Crossmodal modulation of the intracortical depth profile of BOLD signals in auditory cortex

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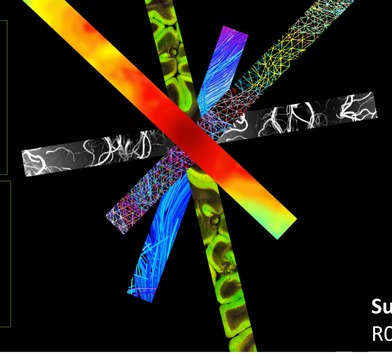

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Background

Previous electrophysiological studies in non-human primates have shown different laminar activation profiles to auditory vs. visual stimuli in auditory cortices and adjacent association areas (Schroeder & Foxe, 2002).

The measured activation profiles could indicate how information from other brain areas and cortical layers could modulate the auditory cortex activation through feedforward (FF) and feedback (FB) connections.

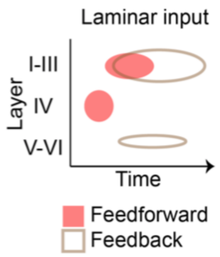

Figure 1. A schematic presentation of feedforward and feedback activation profiles. FF connections arrive first to layer 4 and spread then to layers 1–3. FB connections arrive typically to the layers 1–3 but also to a lesser degree to layers 5–6.

Schroeder & Foxe (2002) found that in auditory cortex, auditory stimulation had FF type profile, and visual stimulation had FB type profile. In superior temporal sulcus, both auditory and visual stimulation had FF type profile.

Aim

In our study we used 7T fMRI to study intracortical depth profiles of auditory cortex in humans by using simple auditory, visual and audiovisual stimuli.

Experiment

We presented 11 subjects with 4 runs of 5-stimulus trains of 300-ms auditory (A) noise bursts, visual (V) static checkerboard patterns, and their audiovisual (AV) combinations (adapted from Raij et al., 2010).

Subjects were asked to detect occasional targets (pure tone and/or diamond shape).

The data were acquired with a 7T scanner with 0.75 mm resolution for anatomical MRIs and 1.0 mm resolution for functional MRIs.

We used a new 3D EPI prototype sequence WIP1080 from Siemens to increase the SNR of our small voxels in fMRI.

Analysis

Figure 2. fMRI data was resampled into 11 equally spaced surfaces within the gray matter for defining the laminar activation profile.

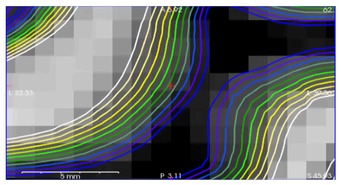

Figure 3. We used Freesurfer FsFast pipeline to calculate percent signal changes of the BOLD signals on each of the 11 surfaces on 8 anatomically defined regions of interest on the auditory cortex and adjacent areas for each subject.

Results

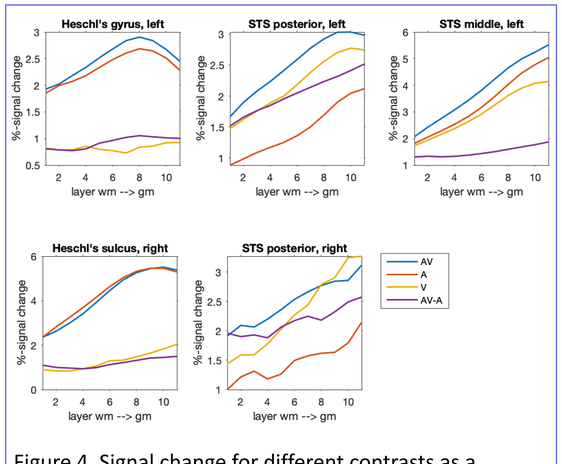

Figure 4. Signal change for different contrasts as a function of cortical layers. Linear mixed-effect model of contrast AV-A was used to determine how combining A and V inputs changed the BOLD across the layers.

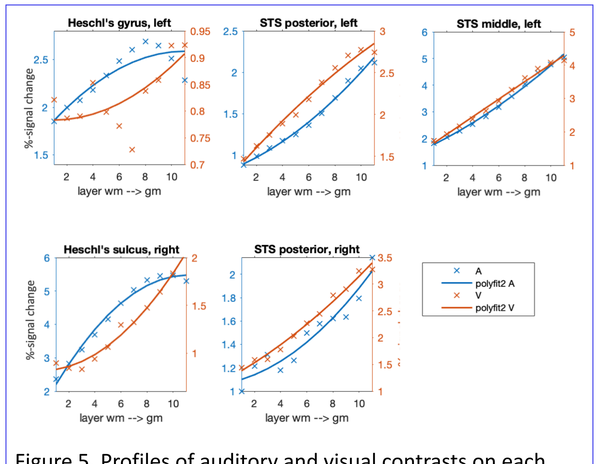

Figure 5. Profiles of auditory and visual contrasts on each area with a second-degree polynomial fitted to the curves. The difference between the A and V nonlinear slopes was larger in auditory areas HG/HS vs. than in the polymodal STS, broadly consistent with Schroeder and Foxe (2002).

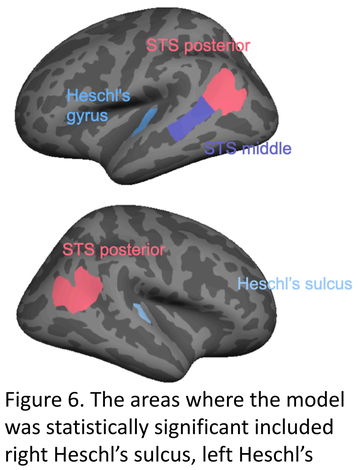

Figure 6. The areas where the model was statistically significant included right Heschl's sulcus, left Heschl's gyrus, and posterior and middle superior temporal sulcus.

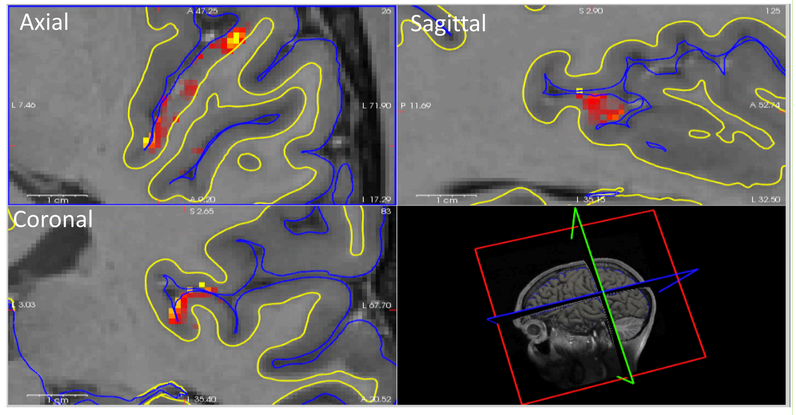

Figure 7. Signal-%-change (scale 0–1.4) on one subject's Heschl's gyrus (left hemisphere) for contrast AV-A, yellow: wm → blue: gm

Conclusions

Our results suggest that the cortical depth profiles of BOLD signal could be modulated differentially for unisensory and multisensory stimuli in auditory cortices and STS, possibly reflecting effects of FF and FB connections from different layers and brain regions.

For future work, further studies are still needed for distinguishing between neuronal vs. venous draining effect, controlled here by using subtraction techniques, in laminar BOLD signals.

References

Schroeder & Foxe, 2002. The timing and laminar profile of converging inputs to multisensory areas of the macaque neocortex. *Cognitive Brain Research*, *14*, 187–198

Raij et al., 2010. Onset timing of cross-sensory activations and multisensory interactions in auditory and visual sensory cortices. *European Journal of Neuroscience*, *31*(10), 1772–1782