

Selective attention to one of two competing auditory rhythms modulates phase of brain response

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Introduction

When listening to multiple, competing sounds, what brain mechanisms might enable us to attend to one sound while resisting the influence of other sounds? Do auditory attentional mechanisms only enhance the amount of neural activity to an attended stimulus, or do they also alter the timing of that activity?

Mechanisms of selective attention were studied in a rhythm synchronization paradigm that provides a continuous behavioral measure of attention. We used an ongoing measure of primary auditory cortical response, the auditory steady state response (aSSR), allowing simultaneous measurement of brain response to two concurrent stimuli.

Background:

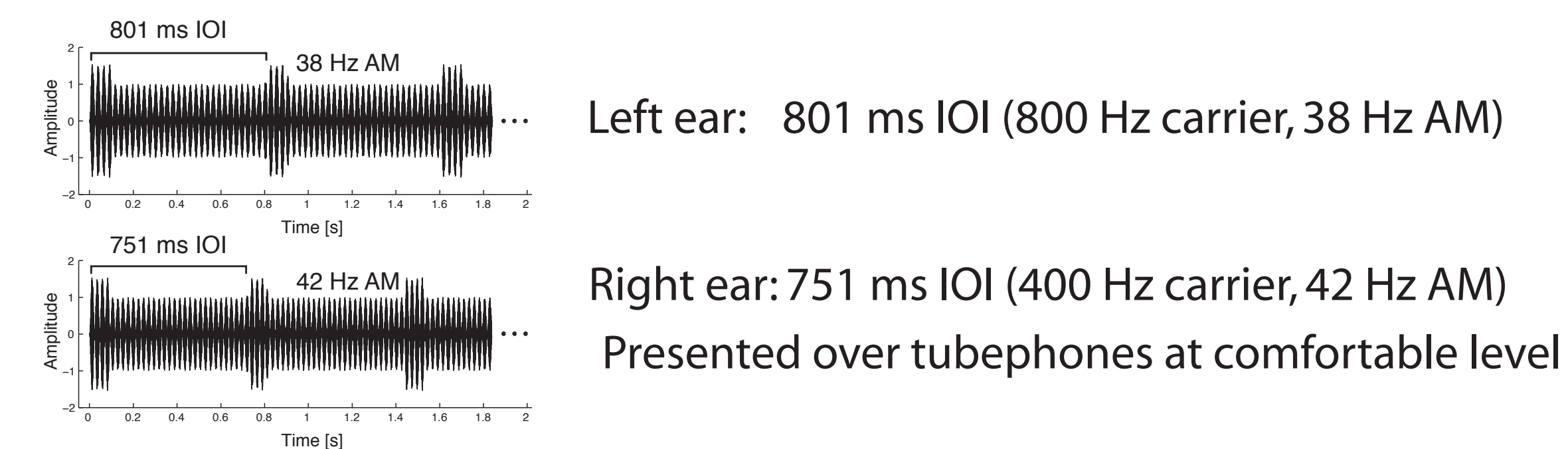
Attention has a small effect on aSSR power (Iversen, et al. 2004; Ross, et al. 2004; Bidet-Caulet, et al. 2007). Iversen, et al. (2004) also found an increase in aSSR interhemispheric coherence with selective attention to a sound in the presence of visual distractors.

The present study examines within-modality selective attention to an ongoing stimulus (rather than to transient events), measuring amplitude, phase and partial coherence of the aSSR.

Methods: Task and stimulus

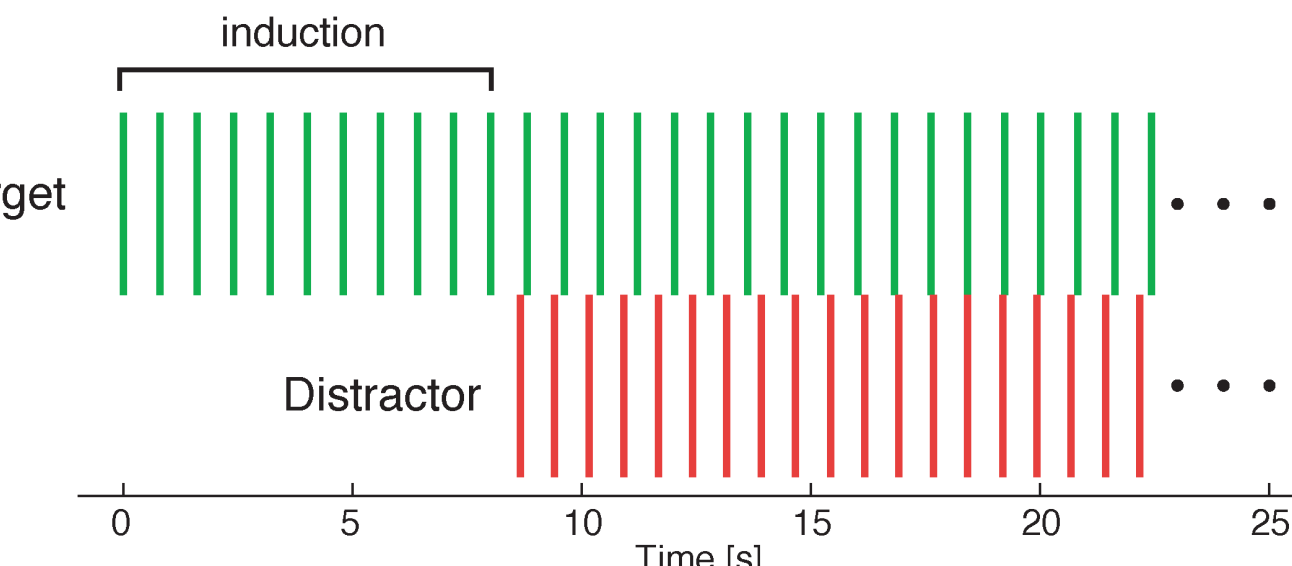
Stimulus: Two auditory metronomes (Target and Distractor)
Task: Tap in synchrony with Target, ignoring Distractor

Auditory stimulus



Trial structure

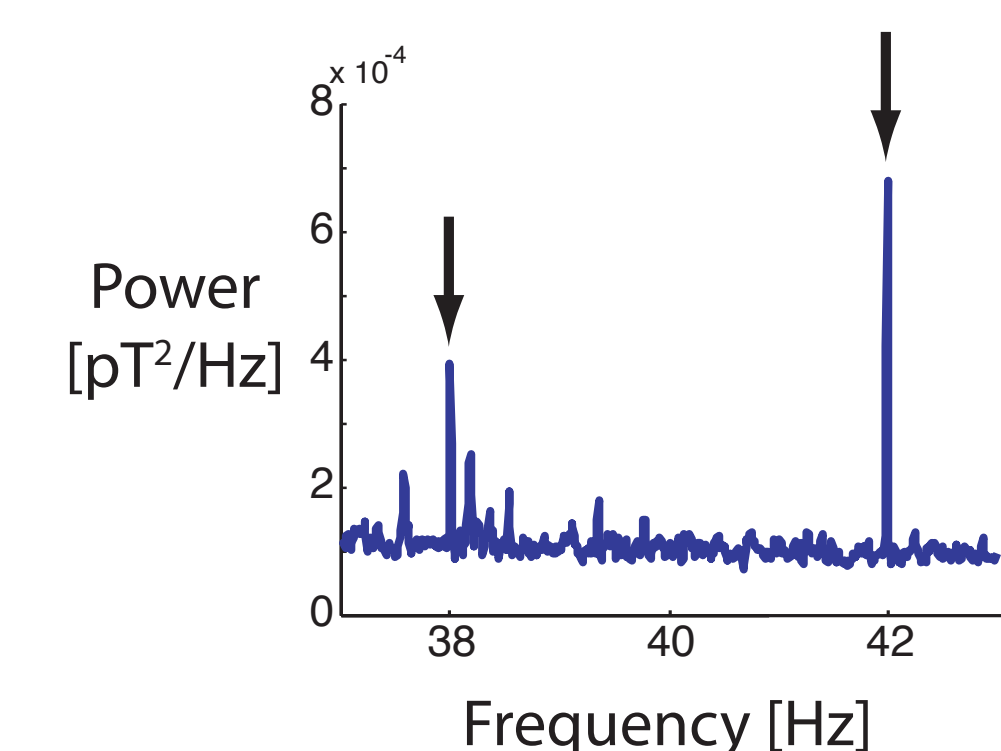
Each stimulus was target for 8 trials.
14 adult participants
Measure tap times



Methods: Neural recording

Whole-head MEG (148 magnetometers, 4-D Neuroimaging)
Two concurrent auditory steady-state responses (aSSR)

Figure: Spectrum for one sensor in one 68 s trial showing frequency peaks associated with auditory SSR evoked by the two stimuli.

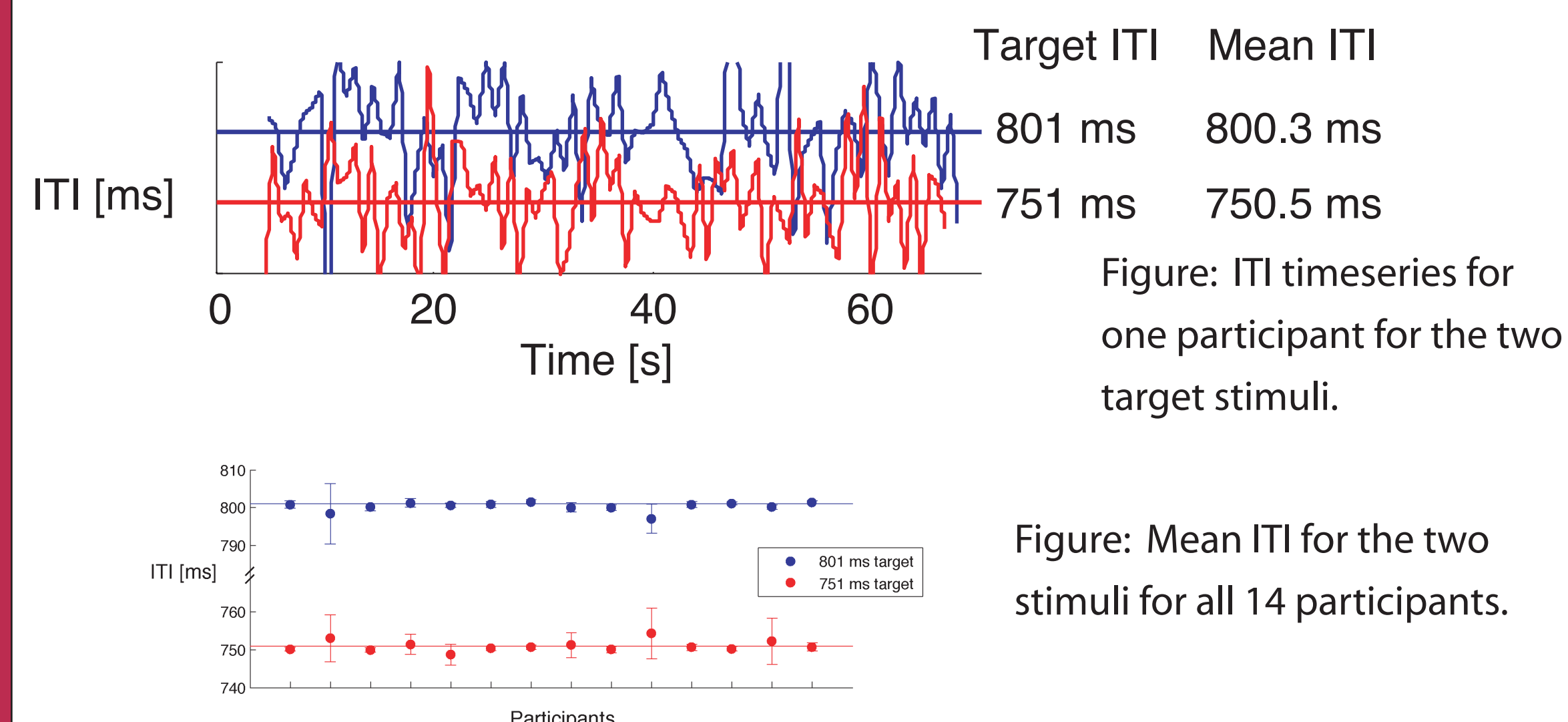


Dependent measures:

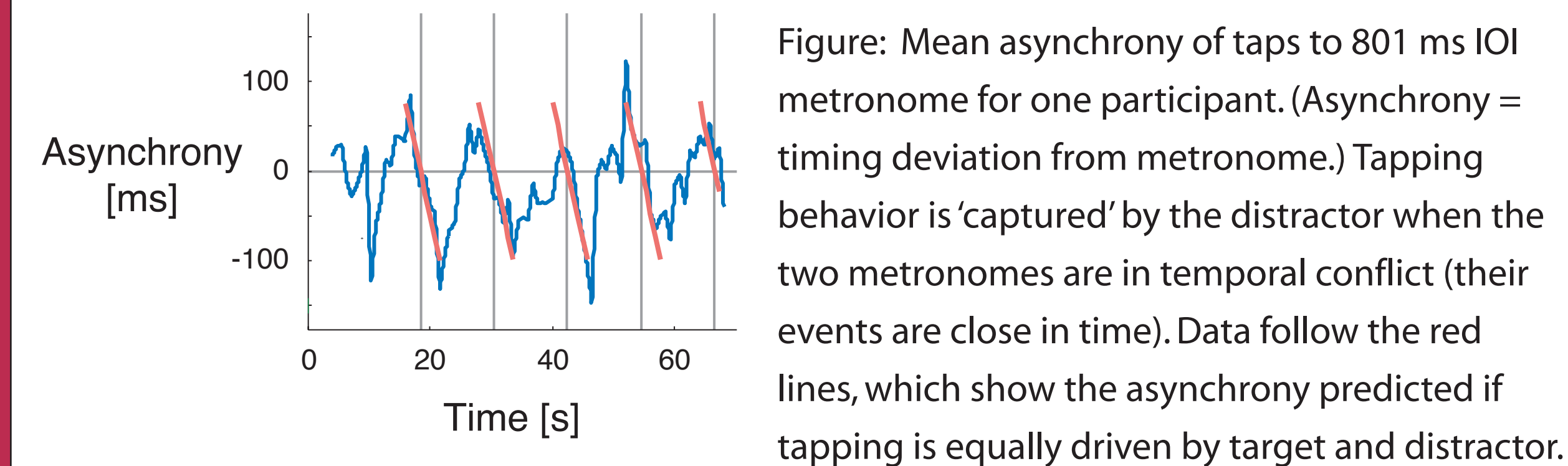
- Power and Phase of aSSR at each sensor
- Partial coherence between distant channel pairs.

Results: Behavior

People can match the tempo of the attended target...

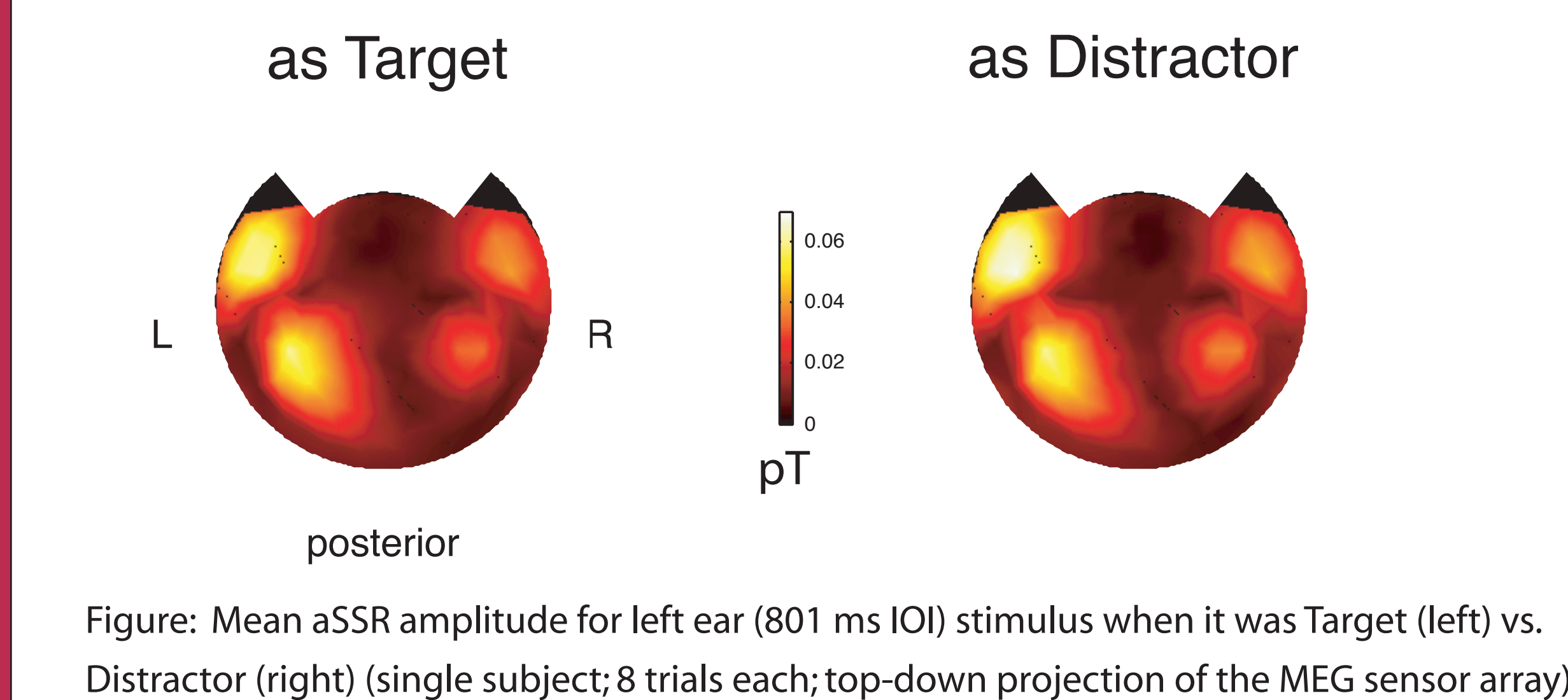


...but tap timing is strongly affected by the distractor



Results: Power

Example of Topographic Maps of aSSR Power



aSSR Difference (Target - Distractor)

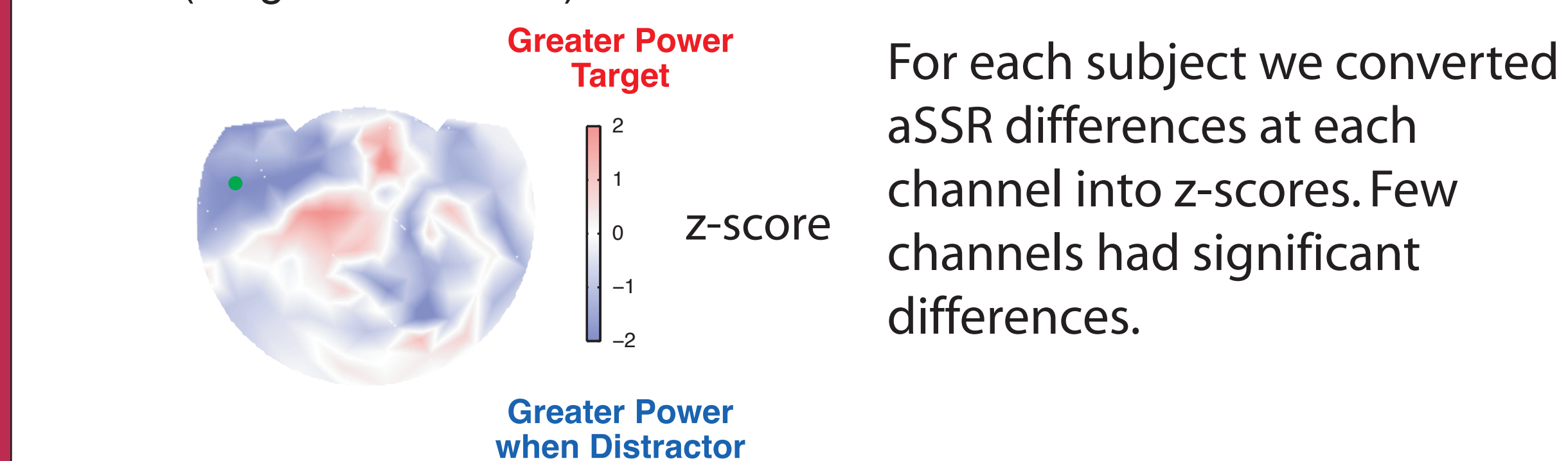


Figure: aSSR amplitude difference in one subject. Shown is the z-score computed across 8 runs in each condition.

No consistent effect of selective attention on aSSR power

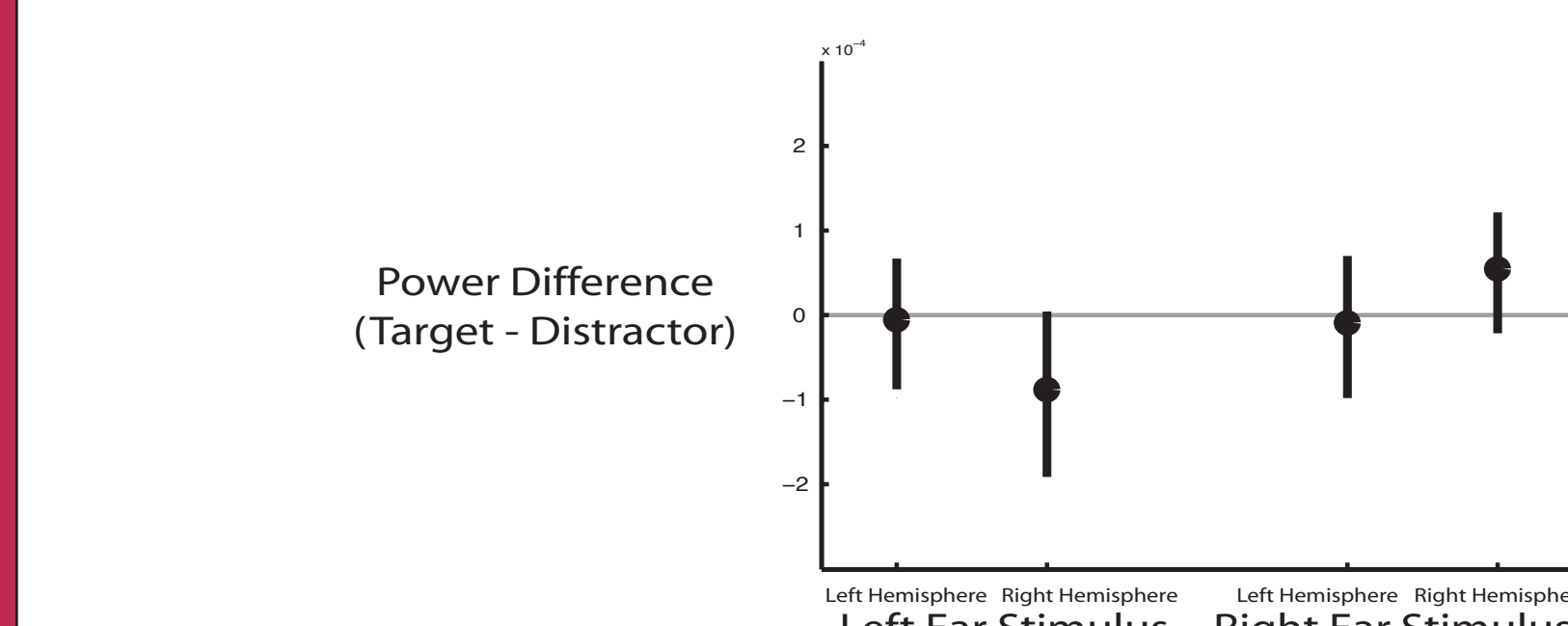


Figure: Grand mean power differences (n=13) for the two stimuli, indicating the difference in response to each stimulus as Target vs. Distractor. Differences for each participant were computed across all channels with SNR > 2 dB, separately for the left and right hemispheres. No differences reached statistical significance.

Results: Phase

Example of Topographic Maps of aSSR Phase

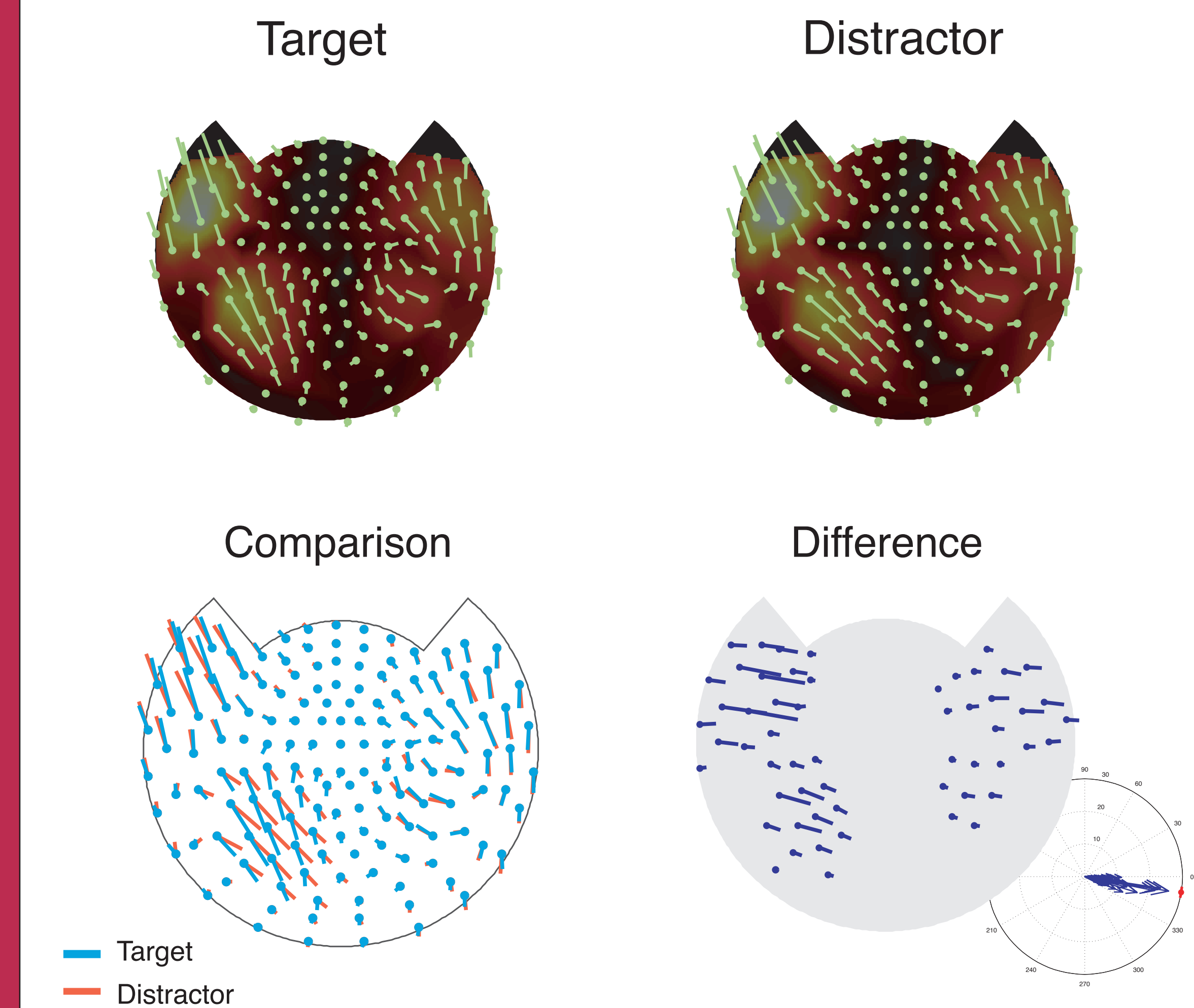


Figure: aSSR phase for one stimulus (801 ms IOI) averaged across 8 runs with the stimulus as target (top left) and 8 runs as Distractor (top right), for one participant. Dots indicate sensor positions and vectors indicate resultant phase. Vector length indicates greater phase consistency. Comparing phases (bottom left) shows the target phase to be delayed relative to Distractor, yielding a negative difference (bottom right).

Selective attention changes aSSR phase

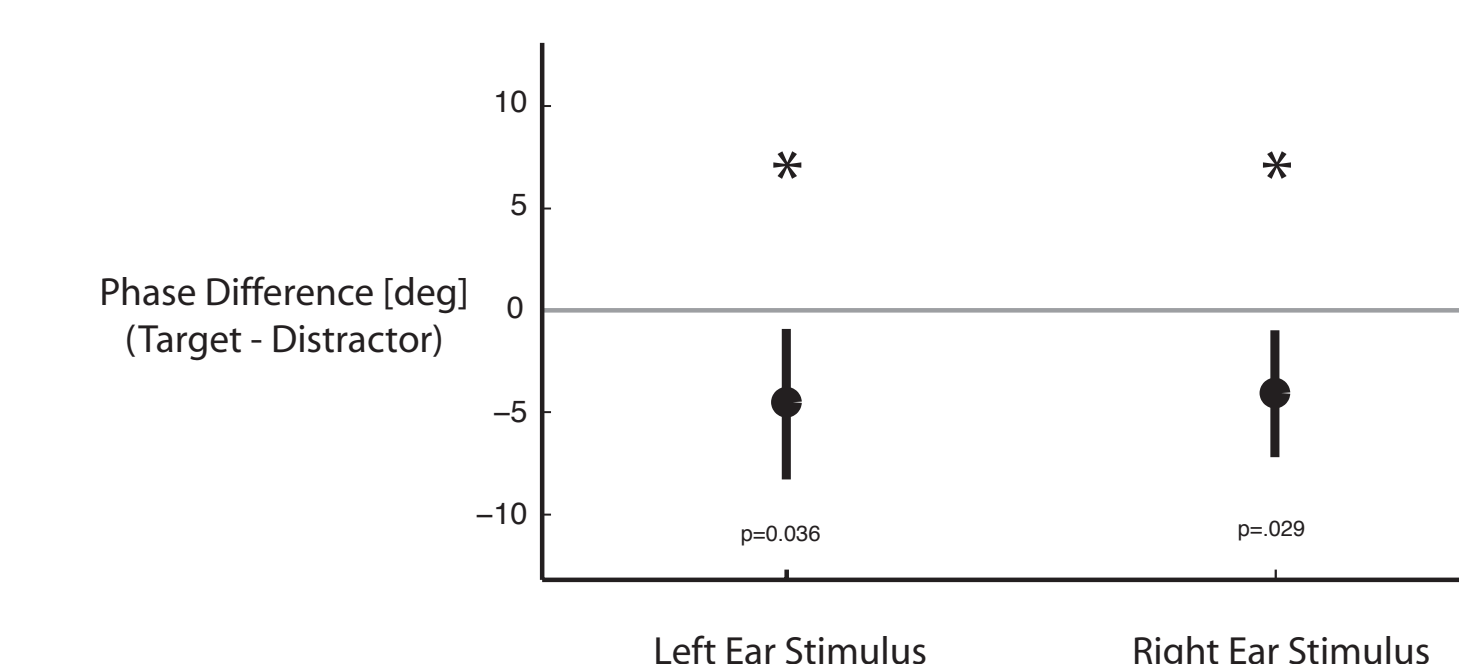
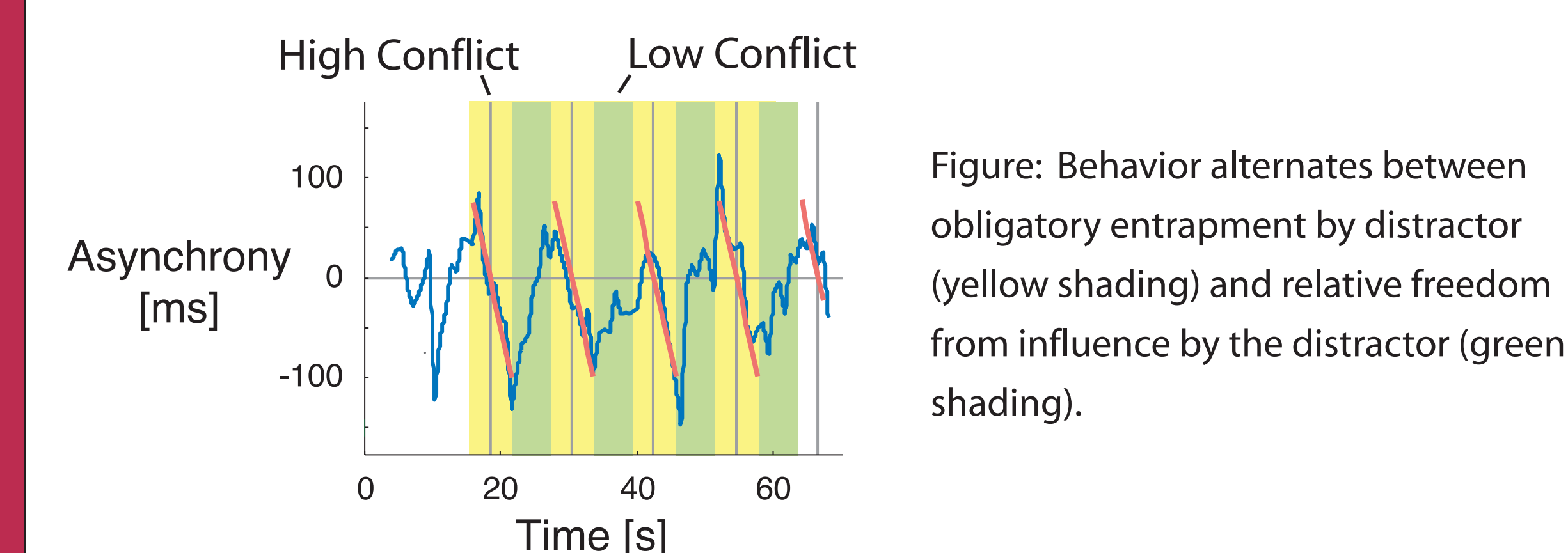


Figure: Grand mean phase difference (n=13) for the two stimuli. Mean phase difference for each participant was found across all channels meeting SNR criterion (one case with fewer than 10 such channels were excluded). Differences are -4.5 and -4.0 degrees for the two stimuli. Both stimuli reached significance individually (p=0.036; p=0.029, t-test, df=13), but not after comparison for multiple comparisons (p<0.025).

Contast: High vs. Low Temporal Conflict



Phase difference occurs only at times of greatest temporal conflict between the two stimuli

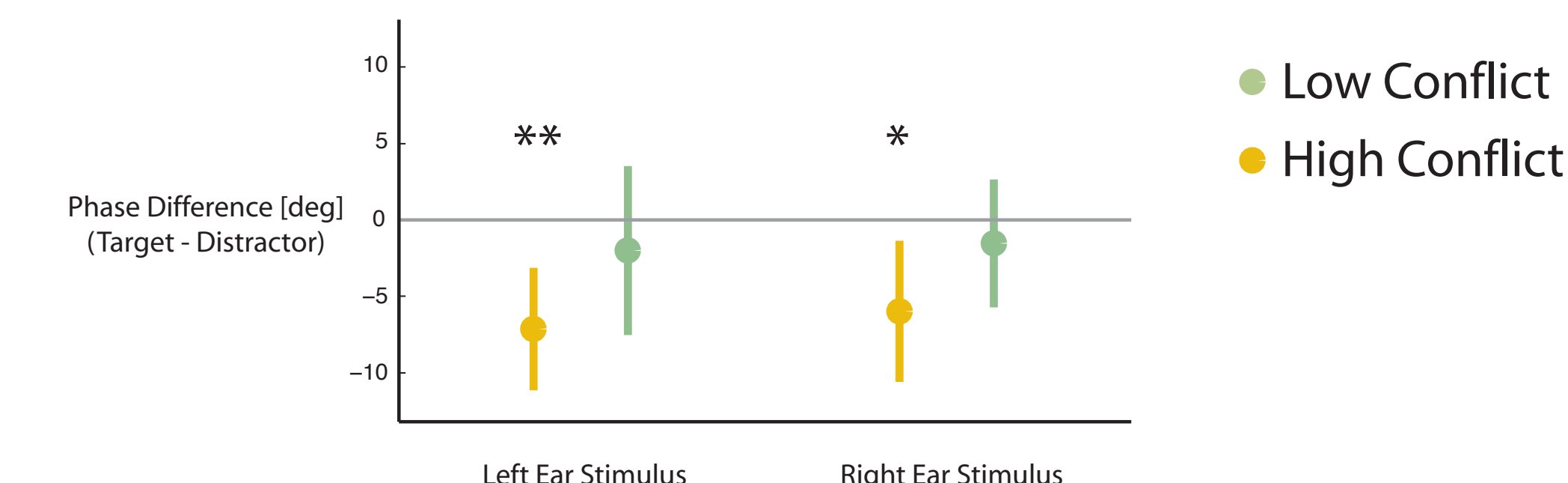
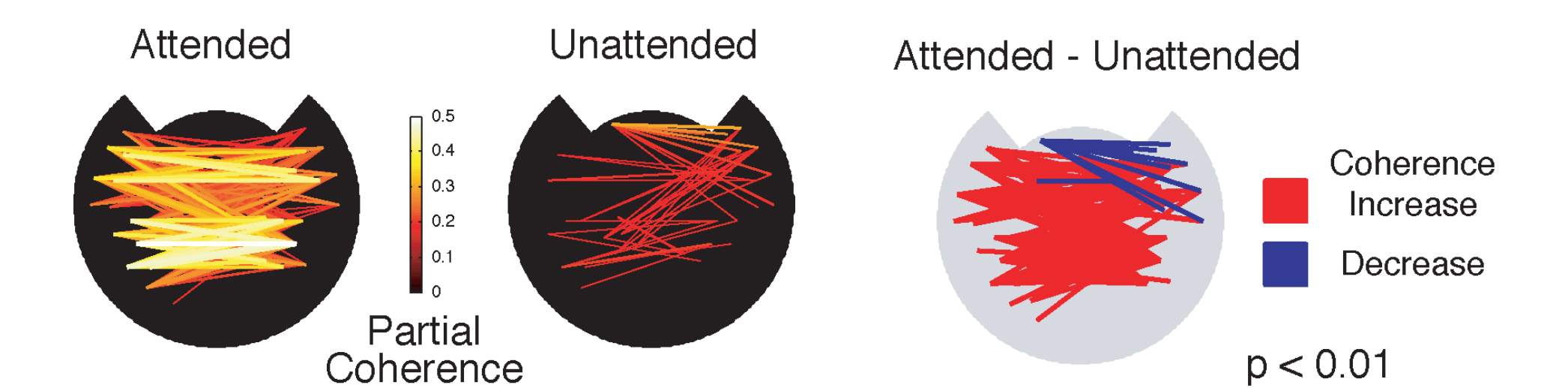
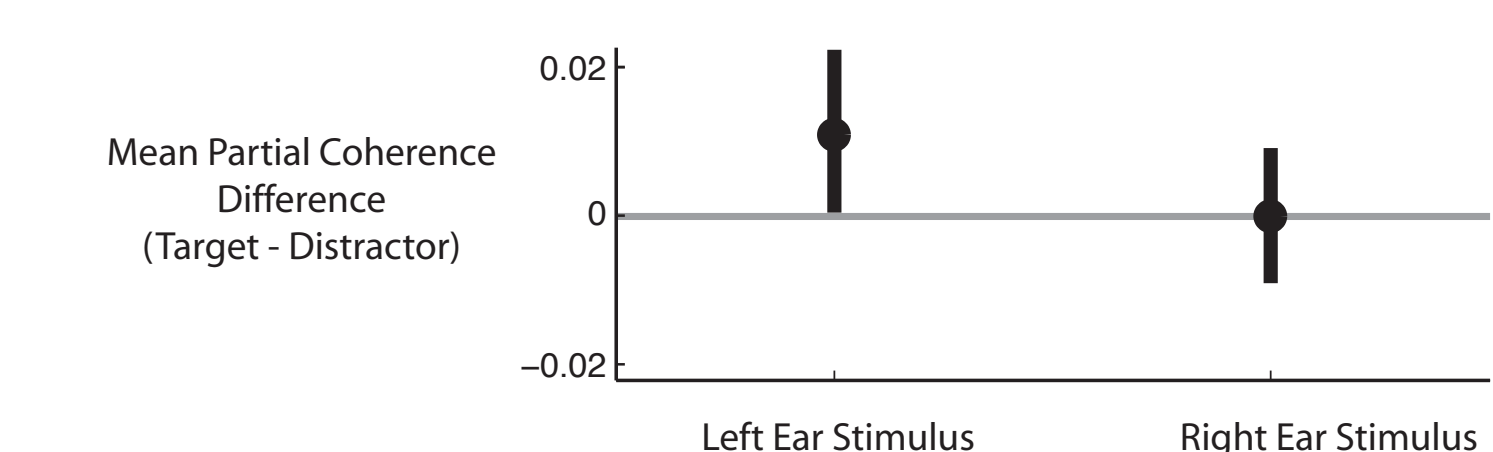


Figure: Grand mean phase difference (n=13) depends on the degree of temporal conflict between target and distractor. Phase differences exist only during periods of high temporal conflict, when distractor is impossible to ignore. Differences are -7.1 and -6.0 degrees (p=0.0046; p=0.027).

Results: Partial Coherence



Selective attention does not modulate inter-hemisphere partial coherence



Conclusions and Discussion

Attention influenced the timing of ongoing, stimulus-related activity in primary auditory cortex, rather than the amount of activity.

Attention resulted in a small phase delay in the aSSR (~6 deg.), but only during times when the target and distractor were in temporal conflict. Although at these times the participants could not avoid having their behavior affected by the distractor they may represent periods of higher attentional effort.

The same experiment, repeated with diotic stimulation, yielded similar results.

aSSR methods can be used to study selective attention among multiple concurrent auditory stimuli.

These results raise the following questions:

1. What mechanisms are associated with a phase delay?
2. Why did attention not affect the strength of the aSSR ?
3. What aspects of beat synchronization are sensitive to attention?

References

- Bidet-Caulet, A., et al. (2007). Effects of selective attention on the electrophysiological representation of concurrent sounds in the human auditory cortex. *J Neurosci* 27: 9252-9261.
- Chen, Y.C. et al. (2003). The power of human brain magnetoencephalographic signals can be modulated up or down by change in an attentive visual task. *PNAS* 100: 3501-3506.
- Iversen, J.R., et al. (2004). Attentional modulation of cortical auditory and visual steady-state responses in a bimodal paradigm. *Soc Neurosci Abstr.*
- Ross, B., et al. (2004). The effect of attention on the auditory steady-state response. *Neurol Clin Neurophysiol* 22:1-4.

Acknowledgements

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