Intracranial stereotactic EEG study of crossmodal influences in human auditory cortex

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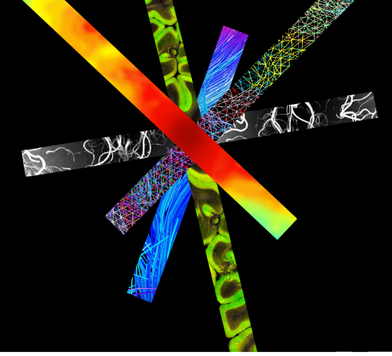

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Introduction

Crossmodal visual influences occur already at early stages of human auditory cortex (AC) processing. The mechanisms and role of these effects are still unclear.

Conservative hypothesis: Crossmodal visual influences modulate sound processing, but do not directly activate human AC neurons.

Alternative hypothesis: Based on certain single-unit animal models, visual stimuli could trigger AC firing patterns, which may even carry information of the non-auditory stimulus.

Method

Stimuli: 300-ms noise bursts (auditory, **A**), checkerboards (visual, **V**), and noise burst + checkerboard combinations (audiovisual, **AV**).

Intracranial stereotactic EEG (SEEG) in 8 patients undergoing preoperative monitoring.

SEEG loci determined by clinical criteria: one bilateral, 4 left-hemisphere, and 4 right-hemisphere implantations.

Measure of interest: **intracranial 65-240 Hz high broadband gamma (HBG)** activity, potential correlate of firing activity.

SEEG inverse modeling to facilitate anatomically normalized group analyses in four regions of interest (ROI, **Fig. 1**).

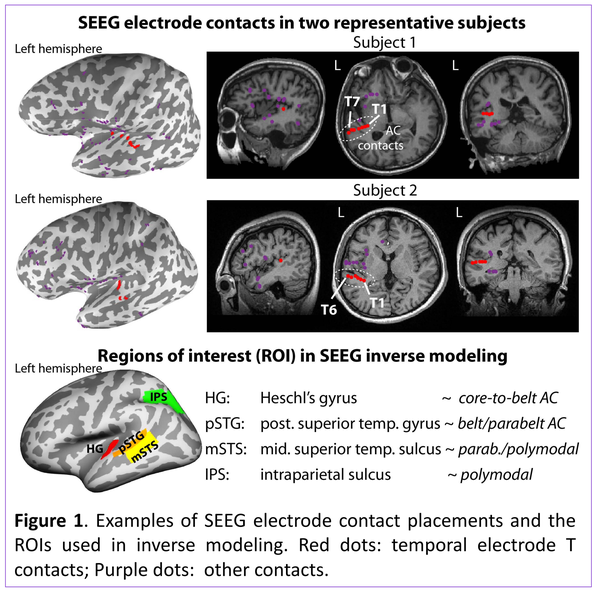

Figure 1. Examples of SEEG electrode contact placements and the ROIs used in inverse modeling. Red dots: temporal electrode T contacts; Purple dots: other contacts.

Results

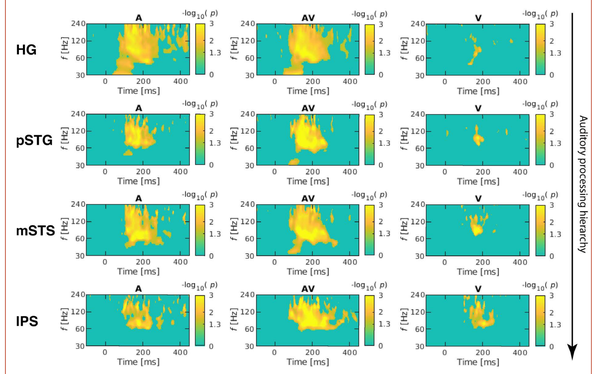

Figure 2. Group ROI analysis shows prominent HBG to A and AV stimuli, but less so to V stimuli. The time-frequency representations (TFR) show uncorrected statistical significance of group analyses combining data from 9 hemispheres of 8 subjects. Statistical significance determined based on one-tail t-tests.

HBG activity was highly robust and statistically significant after A and AV stimuli, but weak after V stimuli, in superior temporal AC areas (**Fig. 2**).

Visually-induced HBG activity emerged is ROIs overlapping auditory association and polymodal processing areas.

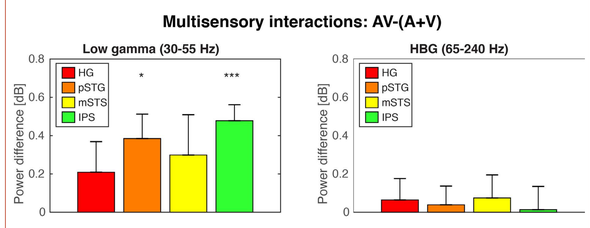

Figure 3. Time-frequency of interest analysis of MSIs of low gamma and HBG activity. The post-stimulus power values were averaged at 100-450 ms within the two frequency ranges. Significant MSIs were found only at the low gamma range. *p<0.05, ***p<0.001; two-tail t-test. Error bars show the standard error of mean.

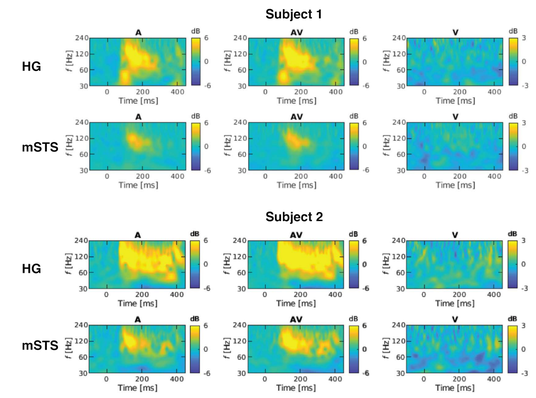

Figure 4. **Source-estimate data** in two representative individual subjects, analyzed from HG and mSTS. The data show $\log_{10}$ normalized power relative to the pre-stimulus baseline.

Super-additive multisensory interactions (MSI), defined as AV>A+V, were not observed in HBG activity estimates in ACs and other ROIs studied (**Figure 3**).

Evidence of super-additive MSIs was , however, found at the low gamma range (30-55 Hz) in the areas pSTG and IPS.

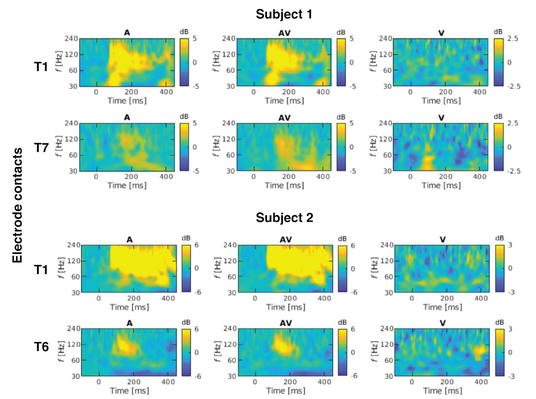

Figure 5. **SEEG electrode data** in two representative individual subjects. In both subjects, the contact T1 is in medial HG. The contacts T7 of Subject 1 and T6 of Subject 2 are in or near mSTS (see Fig 1). Note the considerable resemblance between the source models in Fig. 4 and these SEEG data. The data show $\log_{10}$ normalized power relative to the pre-stimulus baseline.

Figures 4 and 5 show examples of gamma-band activity to A, AV, and V stimuli in two representative subjects.

The source estimates of HBG (**Fig. 4**) were remarkably consistent with those analyzed from the intracranial SEEG contacts from the same areas (**Fig. 5**).

Conclusion

- No evidence of robust and statistically significant HBG activity triggered by visual stimuli in ACs.
- This finding was consistent in group analyses of source estimates and individual-level SEEG contact data.
- Assuming that intracranial "non-oscillatory" HBG activity is a correlate of local firing, our results suggest that crossmodal visual inputs trigger mainly modulatory effects in or near ACs.
- Super-additive MSI effects (AV>A+V) were observed at the lower gamma band range (below 55 Hz) in pSTG (non-primary AC) and the polymodal IPS.
- Source modeling of SEEG data could provide a feasible method for anatomically normalized group analyses of intracranial neurophysiological recordings in humans.

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