The active fovea: A fine dissection of the Preferred Retinal Locus in space and time

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Résumé

During fine visual tasks, eyes undergo complex fixational eye movements (FEM) comprised of drift and microsaccades. The peak of the distribution formed by the aggregate FEM is generally considered to be the preferred retinal locus (PRL), defined functionally as the retinal position used to see or guide gaze. A refined definition of the PRL satisfying either the best performance (acuity) or stability (motor) will help inform us about human foveal vision at its finest scale.
A high-speed, sub-arcmin, retinal-image-based eye-tracker (Adaptive Optics Scanning Laser Ophthalmoscope:AOSLO) was used to measure the PRL properties for a cadenced, fine-discrimination task. The AOSLO projects and unambiguously records the stimulus location over the constantly moving retinal image. Six subjects reported offsets between two tiny 2x1 arcmin horizontal Vernier bars separated by 1 arcmin along 7 offsets of 6 arcsecs. The bars were decrements presented within a 0.9◦ red AOSLO 30 frame-per-second display containing four fixation guides. Stimuli were flashed for two frames every 2 sec in a cadence, so subjects could adopt a constant fixation strategy. 2100 trials of these micro-flashed Vernier targets were presented in pseudorandom order for each participant, allowing us to map for the first time the change in acuity across the foveola, in 2D.

Spatially-defined PRLs and fixation stabilities (ISOA) were computed for either all fixation points (PRL), fixation points during stimulus onset, saccade starting positions, saccade landing positions and the subset of positions leading to correct responses for the smallest Vernier offset (cPRL). Temporally defined PRLs were isolated at mid-drift duration between saccades or by the stable eye position plateau observed 200-400ms after stimulus onset (itPRL). Saccade rate, amplitude and landing distance to cPRL, corresponding fixation stability all work to reduce and converge 200-400ms after Vernier appearance. Interestingly this most stable, congruent epoch appears driven by finely programmed saccades in timing and landing position.
Accurate image placement on the retina in both space and time is important for fine visual tasks.The observation of fixation stability decreasing after the brief stimulus may indicate a strategy to integrate visual information from naturally more stationary targets. Overall, cPRL and itPRL offer the most reliable and meaningful functional definitions of the PRL. Finally, the 2D mapping of acuity on the foveola revealed surprising peaks in acuity at specific landmarks that will be further detailed.

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Mots-Clés: eye movements, foveal vision, fixational eye movements, saccade, retinal tracking, adaptive optics, hyperacuity, preferred retinal locus