with sector-wise precision.



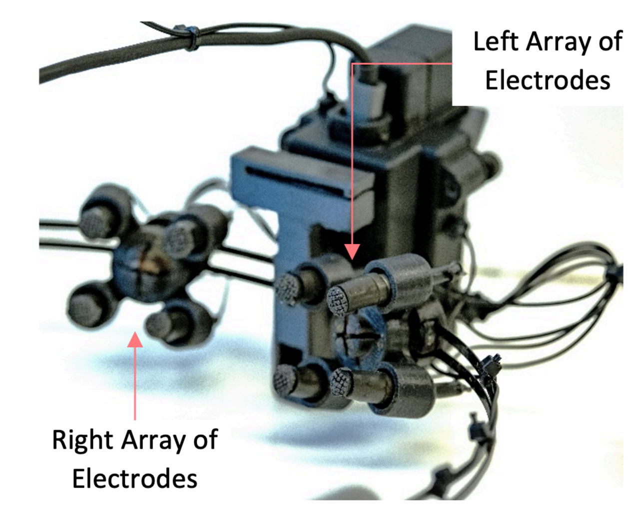


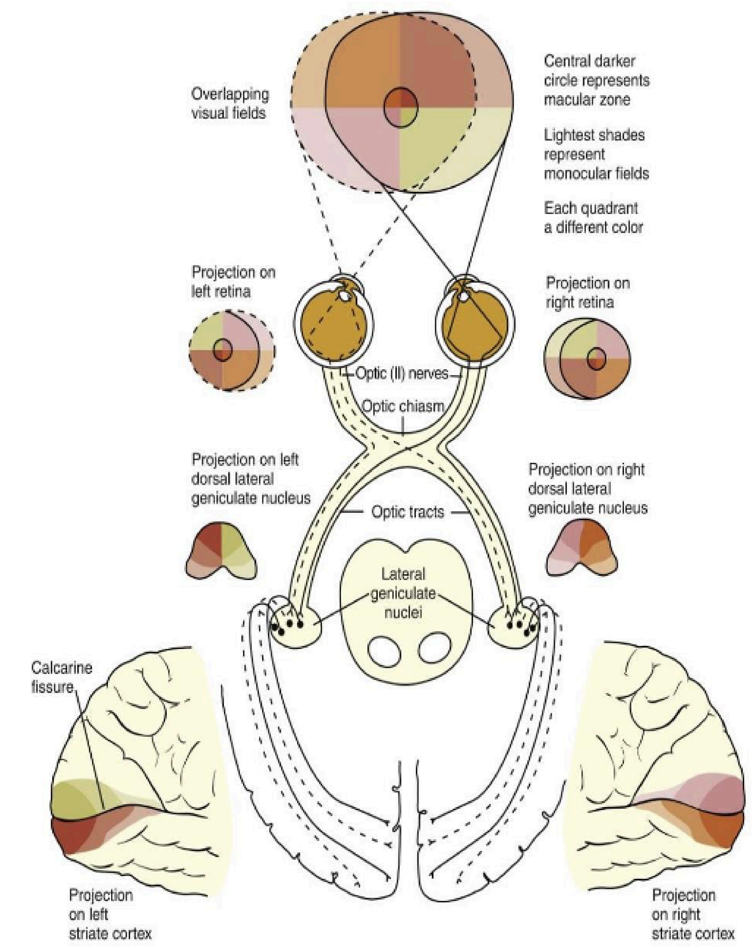


Signal and Noise Latencies

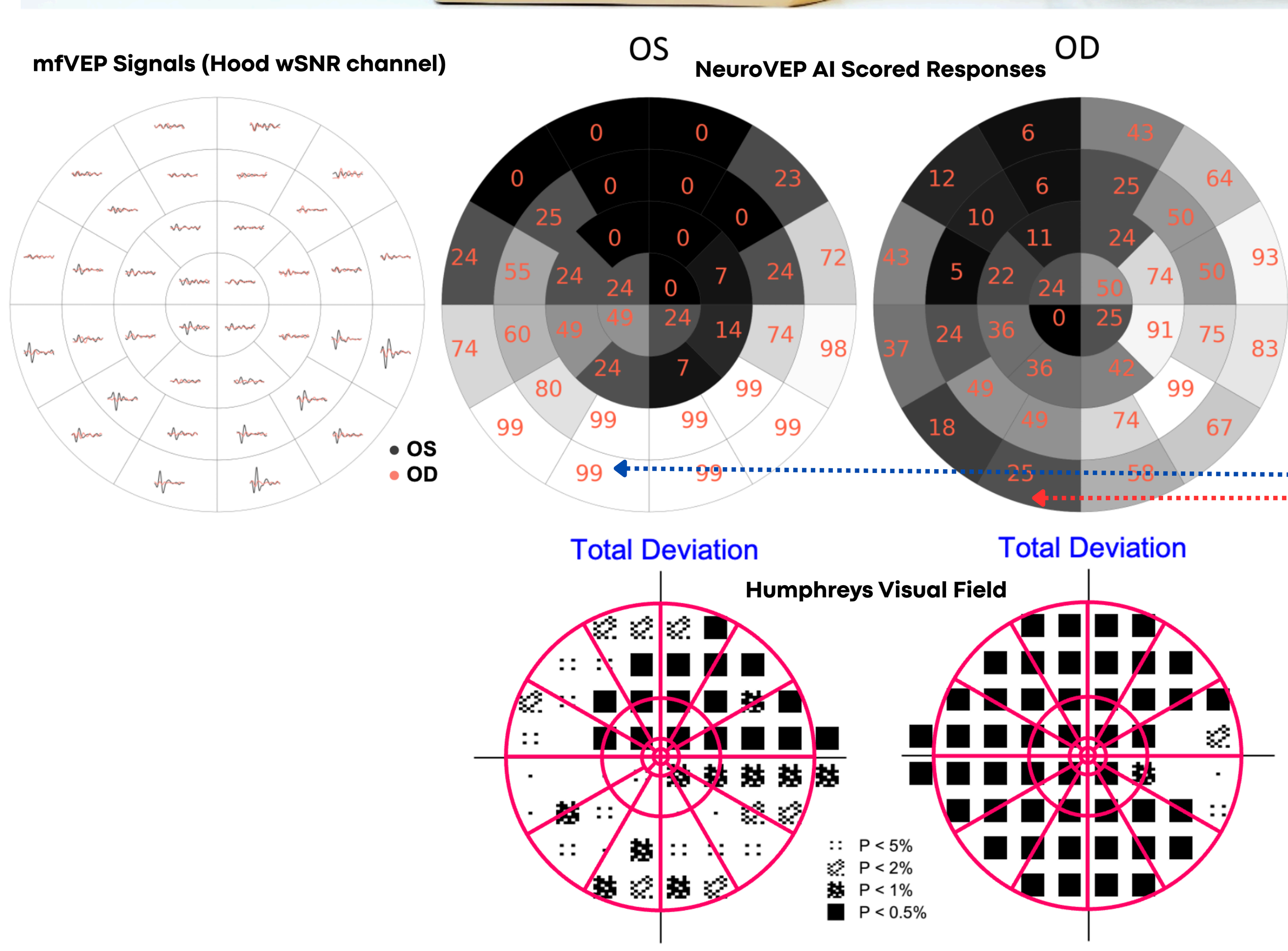


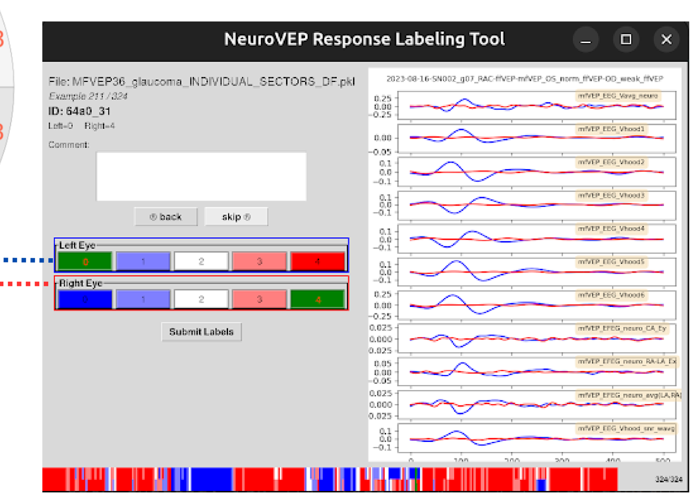
Pattern Reversal 36 sector mfVEP Stimulus





Retinotopic Visual Field to Optical Pathway Map
Image: Remington, L.A. and D. Goodwin. 2021: Elsevier Health Sciences.





Streamlined Human Expert Response Review/Labeling Tool
Screenshot: tool used by expert to manually rate sector-level responses in healthy subjects and glaucoma patients. Each plot shows waveform responses (blue = left eye, red = right eye) across key mfVEP channels. The tool enables researchers to assign severity scores (0 = healthy, 4 = definite defect) and supports machine learning refinement through curated labeling and future training augmentation.

Results

Sector-Level Agreement: NeuroVEP results aligned well with HVF outcomes. In one representative subject, 6/8 zones matched in OS and 5/8 in OD.

Classifier Evaluation:

- Models initially trained on healthy + artificial defect (AD) data.
- On glaucoma cases, pilot classifier reached ~91% accuracy.
- Current evaluation reveals high specificity, lower sensitivity.
- New ANN majority-vote and interocular harmonization algorithms are under further development, with promising results forthcoming.

Labeling Tool Insight:

- A response labeling GUI enables human-in-the-loop scoring for model refinement.
- Severity scores: 0 = healthy → 4 = definite defect.

User Feedback & Feasibility:

- Average test duration: ~12.5 mins for two eyes, monocularly.
- Setup time: 3–5 mins.
- Subjects reported high comfort and engagement. Can listen to music or podcast for the duration.

Conclusions

NeuroVEP enables objective, portable glaucoma diagnostics using cutting edge proprietary tech. and AI algorithms. It is less sensitive to patient compliance issues than HVF, making it suitable for diverse clinical settings. With continued improvements to the classifier, labeling protocols, and expanded training data, NeuroVEP may offer earlier and more precise detection of glaucomatous field loss.

Citations & Acknowledgements

S. Mohammad Ali Banijamali (2023), Portable Brain and Vision Diagnostic System for Age-related Macular Degeneration and Multiple Sclerosis/Optic Neuritis.

Versek C et al. Portable Diagnostic System for Age-Related Macular Degeneration Screening Using Visual Evoked Potentials. Eye Brain. 2021;13:111-127. doi 10.2147/EB.S295745

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NeuroVEP™

1 NeuroFieldz Eye-Brain Diagnostics

2 Northeastern University

2R44AG057250-02A1

NIH National Institute on Aging

3 ADVANCED EYE CENTERS