Functional Consequences of Fixational Eye Movements in People with Macular Disease

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Purpose: A recent theory postulates that slow-drifts of fixational eye movements (FEMs) serve to reformat the visual input of natural images, so that the amplitude of the spatial frequencies (SFs) of the input image no longer decreases in proportion with 1/SF, but is equalized across a range of SFs. This “spectral whitening” effect is postulated to improve the processing of high-SF information. This theory requires normal FEMs with small-amplitude slow drifts that approximate Brownian motion. Given that people with macular disease exhibit abnormal FEM characteristics, with large amplitude of slow drifts and microsaccades, do their FEMs also result in spectral whitening?

Methods: Retinal images of 16 observers with bilateral macular disease (age: 58–87, logMAR acuity: 0.48–1.32) and 14 age-matched adults (controls) with normal vision (age: 62–84, logMAR acuity: ≤0.0) were recorded using a Rodenstock scanning laser ophthalmoscope while observers monocularly viewed a 1° cross for trials of 30 s. FEMs were recovered from the recordings using a brute-force cross-correlation algorithm at a sampling rate of 540 Hz. Segments of FEMs of durations ranging from 50 to 500 ms, without (i.e. drift-only) or with intervening microsaccades, were extracted from the eye-position trace of each trial. Each of these segments was used to create a movie, simulating how a natural scene image moved on the retina due to FEMs. 48 images were used as input to recreate these movies. The spatio-temporal amplitude spectrum of each movie was computed using a 3D Fast Fourier Transform.

Results: Across all conditions (different segment durations, drift-only or drift+microsaccades) and observers (macular disease vs. controls), the amplitude spectrum of the movies simulating the effect of FEMs shows a reduction for low SFs, such that the spectrum is virtually constant for SFs up to ~10 c/deg (“spectral whitening”). The extent of whitening changes minimally with duration, is slightly less (10%) when microsaccades are present, and ~20% less in people with macular disease than in controls.

Conclusions: Our finding that spectral whitening is observed under a variety of conditions invalidates the assumption that whitening is a property of normal fixational drifts. More importantly, whitening is observed in people with macular disease, implying that the abnormal FEMs of these individuals may also benefit vision by improving the processing of higher-SF information.

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Integrating oculomotor and perceptual training to induce a pseudo fovea: a model system for studying central vision loss

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Purpose: People with central vision loss (e.g. macular degeneration) often adopt eccentric retina locations outside the affected macular region for fixation (pseudo fovea or Preferred Retina Locus, PRL). Despite its significant role in visual function, the mechanism underlying the emergence of PRL still remains unclear. Here, we developed a novel training paradigm that can effectively induce a PRL at any intended retina location by integrating oculomotor control and pattern recognition training. We proposed it as a model system to study the nature of PRL development and its impacts on various aspects of visual function.

Methods: A simulated central scotoma (12° in diameter) was induced in eight normally-sighted subjects through a gaze-contingent display. A subject’s entire peripheral visual field was blurred, except for a small circular aperture (5° in diameter) with a location randomly assigned to each subject (to the left, right, above, or below the scotoma). Under this viewing condition, subjects performed a highly structure at the PRL has not been investigated thoroughly and investigating the structure-function correspondence at the PRL is important for understanding visual performance. In this study we relate localized sensitivity changes in the vicinity of the word-fixation PRL of subjects with bilateral CFL (as previously reported) to structural measures of their outer retina.

Methods: Twelve subjects (20-89yrs) with bilateral CFL due to age-related macular degeneration or Stargardt’s disease participated. The word-fixation PRL for a 3-letter word at each subject’s critical print size was determined with NIDEK MP1 micro-perimeter. Supra-threshold screening to detect micro-scotomas (MSs) was performed using Goldmann Size II targets (13 arc min, L_bg = 127 cd/m², L_g = 1.27 cd/m²) with a sampling density of 12 arc min in a grid region centered on the PRL.

The PRL region was imaged using a high-density optical coherence tomography scan with averaging of 9 B-scan frames. After offline image registration, regions of interest in the OCT image (496 by 154 pixels) corresponding to the MP1 test locations were identified and manually segmented using a custom MATLAB program. The outer and inner margins of retinal pigment epithelium (RPE), inner margins of outer nuclear layer (ONL) and internal limiting membrane (ILM) were traced to determine the thickness of RPE, ONL + photoreceptor layer and the total retinal thickness. These thicknesses were compared between the MS and Non-MS locations in each subject.

Results: Three subjects with no MSs and 1 subject with a poor quality OCT scan were excluded from thickness analysis. A total of 165 B-Scans were analyzed, 52 (32%) from locations with MSs. The range of thickness ratios (layer thickness in the location of a MS / average layer thickness in same eye in Non-MS locations) for RPE, ONL + photoreceptor and total retina were: 0.26–2.13, 0.31–1.6 and 0.78–1.1 respectively. Mean thicknesses of all 3 layers did not differ significantly in MS and Non-MS locations (t (7), p = 0.47, 0.43 and 0.09).

Conclusions: Structure-function correlation in regions of MS at the PRL in subjects with bilateral CFL was poor. This may be attributable to disease diversity and/or functional changes preceding structural changes at the PRL.

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decreasing oculomotor and pattern recognition task. Changes in various aspects of visual function were also evaluated before and after training at PRL and non-PRL locations.

**Results:** After 6–10 hours of the training, all subjects formed their PRL within their clear window (training location). We also found significant improvements in the precision of oculomotor control (ps<0.01) and pattern recognition performance (>=19%, ps<0.01) over the course of the training. Furthermore, there were significant improvements in some untrained tasks (>=18%, ps<0.04) such as crowded letter recognition, reading, and spatial attention at PRL location, suggesting transfer of learning to untrained stimuli and tasks.

**Conclusions:** Our results demonstrated that, within a relatively short time period, a stable PRL could be induced at any intended retina location in normally-sighted subjects with a simulated central scotoma. Furthermore, our oculomotor and perceptual training appeared to improve high-level visual function such as letter recognition, reading, and attention. Our findings suggest that our integrative training paradigm may serve not only as a model system to study the dynamic nature of the PRL formation, but also as a viable rehabilitative regimen for individuals with central vision loss.

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**Program Number:** 6102
**Presentation Time:** 11:45 AM–12:00 PM
**Searching for objects in everyday scenes and recognising faces: measuring performance in people with dry age-related macular degeneration (AMD)
**Purpose:** Treatment success in a clinical trial for age-related macular degeneration (AMD) would ideally be aligned to measurable performance in visual tasks rather than imperceptible changes on a clinical chart. We sought to test the hypothesis that patients with dry AMD perform worse than visually healthy peers on computer-based surrogates of ‘real world’ tasks in a prospective case-control study.

**Methods:** People (>60 years, logMAR binocular visual acuity (BVA) 0.7 or better) categorised with varying severity of dry AMD performed two previously validated computer-based ‘real world’ visual tasks. In a search task, participants were instructed to find items within digital photographs of everyday indoor and outdoor scenes (Smith et al 2011). Average search times across the images were recorded for each participant. In a face recognition (FR) task participants completed a modified version of the Cambridge Face Memory Test (Glen et al 2012). Percentage of correctly identified faces was used as an outcome measure for performance for each participant. Comparisons for both tasks were made against a 90% variability. The mean loss of colour vision increased from normal to AMD (Age related maculopathy).

**Results:** People (>60 years, logMAR binocular visual acuity (BVA) 0.7 or better) categorised with varying severity of dry AMD performed two previously validated computer-based ‘real world’ visual tasks. In a search task, participants were instructed to find items within digital photographs of everyday indoor and outdoor scenes (Smith et al 2011). Average search times across the images were recorded for each participant. In a face recognition (FR) task participants completed a modified version of the Cambridge Face Memory Test (Glen et al 2012). Percentage of correctly identified faces was used as an outcome measure for performance for each participant. Comparisons for both tasks were made against a 90% variability. The mean loss of colour vision increased from normal to AMD (Age related maculopathy).

**Conclusions:** Loss of chromatic sensitivity may be the earliest detectable change in ARM. The means of RG and YB losses correlate well with various ARM classifications, in spite of wide inter subject variability. The mean loss of colour vision increased from normal aging to soft drusen to reticular drusen (NA < soft drusen < RPD, R^2=0.9). Drusen size and patchy autofluorescence correlated with loss of chromatic sensitivity in accordance with AREDS study and FAM group, respectively. Early GA eyes and eyes with CMT < 200 µ had significantly greater CAD thresholds. Six eyes with abnormal baseline, but variable CAD thresholds converted to wet AMD at one year.

**Commercial Relationships: Roopa Vemala, None; Sobha Sivaprasad, None; John L. Barbur**
Spatial summation across the 10-2 visual field in normals and age-related macular degeneration

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**Purpose:** The Goldmann (G) size III stimulus of the Humphrey Visual Field Analyzer (HVFA) is routinely used to assess contrast sensitivity across the visual field. However, reports on spatial summation characteristics of the 30-2 paradigm suggest that GIII tests outside complete spatial summation and using this stimulus may result in smaller differences in contrast thresholds between normal and those with ocular disease. The 10-2 paradigm is a highly relevant test for ocular diseases affecting the central 20-degree field but the spatial summation characteristics of this paradigm including the location of the critical area (Ac) and slope of partial summation are unknown. Thus we investigated spatial summation changes in the 10-2 paradigm between normal and those with age-related macular degeneration (AMD).

**Methods:** We measured thresholds for one eye from 37 normal subjects aged 20-62 years (mean: 36±11 years) using the HVFA 10-2 full threshold paradigm with GI to GV stimuli. Spatial summation curves were plotted for each test location by fitting data with a two-line fit and derived Ac and slope of partial summation. After verifying Ac and partial summation slope do not change with age, we converted subject data to 50-year-old equivalent using published dependent upon the subject’s refractive state and working distance. Similar procedures to 11 patients with intermediate AMD (range: 61-80 years; mean: 71±6 years) and compared spatial summation characteristics of this group to normative data.

**Results:** Normative Ac was established for the 10-2 paradigm and found to increase with eccentricity, consistent with previous studies using other test paradigms. GIII stimulus always exceeded Ac and tested visual function within various stages of partial summation across the 10-2 paradigm. A bigger difference in contrast thresholds was generally observed between normal and AMD patients when using a test stimulus at or within complete spatial summation (GI or GII).

**Conclusions:** Normative Ac values indicate that GI and GII test sizes operate within complete spatial summation while the standard GIII stimulus operates across a range of partial summation in the HVFA10-2 paradigm. Our results suggest that using test stimuli at or within complete spatial summation reveals a greater loss compared to the standard GIII stimulus in the 10-2 paradigm in patients with intermediate AMD.

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**Presentation Time:** 12:30 PM–12:45 PM

Self-assessment of visual function using new single-use printed charts

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**Purpose:** It is desirable that the progress of degenerative retinal diseases should be continuously monitored so that therapeutic intervention can be instituted in a timely manner. We are investigating the possibility that this could be achieved by self-assessment of contrast sensitivity (or other visual function) using simple printed paper charts that can be used by subjects in their own homes.

**Methods:** Subjects view at reading distance a printed paper chart that displays a series of round patches whose Weber contrast progressively reduces by 0.05 log units. Subjects are required to show which patches they can see by correctly marking the location of the patches on the chart. Once the chart has been marked it is scored using a transparent template showing the correct locations. Contrast sensitivity is reported as the reciprocal of the contrast of the faintest patch whose location is marked correctly. The variability of contrast sensitivity measurements has been examined in many subjects (both normal and impaired vision) who made two contrast sensitivity estimates (test/retest), or a smaller number of normal subjects making multiple estimates (12) on different versions of the chart with patches placed in different randomised locations.

**Results:** Test/retest measurements indicate that there is only a negligible learning effect (the mean retest contrast sensitivity is less than 0.02 log units greater than the initial test value) while the standard deviation of the differences between the test and retest values is less than about 0.08 log units, indicating an underlying standard deviation of less than 0.06 log units for single determinations of contrast sensitivity. This value is consistent with the variability seen with multiple repeated measurements in normals. Comparison of the contrast sensitivity and visual acuity of a group of patients with AMD at various stages shows a high degree of correlation between these two measures of visual function indicating that, in this case, a measurement of contrast sensitivity could be at least as useful in assessing progression as a measurement of acuity.

**Conclusions:** Contrast sensitivity can be satisfactorily measured in the home using the ‘NuBlobs’ charts. Measurements of contrast sensitivity are preferred to acuity measurements because they are less dependent upon the subject’s refractive state and working distance. The charts can be used for different visual conditions.

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