The effect of age on wide-view retinotopic mapping of central and periphery visual areas

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Target Audience: Neuroscientists interested in aging on the visual cortex

Purpose: Neural degeneration and reorganization occur during the process of normal aging [1]. A few fMRI studies have investigated changes in the retinotopic organization in the primary visual cortex with age [1]. However, the visual stimuli used only covered a narrow, central visual field. The goal of this study was to investigate the effects of normal aging on retinotopic mapping measurements with a relatively wide view to include central and periphery visual areas.

Methods: Five old (60.6±3.4 years old) and five young (26.6±3.0 years old) volunteers self-declared normal with no known ocular diseases were scanned at a 3T scanner (Trio; Siemens, Germany). Visual stimulation used checkerboard animations (expanding rings for eccentricity mapping and rotating wedges for polar mapping) that were projected to a customized plastic screen inside the magnet bore. The distance between the subjects' eyes and screen was 10 cm. Retinotopic fMRI was performed using the posterior half of an 8-channel head coil to image the occipital lobe without obstructing subjects' vision to achieve visual simulation from 0~90° in diameter of the visual field. fMRI used EPI with 100 temporal frames, TR/TE=2000/30 ms, 1.7 x 1.7 x 3 mm resolution, and 29 slices parallel to calcarine fissure. Anatomical reference was achieved by T1-weighted MPRAGE sequence (1 x 1 x 1 mm) with the whole head coil.

Anatomical images were processed in Freesurfer for surface reconstruction and retinotopic mapping. fMRI data were processed in FSL. Group analysis between young and old were calculated with significance level P<0.05 and then mapped onto the cortical surface.

Results and Discussion: Wide-view retinotopic mapping results from a typical young subject are shown in Figure 1. Color hue is used to indicate spatial phase changes, defining the boundaries of the visual fields. Early visual areas (V1, V2) and recent recognized extrastriate areas (V6, V7/V3A) in Figure 1 are consistent with a previous wide-view retinotopy study [3]. Area V6 is sensitive to coherent motion and emphasized by greatly enlarged stimuli.

Figure 2 illustrates the group difference between young and old subjects evoked by retinotopy of eccentricity from center to periphery. For the stimulus with visual angle 0°~45°, older subjects showed significantly reduced BOLD activity compared to younger subjects in the areas of primary visual cortex corresponding to the central vision region. For the stimulus with visual angle 45°~90°, older subjects had slightly higher responses than younger subjects in the central visual cortex areas, but slightly weaker responses than younger subjects in the periphery visual areas.

In the whole visual pathway, it has been reported that age-related changes take place from photoreceptors to the brain[1]. Spatial density of rods decreases as a function of age within the central 43° of vision while the loss of rods in the periphery does not significantly correlate with age [4], consistent with our retinotopic fMRI group differences showing the most prominent aging effects within 45° visual receptive field and no age differences in the peripheral cortex (Fig. 2AB). We also found that the cortex corresponding to central vision was more activated in the older subjects compared to young subjects with wide-angle stimuli, in agreement with the previous findings on cortical reorganization counteracting age-related neural decline in the aging brain [5].

Conclusion: Our results demonstrated that wide-view retinotopic mapping could be used to quantify age-related changes in the human visual cortex. Central visual areas of healthy older subjects exhibited weaker BOLD activity for central stimulation and stronger signal for periphery stimulation, indicating the potential central vision loss and neural reorganization with age. Future studies will investigate changes in glaucoma patients.

Reference: [1] Crossland et al., IOVS. 49 (2008), 3734-3739; [2] Duncan et al., Prog. Retin. Eye Res. 26(2007), 38-56; [3] Pitzalis et al., Cerebral Cortex. 20 (2010), 411-424; [4] Curcio et al., IOVS. 34 (1993), 3278-3296; [5] Roberto et al., Neuroimage. 17 (2002), 1394-1402.

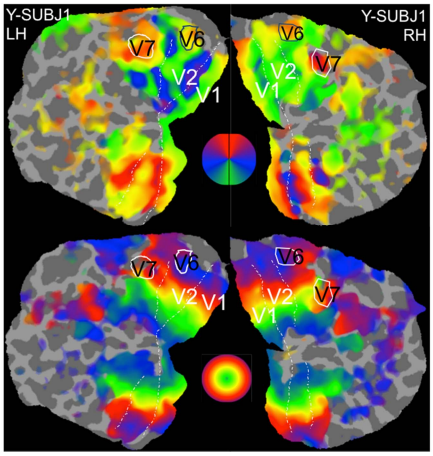

Figure 1. Wide view retinotopy of polar (top) and eccentricity (bottom) maps of a typical young subject (LH: left hemisphere, RH: right hemisphere). The flat maps display boundaries of early visual areas (V1, V2) and motion sensitive visual areas (V6, V3A/V7).

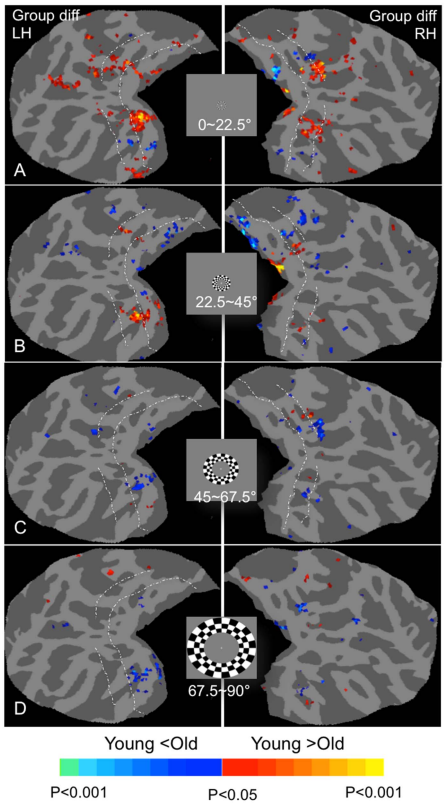

Figure 2. Group difference maps on the flattened occipital cortex for 4 simulation patterns covering the visual field from 0 to 90° (A-D, the stimuli and region of vision are shown in the inset between left/right hemispheres). Contrasts of young>old (red) and old>young (blue) is calculated with P<0.05.