



Violation of rule-based auditory patterns is detected independently of attention

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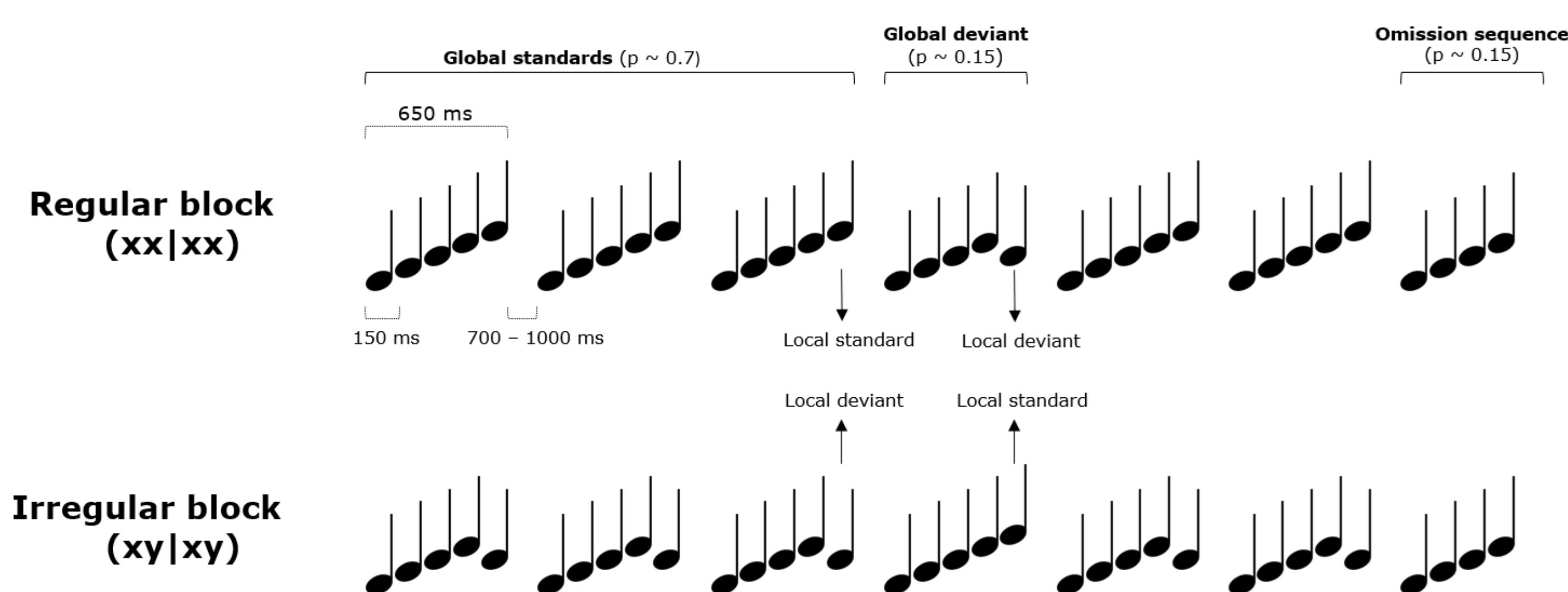


1. Introduction

Encoding of predictable auditory fluctuations constrains sensory processing, freeing up cognitive resources and ensuring sensitivity to surprising and potentially important events. Simple auditory regularities are encoded automatically, even in unconscious states, as reflected in the mismatch negativity (MMN) upon deviance. When regularities are embedded in patterns unfolding over time, however, encoding is believed to require attention-dependent top-down processing, reflected in the P3b upon deviance (Bekinschtein et al., 2009). In contrary to this view, recent studies have shown attention-independent electrophysiological responses to violations of rule-based auditory patterns (Kompus et al., 2020).

We tested the implied attention-independent encoding of rule-based, or global, auditory regularities by manipulating attentional engagement while recording EEG during a modified version of the local-global paradigm.

2. Paradigm and attention manipulation



A modified version of the local/global oddball paradigm (Bekinschtein et al., 2009) was presented through stereo speakers in two within-subject conditions:

- 1) Attended:** participants counted global rule violations
- 2) Unattended:** participants performed a visual monitoring task in which they counted letter-color conjunction targets

Long-term regularities were established by presenting one type of sequence more frequently (global standards). In contexts which differed by block, this global rule is violated either by a sequence that mismatched the within-sequence expectation (global deviant/local deviant) or by a sequence that conforms to it (global deviant/local standard). We isolated the neurophysiological response to violations of rule-based auditory patterns by contrasting global deviants with standards (pooled over local-level status).

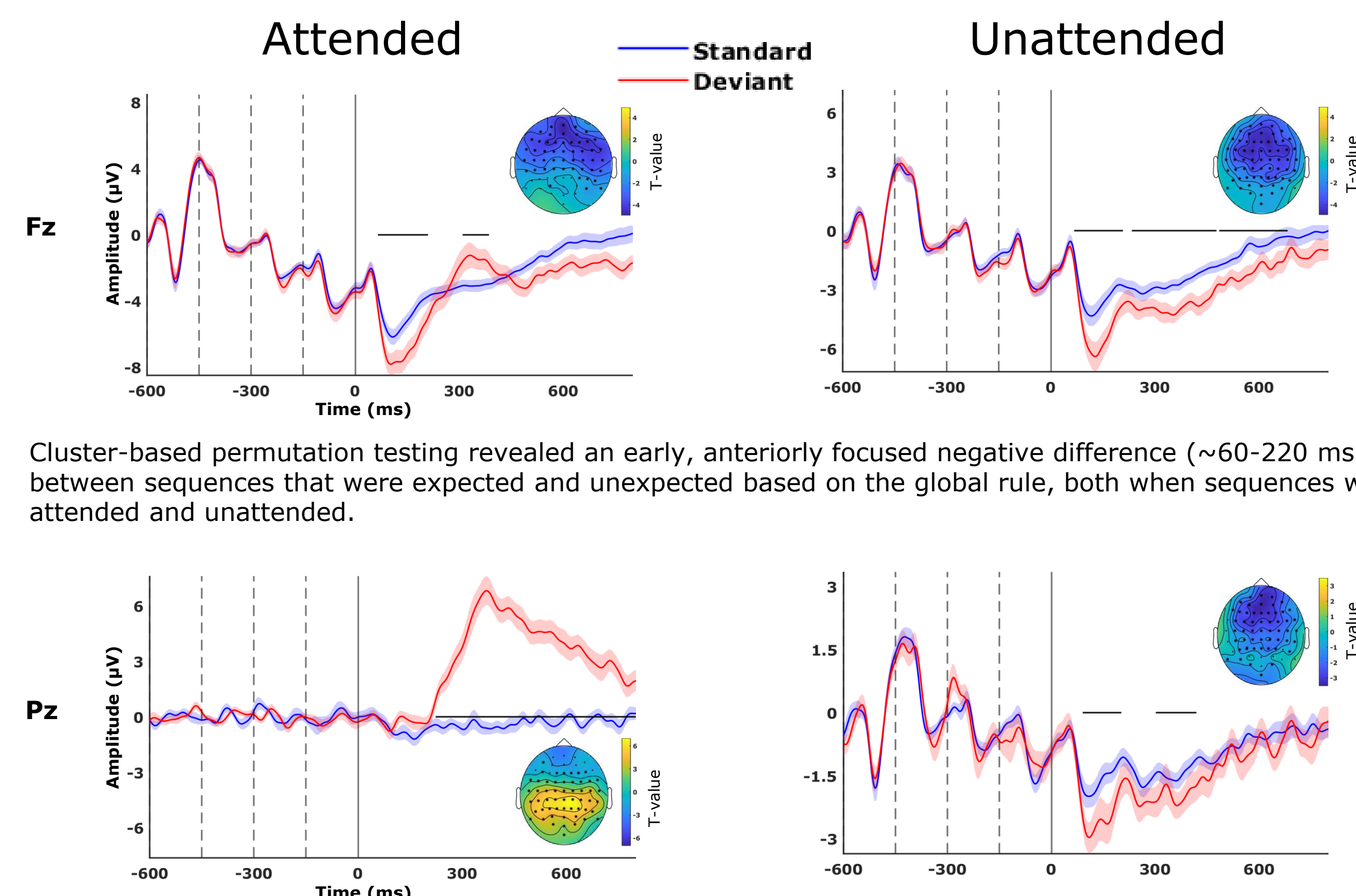
3. Participants, EEG recording, and preprocessing

- 20 healthy adults (13 females, mean age 34.5, SD 11.05)
- EEG recorded from 64 active Ag/AgCl electrodes (BioSemi Active Two System); 4 electrodes monitored eye movements; 2 earlobe electrodes for offline re-referencing
- High-pass filtered, 3rd order IIR zero-phase Butterworth, half-amplitude cut-off 0.1 Hz
- Line noise was rejected by DFT filtering
- Artifactual epochs and channels were rejected based on visual inspection; ICA-based removal of ocular activity; rejected channels were interpolated using spherical splines

7. Summary and interpretation of findings

- ERP results demonstrate that the brain distinguishes rule-incongruent tone-sequences at an early processing stage regardless of whether attention is directed towards the sounds
- A later processing stage, indexed by the P3b, is initiated by rule violations dependent on auditory attention
- At the early processing stage attention and rule-conformity have additive effects on the neuronal response; at the late-stage, these factors interact
- Time-frequency analyses suggest attention-dependent low-frequency modulations in response to rule violations
 - δ/θ -band shows a protracted power increase following deviance, concomitant with a suppression in α/β power
- In sum, the results support the idea that the auditory system is capable of extracting rule-based auditory patterns independently of attention to deploy predictions of upcoming events

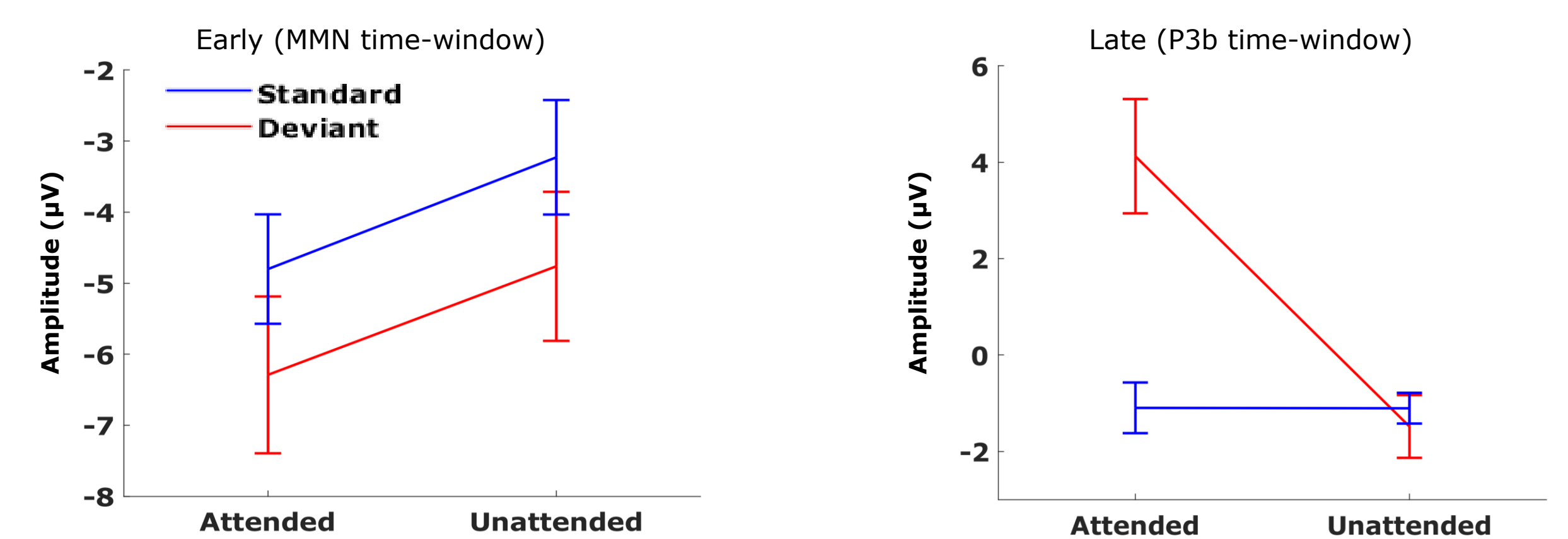
4. Global-level ERPs across attention conditions



Cluster-based permutation testing revealed an early, anteriorly focused negative difference (~ 60 -220 ms) between sequences that were expected and unexpected based on the global rule, both when sequences were attended and unattended.

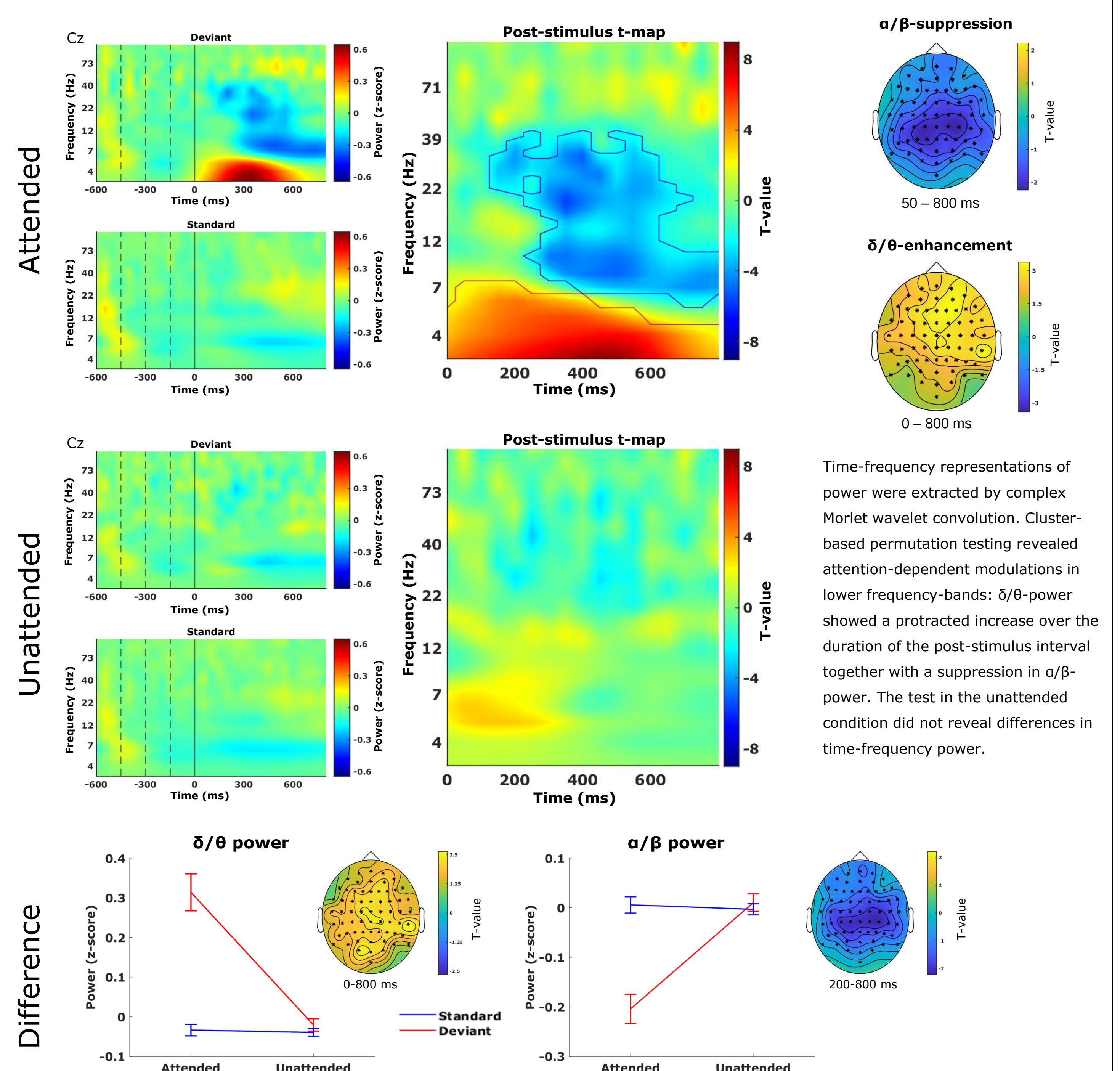
A later-onset, sustained positive difference (~ 230 -800 ms) with a posterior distribution, consistent with the P3b, was found exclusively in the attended condition.

5. Effects of attention and rule-conformity on early and late neuronal responses



Repeated-measures ANOVAs, ran separately for mean amplitudes of MMN (averaged over Fz, FCz, and Cz) and P3b (at Pz), show that attention and rule-conformity independently influence the magnitude of early neuronal response, i.e., attention enhances the response, while rule-conformity suppresses it. At the late stage, attention and rule-conformity interact, i.e., the deviance response is contingent on attention.

6. Time-frequency representations



Time-frequency representations of power were extracted by complex Morlet wavelet convolution. Cluster-based permutation testing revealed attention-dependent modulations in lower frequency-bands: δ/θ -power showed a protracted increase over the duration of the post-stimulus interval together with a suppression in α/β -power. The test in the unattended condition did not reveal differences in time-frequency power.

Mean power in the spatio-spectrotemporal windows of significant difference between attended and unattended. Topographical plots display t-values averaged over the extent of supra-threshold clusters from the permutation test.

References

- Bekinschtein, T. A., Dehaene, S., Rohaut, B., Tadel, F., Cohen, L., & Naccache, L. (2009). Neural signature of the conscious processing of auditory regularities. *Proceedings of the National Academy of Sciences*, 106, 1672-1677.
- Kompus, K., Volehaugen, V., Todd, J., & Westerhausen, R. (2020). Hierarchical modulation of auditory prediction error signaling is independent of attention. *Cognitive Neuroscience*, 11(3), 132-142.