Lateralized alpha oscillations reflect attentional selection of speech in noise

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Introduction

- Attentional selection of one talker at a particular spatial location facilitates speech understanding against interference.
- Spatial attention to objects in the left or right half space leads to an increase of neural **alpha power** (~10 Hz) in the ipsilateral and a decrease in the contralateral hemisphere.
- This **alpha lateralization** has been evidenced in anticipation of visual [1], somatosensory [2], and auditory stimulation [3,4].
- Research questions:

  Does alpha lateralization in **auditory cortex regions** and in a supramodal **parietal attention network** index spatial attention to one of two **ongoing speech streams**?

  Does alpha lateralization **temporally align** with the presented speech signal?

Methods

- **Participants**: 19 young participants (20–35 years; 11 females).
- **Stimuli**: Two streams of four spoken digits, presented dichotically to left and right ear (Fig.1a). Perceptual onsets of digits were precisely aligned. Digit presentation rate: 0.67 Hz.
- **Task**: Cue on one ear (1000 Hz pure tone, 500 ms duration) indicated the to-be-attended ear. After acoustic stimulation, participants had to report four digits from the to-be-attended ear on a visually presented array (Fig.1a).
- **Data recording**: 306-channel MEG (Vectorview; Elekta Neuromag Oy). Sampling rate: 1000 Hz; offline bandpass filter: 0.3–180 Hz. Data analysis with customized scripts and Fieldtrip toolbox [5].
- **Alpha lateralization index**: Contrast of alpha power at (individually selected) gradiometer channels ipsi- and contralateral to the cued ear: *(ipsi–contra)/(ipsi+contra)* [2]. Positive index = higher ipsilateral alpha.
- **Modulation of lateralization**: Cosine function ($g(t) = A\cos(2\pi f t + \varphi)$) fitted to the lateralization index (least-squares method, f = 0–2 Hz). Cosine amplitude (A) quantifies the modulation of the lateralization index over time.
- **Source analysis**: DICS beamformer estimated oscillatory power separately for attention left/right trials (fourier spectra at 10 Hz ± 2 Hz spectral smoothing) using a common filter (all trials, 0–7.9 s). Alpha lateralization was computed at 10,242 source locations and morphed onto one participant's brain (Fig. 2b).
- **Granger causality**: Autoregressive models (order 10, temporal resolution: 50 ms) fitted to each participants' inter-trial phase coherence (ITPC, 2–8 Hz; Fig 4a), overall alpha power, and alpha lateralization index. Computation of frequency-domain granger spectra using the Fieldtrip toolbox [5].

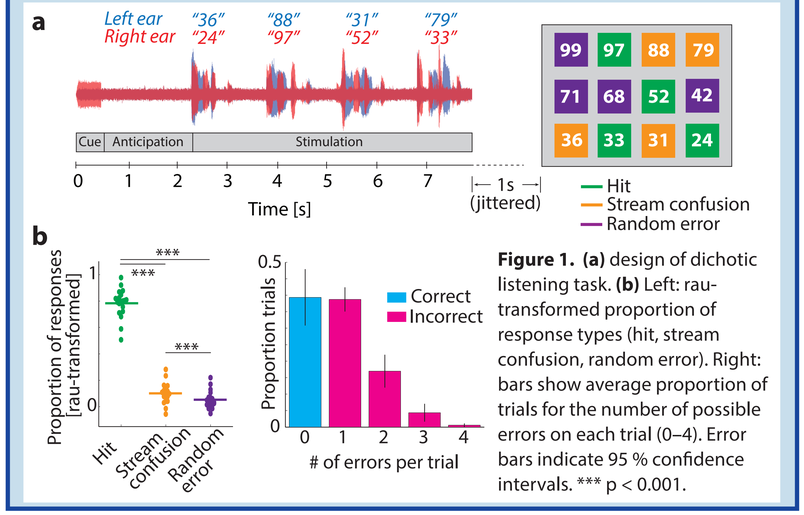

Figure 1. (a) design of dichotic listening task. **(b)** Left: rau-transformed proportion of response types (hit, stream confusion, random error). Right: bars show average proportion of trials for the number of possible errors on each trial (0–4). Error bars indicate 95 % confidence intervals. *** p < 0.001.

Results

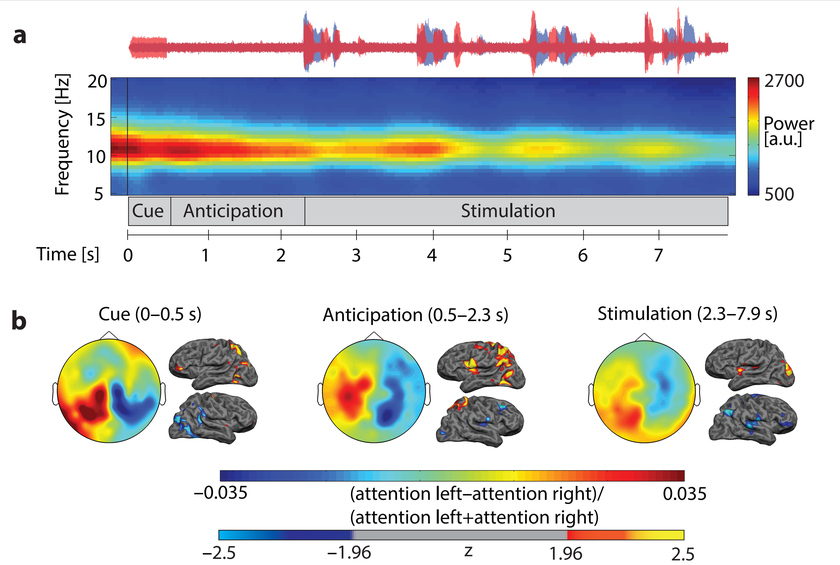

Figure 2. (a) Absolute power averaged across 204 MEG gradiometer sensors. **(b)** Alpha power (8–12 Hz) lateralization in sensor space and in source space for cue, anticipation, and stimulation period. In source space, the lateralization of 19 participants was tested against zero (using one-sample t-tests). T-values were transformed to z-values and overlaid on a partially inflated brain.

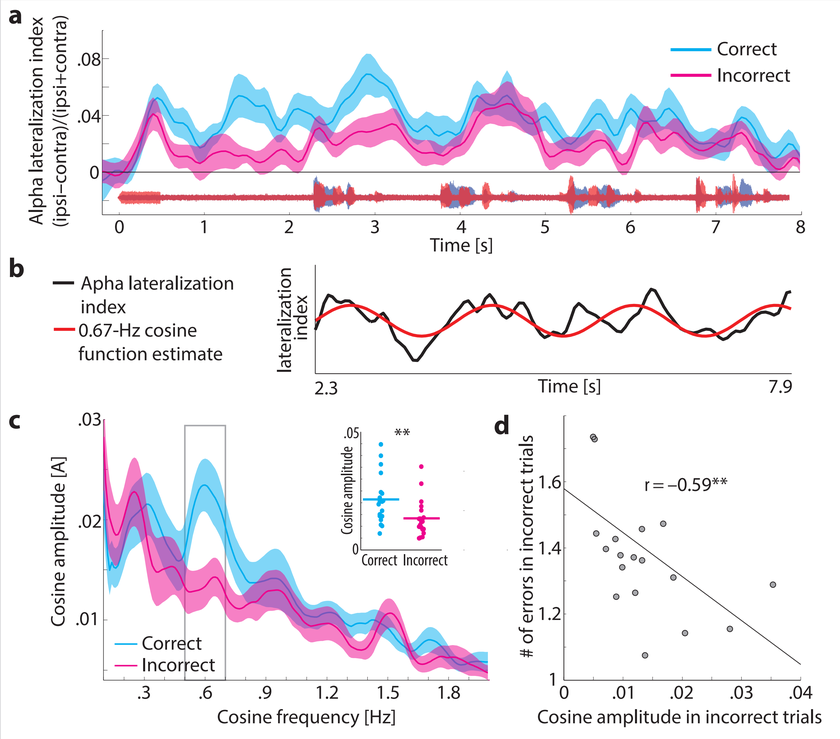

Figure 3. (a) Mean alpha lateralization index (± 1 SEM). Positive index indicates higher relative alpha power at ipsilateral sensors. **(b)** Exemplary lateralization index and 0.67-Hz cosine fit for one participant. **(c)** Estimated cosine amplitude for different frequencies in stimulation period (2.3–7.9 s). Cosine amplitude at 0.5–0.7 Hz was significantly higher in correct trials (p = 0.003). **(d)** In incorrect trials, higher 0.67-Hz cosine amplitude (averaged across 0.5–0.7 Hz) predicted fewer errors (p = 0.009).

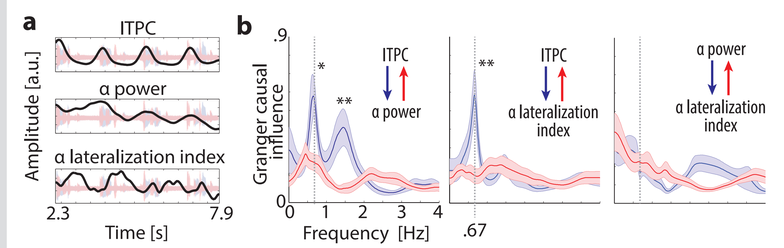

Figure 4. (a) Grand-average inter-trial phase coherence (ITPC; averaged across freqeuncies 2–8 Hz and 24 right and left temporal sensors), alpha power (8–12 Hz; averaged across 204 gradiometer sensors), and alpha lateralization index (averaged across correct and incorrect trials) in the stimulation period (2.3–7.9 s). **(b)** Mutual granger causal influence for all pairs of neural measures at frequencies 0–4 Hz. Shaded areas indicate ±1 SEM. * p < 0.05; ** p < 0.01.

Discussion

Main findings:

(i) Alpha lateralization reflects spatial attention to one of two ongoing speech streams (Fig.2).

High ipsilateral alpha power reflects suppression of stimuli from the unattended side. Low contralateral alpha power reflects enhancement of stimuli from the attended side.

(ii) Alpha power modulations in parietal cortex, but critically also in auditory cortex regions underlie the attentional selection of one speech stream in a two-talker situation.

Alpha power lateralization might thus indicate an attentional filter mechanism that orients supramodal attention in a parietal network and regulates sensitivity in auditory cortex regions to enhance the signal and to suppress noise.

(iii) Alpha power lateralization is not constant during selective attention but entrains to the word rate (Fig.3).

The alignment of alpha power lateralization to the word rate implements the strongest attentional selection at the time periods of individual spoken digits.

Granger causal analysis (Fig.4) suggests that fluctuations of the alpha power lateralization index are driven by the external stimulation. Future studies should test the influence of temporal expectancy on fluctuations of alpha power lateralization.

References

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