

Primary Visual Cortex Activation Induced by Tactile Stimulation in Individuals with Retinitis Pigmentosa

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Introduction

Previous fMRI studies suggest that vision deprivation in humans causes the visual cortex to be modulated by non-visual stimuli, including tactile input (Amedi et al. 2010 and Cheung et al. 2009). The current study measures the extent of cross-modal activation in the visual cortex of late-blind individuals with retinitis pigmentosa (RP), a genetic neurodegenerative disease that results in gradual vision degradation and eventual blindness. We sought to characterize and correlate tactile-evoked visual cortex activity with degrees of vision loss across individuals with RP.

Methods

Eleven subjects participated in the study, including 7 individuals diagnosed with RP and a control group of 6 normally sighted individuals. Both groups completed two tactile tasks: a sandpaper task requiring individuals to determine the relative roughness between two types of sandpaper, and a shapes task requiring subjects to determine if any of a series of raised-line shapes was bilaterally symmetric. These tasks were performed in a block design paradigm, in which the BOLD signal obtained in the active blocks was contrasted with that in resting blocks to identify significantly activated voxels in a whole-brain analysis. We calculated, for each subject, the percentage of significantly activated voxels within a ROI of the primary visual cortex V1. We also used the mean absolute beta value of the activated voxels within the ROI to quantify the amplitude of the significant positive and negative activations. These quantities were evaluated as a function of visual-field loss.

Results

RP subjects with the greatest degree of vision loss (RP1 and RP2) exhibited the strongest visual cortex activation with sandpaper stimulation over the largest cortical extent in V1, while RP subjects with a less severe tunnel vision (RP5, RP6, and RP7) exhibited modest activation of the occipital cortex. Control subjects showed little-to-no response in V1. The strength of the BOLD signal response (as quantified by the mean absolute beta value within the ROI) and percentage of activated voxels within V1 thus decreased with overall increasing visual field for the sandpaper task (Fig. 1, $p < 0.05$). In contrast, for the shapes task, no change was found in the strength and extent of BOLD activation as visual field increased between the RP and sighted control groups ($p > 0.10$).

Comparison of BOLD responses between subjects RP1, RP2, RP5, and RP6 during the sandpaper task revealed a localization of tactile-evoked activity to regions most affected by vision deprivation. Subjects RP1 and RP2 had both central and peripheral blindness and experienced activation of both foveal and peripheral regions of V1 during the sandpaper task. Subjects RP5 and RP6 exhibited only peripheral blindness and had a greater amount of activation in the peripheral regions of V1 when compared to their foveal region (Fig. 2). A similar pattern was observed in 3 of the 7 RP subjects (RP1, RP2, and RP5) during the shapes task (Fig. 2).

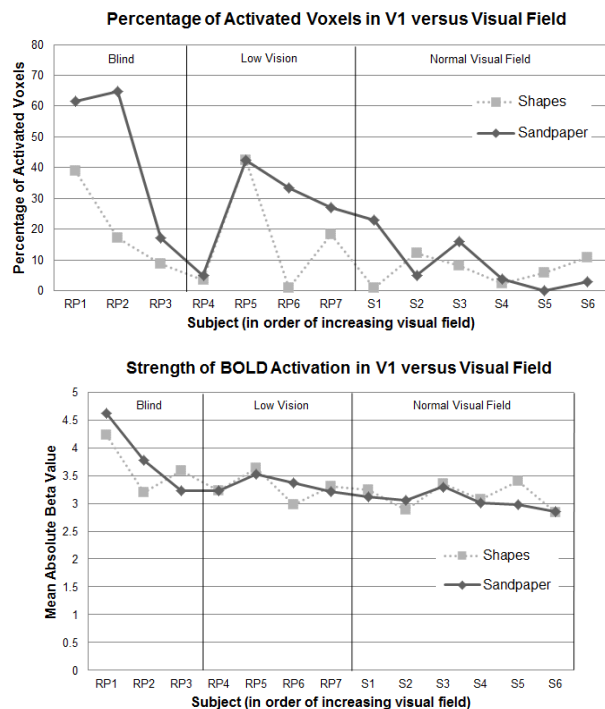


Fig. 1. Top: Percentage of activated voxels in V1 ($FDR < 0.05$) versus visual field loss. Subjects are ranked along the x-axis in descending order of severity of field loss. Blind subjects were those with minimal light perception and severe tunnel vision, while Low Vision subjects included those with moderate tunnel vision. **Bottom:** Strength of BOLD activation (mean absolute beta value) in activated V1 voxels ($FDR < 0.05$) versus visual field loss.

Conclusions

A strong correlation was found between degree of visual field loss and amount of activation observed in V1 that can be elicited through tactile stimulation. Both the spatial spread and the modulation amplitude of the activated voxels are increased with the severity of visual-field loss. These V1 responses seem to be task dependent, with a sandpaper stimulus evoking the strongest, least-specific response when compared to the shapes task. V1 responses to tactile stimulation can thus be used as a measure of the neural consequence of vision loss; this fMRI measure of cross-modal activations in the visual cortex may be used to monitor progress in individuals who have undergone vision replacement therapies.

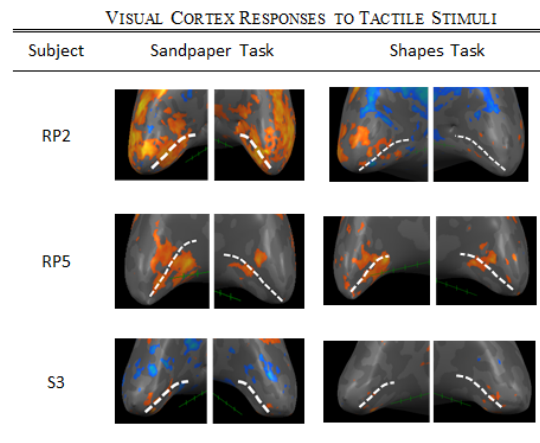


Fig. 2. BOLD responses to the tactile tasks in 2 representative RP subjects (blind RP2 and low vision RP5) and 1 sighted control. For each subject, an inflated representation of the visual cortex is shown (the white dotted line represents the location of the calcarine sulcus, with its posterior end at the occipital pole).