Time of distraction modulates behavioral sensitivity and distractor-evoked neural responses

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Background

Background:

- Attentional sampling operates in a rhythmic manner [1]-[4].
- It is less well studied whether distractor suppression is rhythmic as well [5].

Research question:

Whether distractor suppression across different distractor onset times follows a rhythm in auditory attentional filtering using pitch comparison task.

Behavioral and neural metrics:

- Perceptual sensitivity inversely relates to the degree of distraction.
- 25-Hz inter-trial phase coherence (ITPC) quantifies neural phase-locking to the temporal structure of the distractor (i.e. 25-Hz modulated tone sequence; Fig1).

Methods

Pitch comparison task (Fig.1):

- Participants were instructed to decide whether the two target tones (T1 and T2) are the same or different in pitch.
- Distractor: Random tone sequence displayed at 25 Hz.

Manipulations of pitch comparison task:

- Distractor presence/absence (2): whether a distractor was presented in between T1 and T2.
- Distractor onset (24): The onset time of distractor relative to T1 offset.

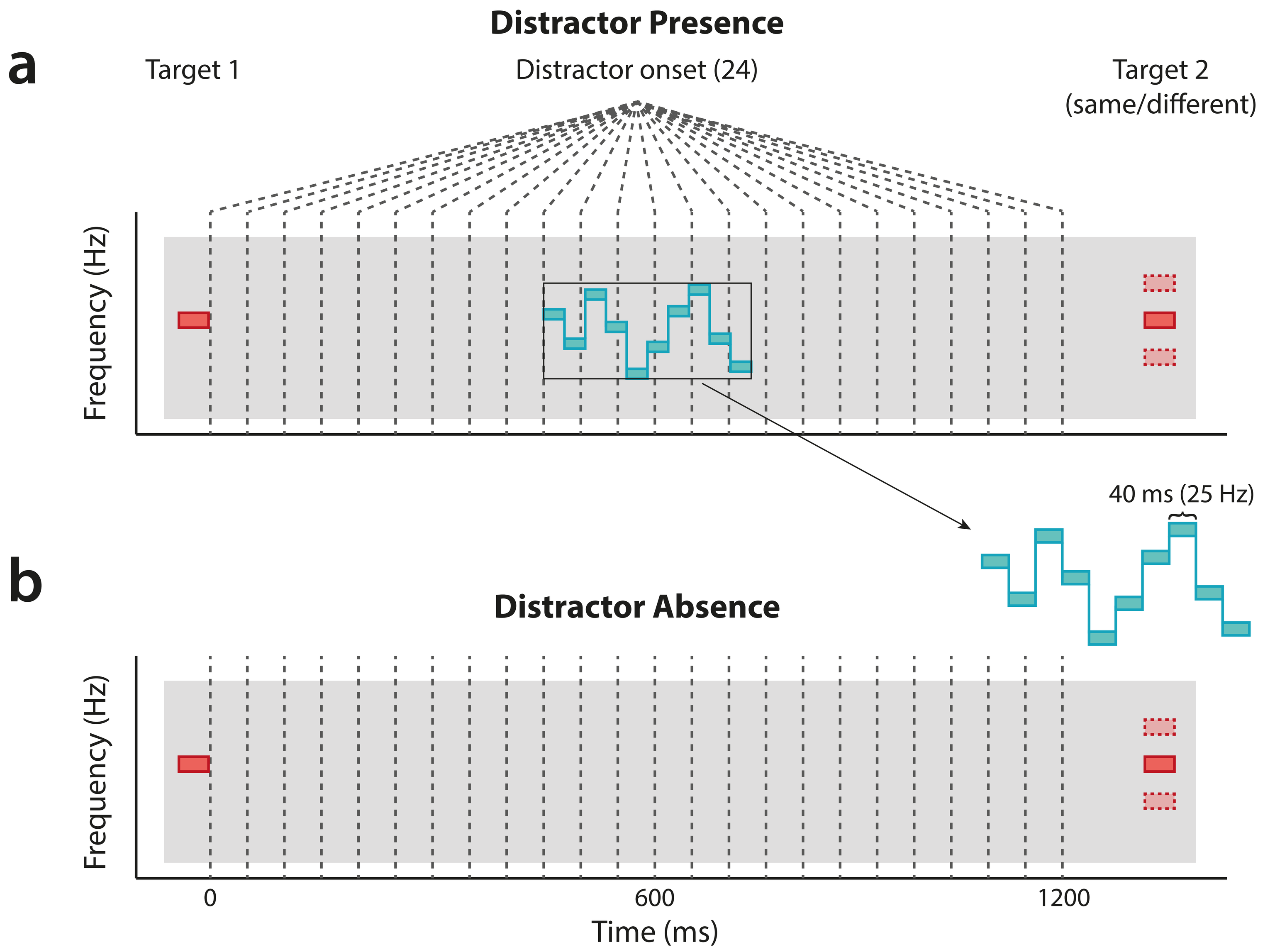


Figure 1. Design of pitch comparison task with distractor presence (a) and absence (b) conditions.

Experiment:

- N = 19 (14 female, mean age = 23)
- EEG recording: 64-channel actiCHamp (Brain Products);
- EEG analysis: average reference; 1–100-Hz filtered; ERP analysis; time-frequency analysis using hanning taper; Linear-mixed effect models for each measure; correlation between behavioral and neural measures.

The behavioral distractor effect

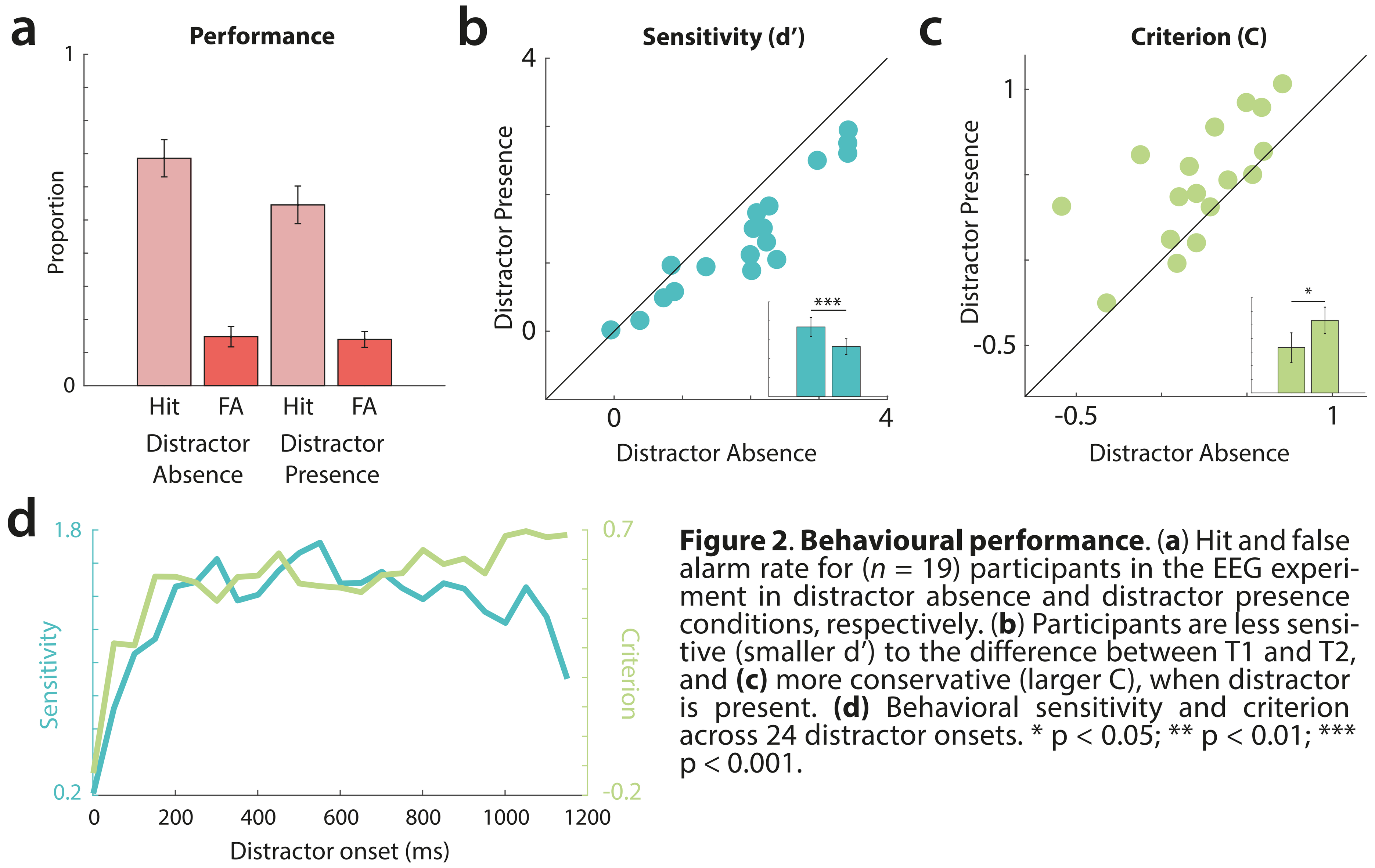
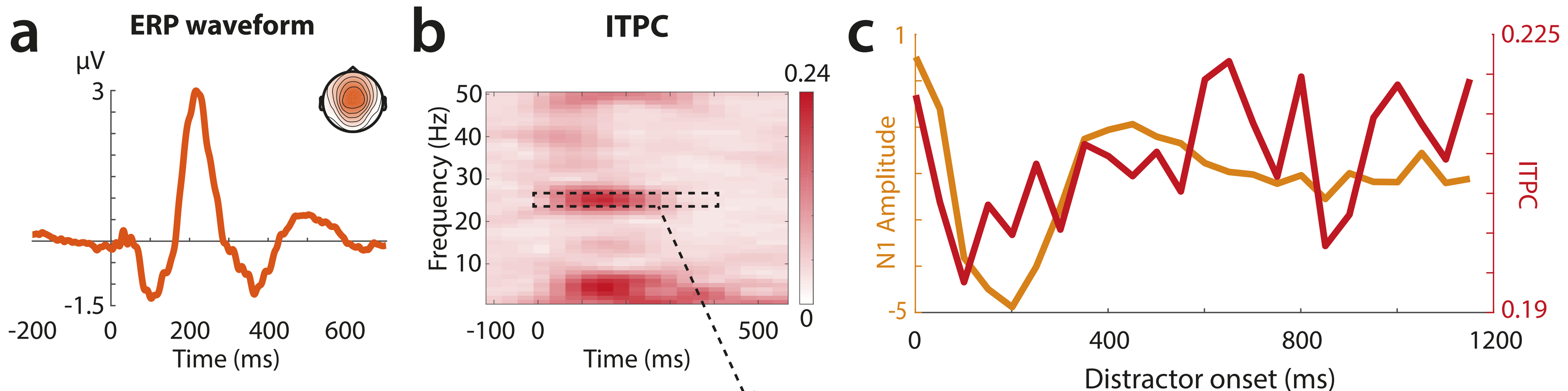


Figure 2. Behavioural performance. (**a**) Hit and false alarm rate for (n = 19) participants in the EEG experiment in distractor absence and distractor presence conditions, respectively. (**b**) Participants are less sensitive (smaller d') to the difference between T1 and T2, and **(c)** more conservative (larger C), when distractor is present. **(d)** Behavioral sensitivity and criterion across 24 distractor onsets. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Distractor-evoked neural responses



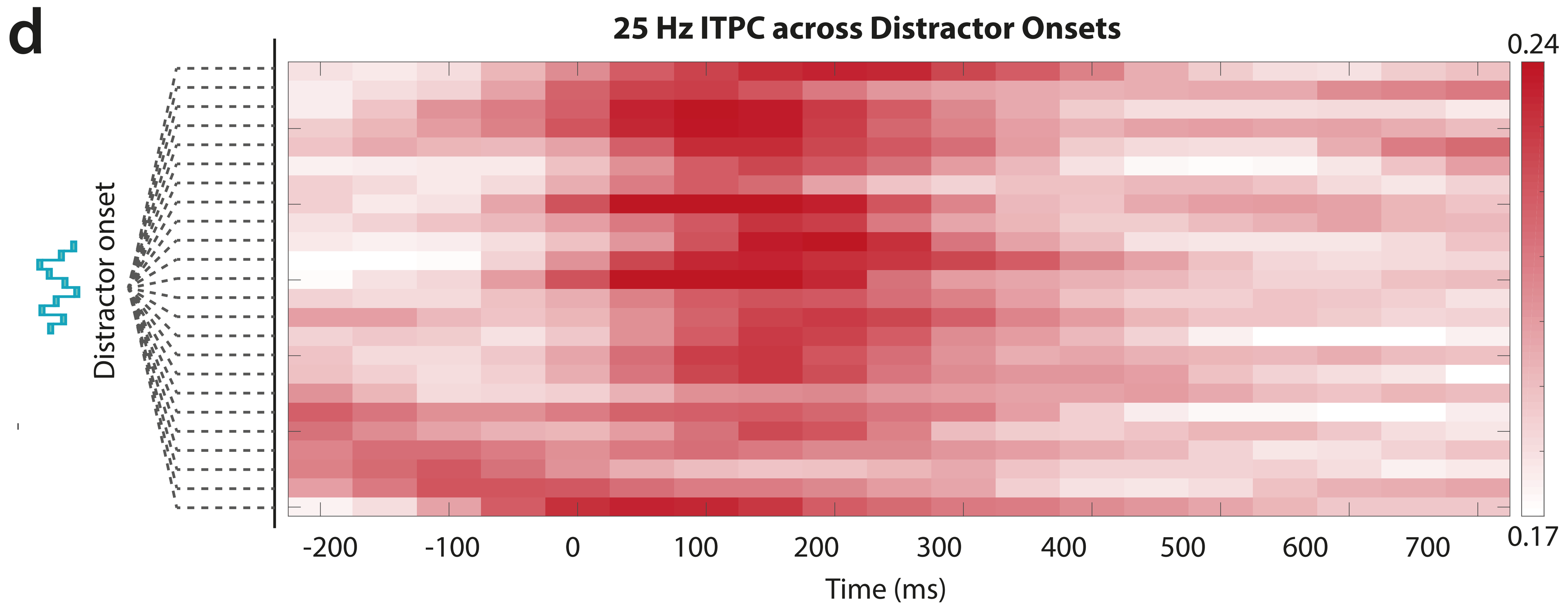


Figure 3. Neural measures of the processing of distractors in the distractor presence condition. (a) Event-related potential (ERP) waveform at Cz of the distractors. Topographic map shows the N1 amplitude between 90 and 110 ms after distractor onset in the distractor presence condition. **(b)** Inter-trial phase coherence (ITPC) weighted averaged across 64 channels after applying spatial filtering based on a passive listening task, wherein participants listened to the distractor tone sequences. A higher ITPC magnitude is shown around 25 Hz, which follows the temporal structure of the distractor. **(c)** N1 amplitude and ITPC across 24 distractor onsets. **(d)** Time series of the 25-Hz ITPC across 24 distractor onsets.

Rhythmicity of distractor suppression

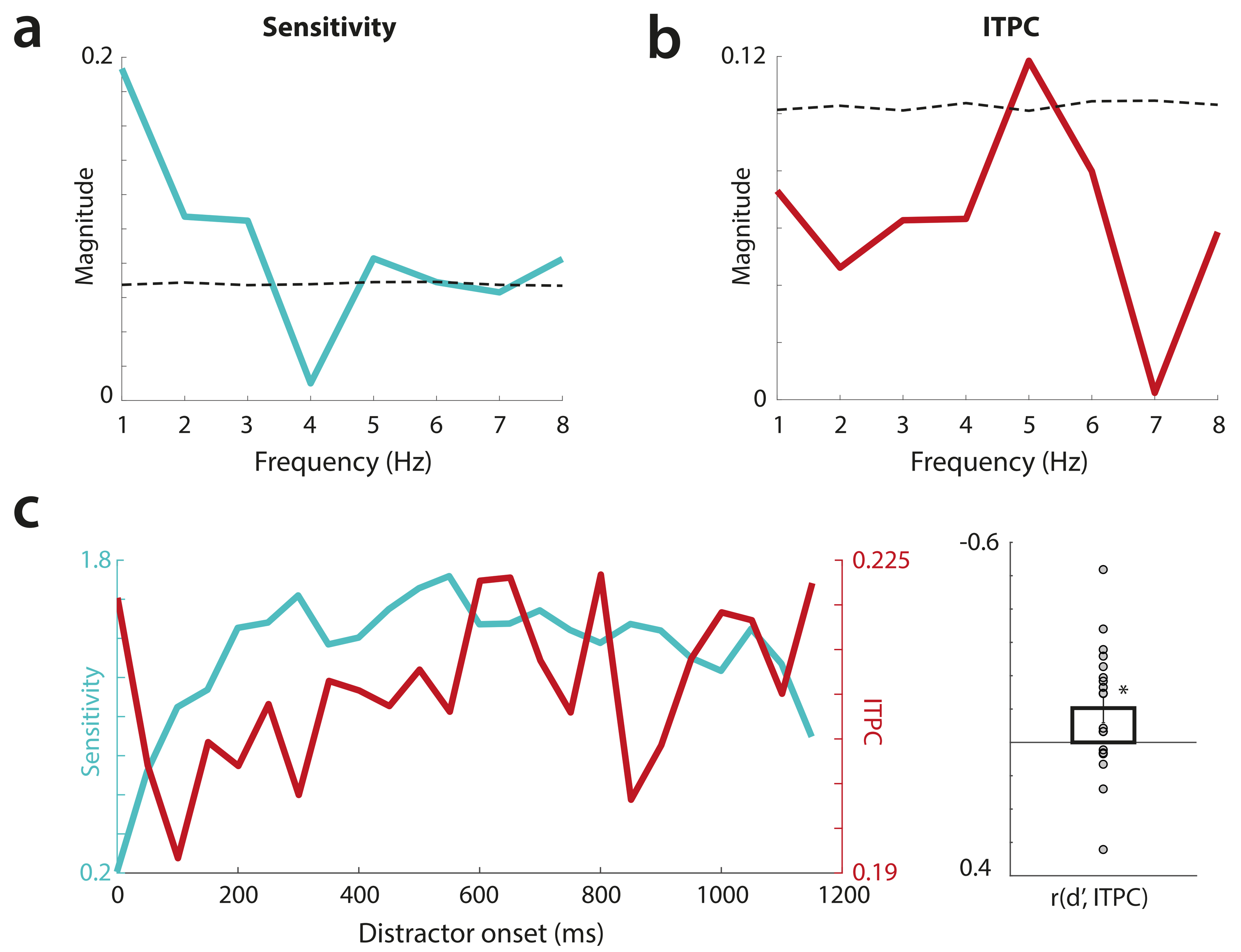


Figure 4. **The rhythmic modulation of distractor onset to behavioral and neural measures.** Linear mixed-effects models with circular sine and cosine predictors were used across frequencies (1-8 Hz) for **(a)** behavioral sensitivity and **(b)** ITPC. The resulted coefficients were compared with 2000 permutations, which were generated by shuffling the sine and cosine predictors for each distractor onset. **(c)** Behavioral sensitivity and ITPC across distractor onsets. Correlation coefficients between sensitivity and ITPC across distractor onsets show significant inverse relationship between behavioral and neural measures of distractor suppression. * $p < 0.05$.

Conclusions

Pitch distractors are detrimental to performance in pitch comparison task (Fig 2):

- Sensitivity (d') is lower when there is a distractor in between the two target tones (i.e. smaller difference between hit and false alarm rate).
- Criterion (C) is higher with distractor (i.e. higher tendency to respond same pitch regardless of the pitch difference).

Time of distraction modulates behavioral and neural metrics rhythmically (Fig 2, 3 & 4):

- Both d' and ITPC are modulated at low frequencies (<8 Hz).
- A negative correlation between d' and ITPC suggests that stronger neural encoding of distractors is accompanied by lower sensitivity in pitch comparison of the target tones.

- Distractor processing follows a rhythm, which is convergingly manifested by the temporal dynamics of behavioral and neural measures of distraction.

References

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