Top Down Influence on the Visual Cortex of the Blind During Auditory Sensory Substitution

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Target audience: Scientists and physicians interested in visual cortex plasticity and sensory substitution.

Purpose: Blind persons may acquire their visual perception indirectly by sensory substitution devices (SSDs), which convert images from a video camera to an alternative sensory signal that is presented to the blind person in place of direct visual information. One such SSD is The vOICe, which converts the images to auditory "soundscapes" that enable interpretation of simple visual environments [1]. We conducted a prospective, unblinded, single center pilot study to investigate whether top down processing networks in the blind are preserved in the setting of auditory SSD use.

Methods: We enrolled 22 adult subjects (12 blind and 10 sighted controls,) who were age and gender matched. Our protocol was IRB approved and all subjects signed an informed consent. MR images were collected on a 3T Siemens Allegra scanner. Subjects were presented a series of vOICe soundscapes that represented bars moving across the image in one of four directions. In order to examine top down influence on the visual cortex during sensory substitution, each subject underwent two fMRI scans with identical sound stimuli within the same experimental session. Subjects first passively listened to the soundscapes without any prior knowledge of their meaning (pre-training scan). Immediately after the pre-training scan, they were instructed on how the soundscapes were encoded and asked to actively interpret the sounds as images during the second scan (post-training scan). Functional MR images were collected with a single-shot gradient echo EPI pulse sequence with the following parameters: TR/TE=2000/26 ms, FOV=20.5 cm, 104x104 imaging matrix, and twenty-eight contiguous 3 mm thick slices to cover the entire occipital lobe. We calculated activation maps for each subject using a combination of in-house software and SPM8 subroutines. Images underwent slice timing correction and realignment, were normalized to MNI space, masked with a subject specific gray matter mask, and smoothed with a Gaussian kernel (FWHM=8 mm). The time course of each voxel was fitted with a general linear model (GLM) with predictors including the stimulus paradigm convolved with a canonical hemodynamic response function, the temporal derivative of this predictor, realignment parameters, and a constant. BOLD % change maps were calculated by dividing the coefficient of the stimulus paradigm predictor by the coefficient of the constant term. The average BOLD % change was calculated in 3 regions of interest (ROIs) corresponding to the primary (Brodmann area [BA] 17), secondary (BA 18), and higher order visual cortices (BA 19). Two-sample t-tests were used to test for differences between groups and paired t-tests were used to compare activation pre- and post-training. Statistical maps were thresholded at an FDR corrected p<0.05.

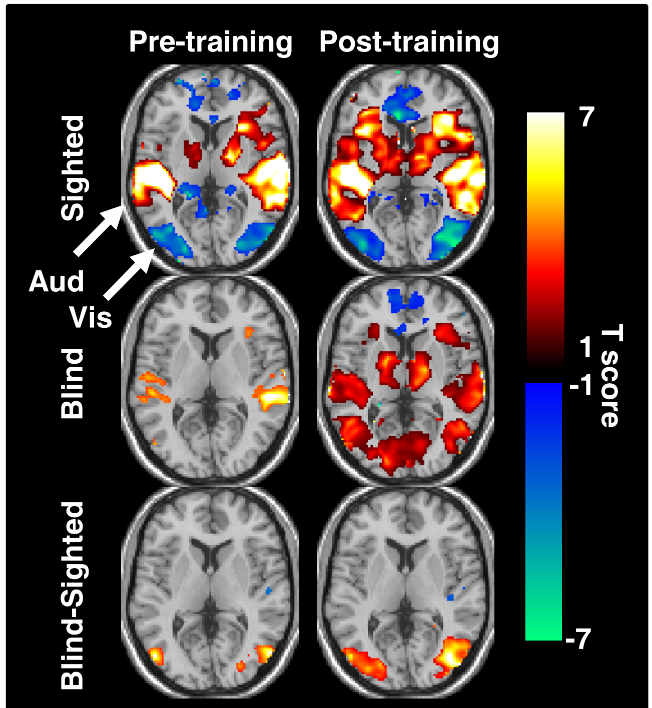

Figure 1. Statistical maps both pre-training (left) and post-training (right). Top row: one-sample t-test within sighted group. Middle row: one-sample t-test within blind group. Bottom row: two-sample t-test showing the difference between the sighted and blind groups. Images thresholded at FDR corrected p<0.05. Aud: auditory cortex. Vis: visual cortex.

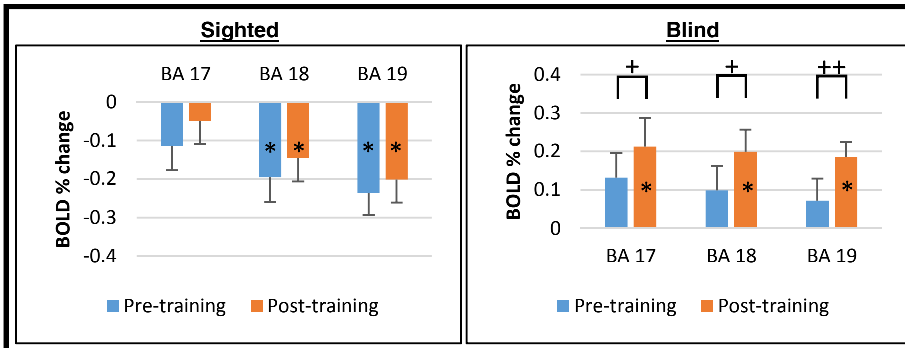

Figure 2. Average BOLD % change in Brodmann area 17 in the sighted and blind groups both before and after training. Error bars represent the standard error. *p<0.05 (one sample t-test), +p<0.1 (paired t-test), ++p<0.05 (paired t-test).

Results and discussion: Figure 1 shows the difference in activation between the sighted and blind groups during both the pre- and post-training scans. While the sighted subjects exhibited negative BOLD responses in the visual cortex consistent with previous literature on cross-modal brain interactions [2-4], blind subjects experienced positive BOLD responses. The BOLD responses in each group both before and after training are summarized in Figure 2. No significant differences were observed between pre- and post- instruction in the sighted group. On the other hand, significant BOLD % increase was observed after training in BA 19 of the blind group compared to pre-training (p=0.037), and trend level significance was observed in BA 17 and BA 18 (p<0.1). This increase in BOLD response despite the presentation of identical stimuli suggests that the visual cortex of blind subjects is significantly influenced by top-down input, a trend which is not observed in age-matched sighted subjects. Whether this top down modulation of alternative sensory stimuli within the visual cortex is an indicator of greater attention to auditory stimuli, and whether this top down modulation represents greater receptivity to cross modal interactions and ability to use SSDs merits further study.

References: [1] Meijer PB. 1992. IEEE Trans BME. 39(2): 112. [2] Kawashima et al. 1995. PNAS. 100(1): 253. [3] Hairston et al. 2008. Neuroreport. 19(2): 151. [4]. Laurienti et al. 2002. J Cog Nsci. 14(3): 420.