Amblyopia-Related Changes in the Fine-Scale Functional Organization of Human Extrastriate Visual Cortex

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Background: Amblyopia is a developmental disorder caused by disruption of symmetric binocular visual input early in life. Most amblyopic individuals suffer from impaired stereopsis. Experimental models of amblyopia in non-human primates suggest a significant reduction in the number of stereo-selective neurons within extrastriate visual cortex. However, these studies were based on a monocular deprivation model that differs from the asymmetric binocular vision of human amblyopes. Here, we studied the impact of strabismus and anisometropia (two major natural causes of amblyopia) on the fine-scale functional organization of specific neuronal structures (including the stereo-selective stripes/columns) in human extrastriate visual cortex.

Methods: We tested the functional organization of color-selective thin- and stereo/motion-selective thick-type stripes/columns in areas V2/V3 in 5 amblyopic (3 strabismic and 2 anisometropic) and 14 control individuals. We used high-resolution (1 mm isotropic) functional MRI, collected in an ultra-high field scanner (7T), to localize these fine-scale structures based on their response to color-vs-luminance varying stimuli (Nasr et al., 2016), 3D-vs-2D random dot stereograms (Nasr and Tootell, 2018) and moving-vs-stationary stimuli (Tootell and Nasr, 2020).

Results: Control subjects (≈50 arc sec randot stereoacuity) showed stereo-selective stripes/columns in V2/V3. In contrast, amblyopic individuals (>250 arc sec) showed no significant (p>0.05) stereo-selective activity in V2/V3. Nevertheless, interdigitated clusters of motion- and color-selective responses were still found in areas V2/V3 of amblyopic individuals, as detected in controls.

Interestingly, the surface area occupied by the motion- and color-selective stripes/clusters was significantly larger (p<0.05) in amblyopic compared to control individuals. We did not find any significant difference in the number of non-selective and/or non-responsive vertices between the two groups, ruling out a general sensitivity loss hypothesis.

Conclusion: The absence of proper binocular input in amblyopia leads to a decrease in the size of stereo-selective stripes/columns, with a corresponding increase in the size of motion- and color-selective sites.