A Novel Paradigm for Vision Functionometry in Glaucoma

Makoto Miyakoshi[1], Scott Makeig[1], Andrew J. Tatham[2], Felipe A. Medeiros[2]

1. Swartz Center for Computational Neuroscience, Institute for Neural Computation, and 2. Department of Ophthalmology, University of California San Diego , La Jolla CA 92093

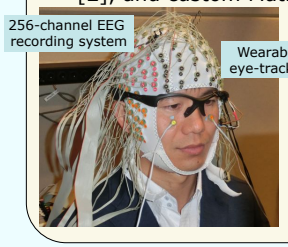
[5646 - A0294]

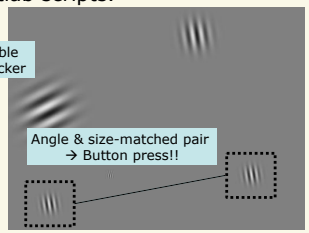
PURPOSE

- Results of standard automated perimetry testing may have a poor relationship to visual experience in daily living.
- We propose a novel approach to **vision functionometry** that examines the **active** use of visual information in **complex** visual environments.
- For this purpose, we developed an **active visual search task** requiring natural saccadic vision to detect the appearance of matching object pairs in an evolving display.

METHOD

- During this pilot session, four sizes of Gabor patches with four possible different orientations were presented to the screen (20-inch LCD monitor positioned 60 cm from the eyes). Five Gabor patches were always visible on a gray computer screen background at pseudo-randomly selected positions in a 3x4 grid. Every 1.66 seconds a new Gabor patch appeared and the longest-displayed patch disappeared.
- The subject (n=1) performed an active search task, indicating by button press the infrequent (15% probability) occurrence of a pair of Gabor patches matching in size and orientation.
- The session comprised 1,886 stimulus presentations (285 targets, 1601 non-targets).
- Infrared eye gaze position data wereobtained from the left eye while 256-channel EEG (brain), EMG (muscle), and EOG (eye) activity data were recorded.
- We developed a method, **ICtrack**, to identify exact saccade onsets and offsets (see steps below; developer, Özgür Yiğit Balkan)
- Event-related potential data were analyzed using EEGLAB [1], MoBILAB [2], and custom Matlab scripts.





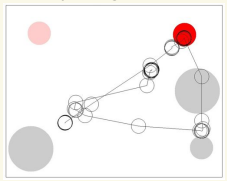
1. Mark saccade on/offsets from eye tracker records (30-Hz sampling rate)

2. Identify **pre-saccadic spikes** around fixation onsets from ICA-decomposed EOG using **ICtrack** (512-Hz sampling rate)

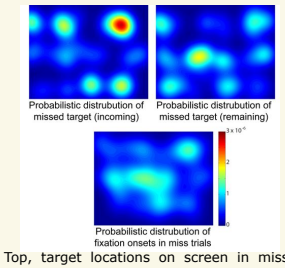
3. Event-related brain potential (ERP) analysis using time-resolved saccade event markers (n = 10,266)

RESULTS

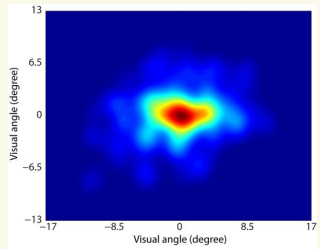
- There were **10,266 saccades** in 1,886 trials (3,138 sec), equivalent to **3.63 saccades / sec.**
- There were 221 hit and 64 missed matches. Response accuracy was 78%; mean reaction time, 959 ms (±321 ms SD). Subject was a young adult with no history of glaucoma.
- Smaller Gabor patches and longer distances between the targets were associated with missed responses and prolonged reaction times.



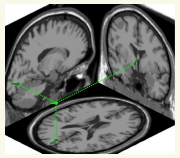
A 'Miss' trial is illustrated. The gaze trajectory included the incoming target (top right) but did not reach the remaining target (top left, dim red disc).



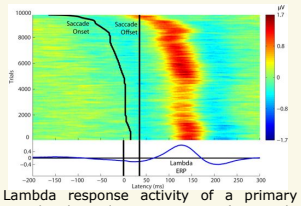
Top, target locations on screen in miss trials for incoming (left) and remaining (right). Bottom, probability density of gaze trajectory on screen.



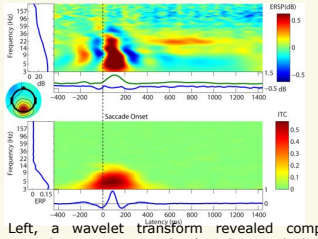
Probability density of directions and distances of saccade endpoints from fixation at saccade onset (0,0).

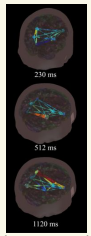


EEG data were resolved into cortical sources by ICA and equivalent dipole fitting. One was localized within the primary visual cortex (green ball). Five other components were localized to visual cortex (not shown).



Lambda response activity of a primary visual independent component (see scalp map on right; here, saccade offset at 0 ms) sorted by saccade length. Note: lambda response latency is time-locked to saccade middles, not to saccade offsets.





Left, a wavelet transform revealed complex spectral perturbation structure (top) with partial phase locking at saccade onset (bottom). Right, stimulus event-related information flow at 8-13 Hz, showing a cortical network related to visual target detection.

CONCLUSION

- The task efficiently elicited saccades across the visual field.
- 'Miss' trials exhibited inhomogeneity in missed target positions and gaze trajectory coverage, suggesting individualized visual search habits and/or strategy.
- We hypothesize that alteration in or loss of visual field should prompt spatially compensatory saccades in glaucoma patients, with accompanying differences in cortical EEG activity.
- The proposed task and analysis, combined with EEG source imaging, could yield a useful test battery for vision functionometry in glaucoma and other eye diseases.

References: [1] Delorme A, Makeig S. 2004. EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. J Neurosci Methods 134:9-21.

[2] Ojeda A, Bigdely-Shamlo N, Makeig S. 2014. MoBILAB: an open source toolbox for analysis and visualization of mobile brain/body imaging data. Front Hum Neurosci 8.

Commercial Relationships: FAM: Alcon Laboratories, Inc. (F, R), Bausch & Lomb (F), Carl-ZeissMeditec (F, R, C), Heidelberg Engineering (F), Merck, Inc. (F), Allergan, Inc. (F, R, C), Sensimed: (F), Topcon, Inc. (F), Reichert, Inc. (F, R), National Eye Institute (F), Novartis (C)

Support: Gift from the The Swartz Foundation, NIH Grant EY21818 (FAM), and an unrestricted grant from Research to Prevent Blindness, NYC, New York