Selective modulation of interhemispheric connectivity by TACS stimulation influences auditory perception

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Introduction

Functional connectivity plays a major role for information encoding, transfer, and integration. Binaural integration describes the phenomenon that different auditory cues presented to the left and the right ear (dichotic listening) can become integrated into a unified percept. This phenomenon presumably relies on interhemispheric functional connectivity [1]. In a recent study [2], we found evidence for this hypothesis showing that the modulation of interhemispheric oscillatory synchrony by means of bi-hemispheric high-density transcranial alternating current stimulation (HD-TACS) affects binaural integration of dichotic acoustic features. Here, we combined bi-hemispheric high-density TACS over the lateral superior temporal lobe with concurrent fMRI to test whether the TACS effect is mediated by changes in effective brain connectivity.

Auditory Integration

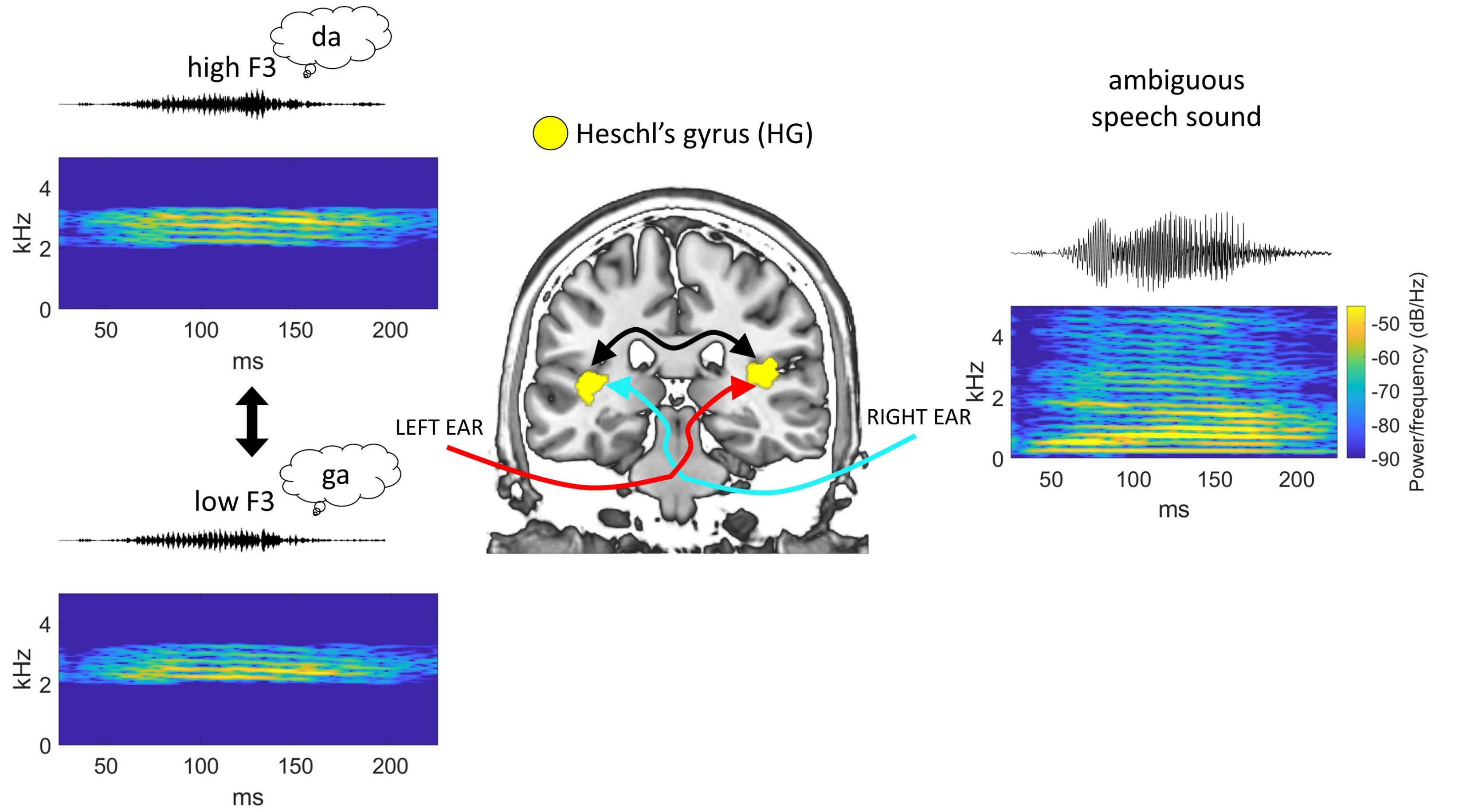

Fig. 1. Center: Dominant processing pathway underlying binaural integration. The red line represents the processing pathway of left-ear speech cue (either high or low frequency third formant (F3)). Left side: Sound pressure waveform and corresponding sound spectrogram of the speech cue presented to the left ear. Left side up: high F3 supporting a /da/ interpretation. Left side below: low F3 supporting a /ga/ interpretation. Right side: Sound pressure waveform and corresponding spectrogram of the ambiguous speech sound presented to the right ear [3].

Design

28 right-handed native-Dutch volunteers (mean age 21.9, 9 male)

Within-subject design

8 task fMRI runs (4 TACS and 4 sham runs)

88 task trials per run (60 ambiguous stimuli, 28 unambiguous stimuli)

Whole brain fMRI data (resolution 2x2x2 mm, 66 slices)

Multiband sparse sequence (TR=3000 ms, TA=930ms, TE=34ms).

128 Volumes per scan run

1 additional passive baseline run (336 Volumes, TR=2000ms), at the beginning of the experiment.

References

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3. Preisig, B. C., & Sjerps, M. J. (2019) Journal of the Acoustic Society of America 145, EL190–196.
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Experimental Procedure

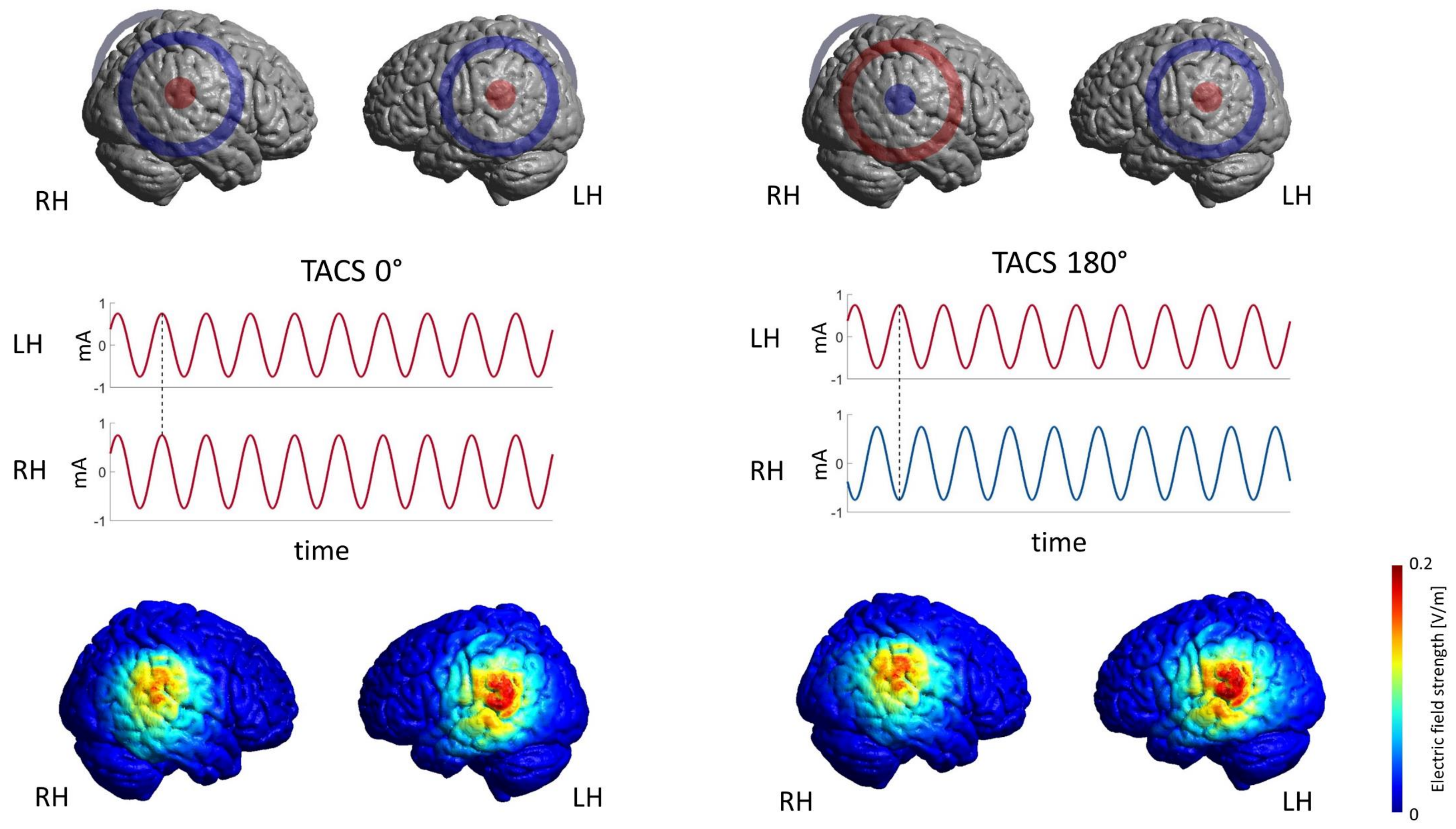

Fig. 2. Top: Stimulation electrodes were centered over CP6 (right hemisphere) and CP5 (left hemisphere) [2]. Middle: The interhemispheric phase synchrony was manipulated using 40Hz TACS with an interhemispheric phase lag of 0° (TACS 0°) or 180° (dotted line, TACS 180°). Electrode colors represent the polarity of the current for the timepoint highlighted by the dotted line (positive = red; negative = blue). Bottom: Simulation of the electric field strength induced by bi-hemispheric TACS in a template brain. RH: Right hemisphere; LH: Left hemisphere

TACS modulates local brain activity

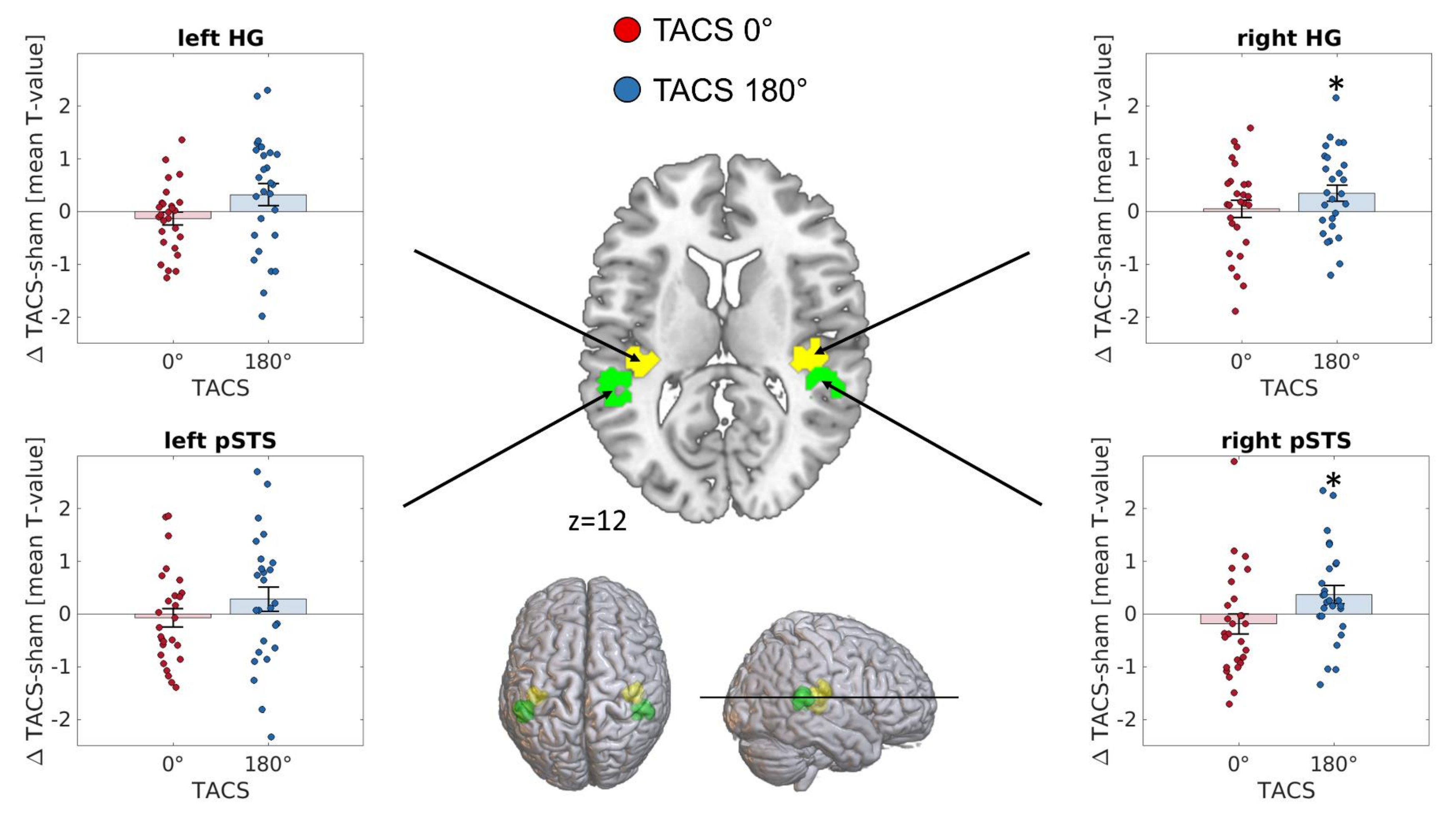

Fig. 3. Participants' mean activation within the ROI is shown for each stimulation condition (TACS 0°, TACS 180°) relative to sham. Dots represent the data points of single participants. Bars and error bars represent mean ± SEM across participants. TACS stimulation modulates activity in the auditory speech network. TACS 180° induced a significant increase in activity in right HG and right pSTS compared with sham. HG: Heschl's gyrus, pSTS; posterior superior temporal sulcus.

Behavioral performance

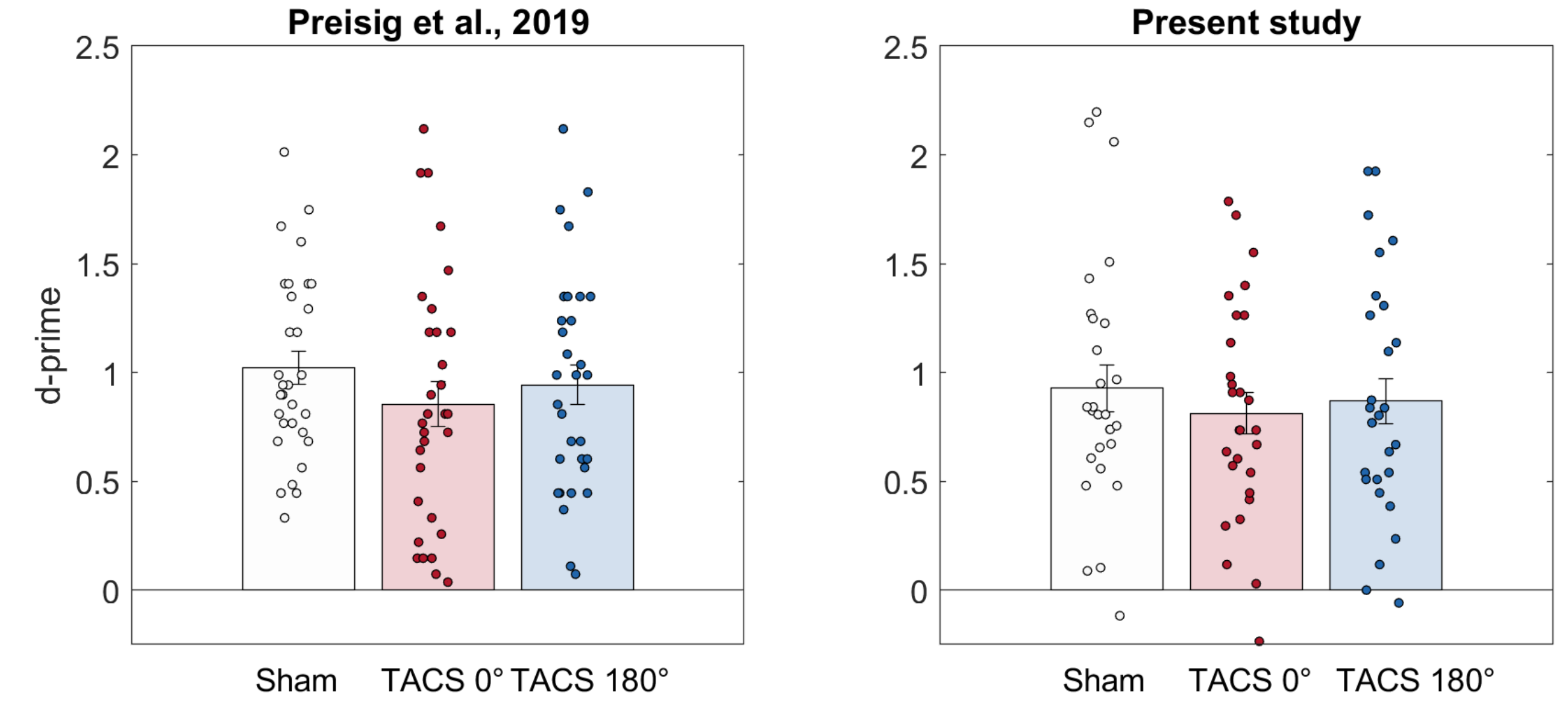

Fig. 4. Binaural integration (d-prime, mean ± SEM) as a function of TACS condition (sham, TACS 0°, TACS 180. In line, with [2, left chart] binaural integration was lower for the TACS 0° condition as compared to sham (paired t-test, p = .036, one-tailed, effect size: d=0.21). Dots represent the data points of single participants.

Connectivity between primary auditory cortices (HG) is selectively modulated by antiphase TACS

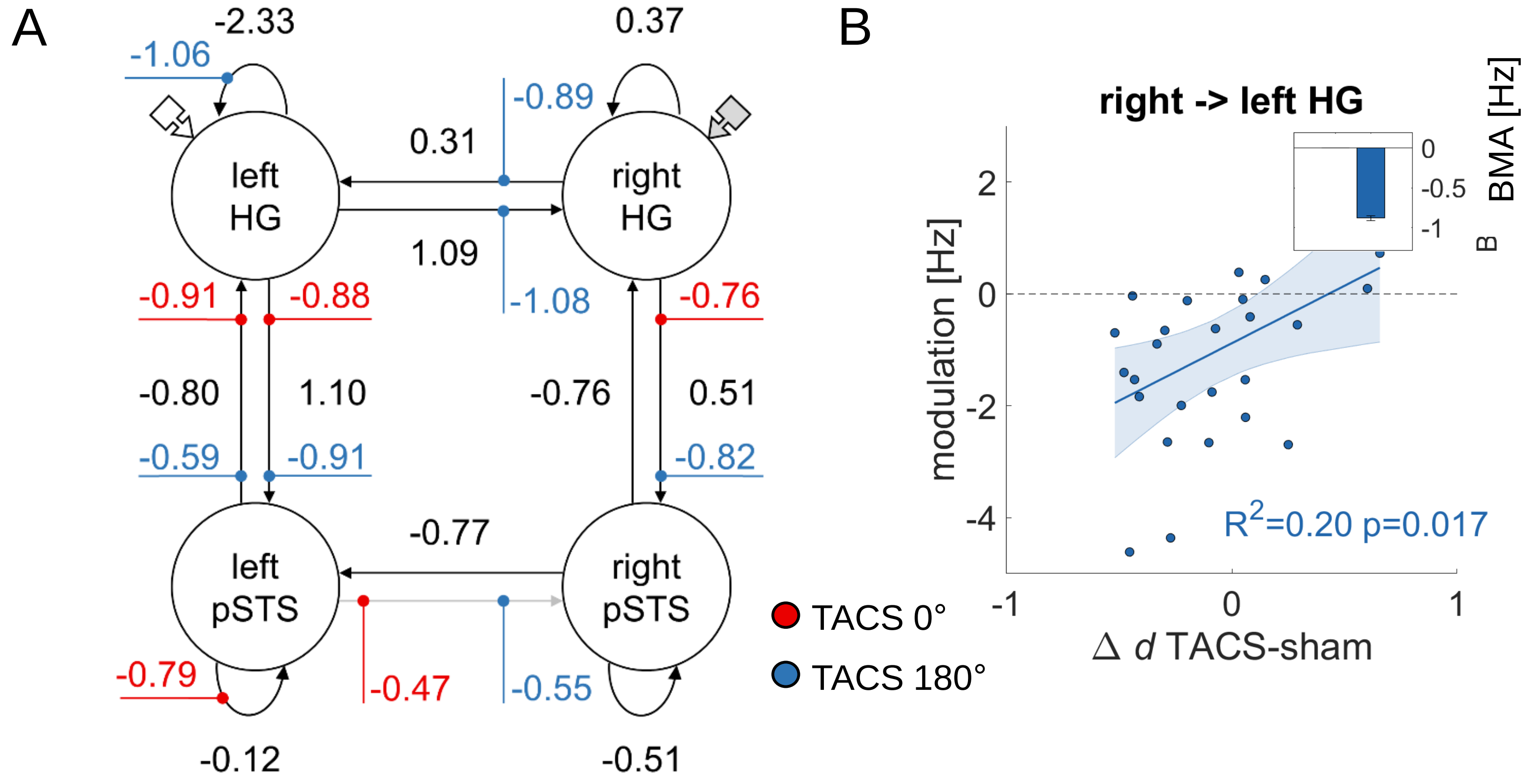

Fig. 5. (A) Regions of interest (ROI) and the average modulation (in Hz) of their connections by TACS. The numbers on the arrows represent average coupling parameters in Hz. Bilateral gamma TACS with a phase lag of 180° (TACS 180°), but not TACS 0° reduced interhemispheric coupling. (B) The strength of TACS modulation on the connection right to left HG is significantly correlated with TACS induced modulation of the binaural integration score. *Note.* BMA: Bayesian Model Average.

Discussion

Interhemispheric connectivity between primary auditory cortices (HG) is selectively modulated by antiphase TACS (phase lag 180°)

The putative mechanisms is that the induced phase lag (180°) is maladaptive for interhemispheric information transfer, and thus reduces interhemispheric coupling

Consistent with the idea that neuronal groups which do not undergo coherent excitability fluctuations communicate less efficiently [4]

In-phase TACS (phase lag 0°) is not beneficial but detrimental for binaural integration, because it reduces intra-hemispheric connectivity

The effect of in-phase TACS is depending on baseline performance. In participants with good performance, who show an optimal level of gamma band oscillatory activity, reflecting a high neural signal-to-noise ratio, TACS may add noise that makes performance worse [5]

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