POST-ERROR MODULATIONS OF THETA AND ALPHA ACTIVITY IN THE AUDITORY CONDENSATION TASK

N.A. Novikov, D.V. Bryzgalov, B.V. Chernyshev

National Research University "Higher School of Economics", Moscow, Russia

NATIONAL RESEARCH UNIVERSITY

Laboratory of cognitive psychophysiology

http://social.hse.ru/en/psy/cognpp/

Introduction

Cognitive control is a set of neural processes that subserve goal-directed behavior (Yeung, 2013). Detection of errors causes an increase of cognitive control, which may lead to adjustments in stimulus processing systems, and to an adaptive increase of motor threshold (Danielmeier, Ullsperger, 2011). These adjustments manifest themselves in behavior (e.g. resulting in post-error slowing), as well as in changes of spectral activity, registered by EEG, specifically in theta and alpha bands (Cavanagh and Frank, 2014, Mazaheri et al., 2009). The present study is aimed at investigating post-error modulations of theta and alpha activity and their relations to behavior in an attentionally demanding task that imply no to-be-inhibited prepotent responses.

Experimental Paradigm

We used an auditory version of the condensation task (Posner, 1964; Chernyshev et al., 2015). Subjects (N=71) listened to a random sequence consisting of four prerecorded audio stimuli (duration: 40 ms) with SOA of 2500 ± 500 ms. Each tone was a sinusoidal signal of either 500 Hz ('low') or 2000 Hz ('high'), either a pure tone ('pure') or mixed with broadband noise ('noised'). The participants were instructed to respond stimuli with pressing left or right button on a gamepad, according to the memorized rule (see Table 1). Correct answers were immediately followed by a positive feedback.

	PURE	NOISY
HIGH	Left	Right
LOW	Right	Left

Table 1. Stimulus-to-response mapping

Results

Methods

Correct answers and Errors: RT < 1700 ms

cC – correct trials following correct ones

cE – errors following correct trials

eC – correct trials following errors

Post-error slowing (PES) = RT(eC) / RT(cC)

RT matching: for each cE/eC trial we selected a cC trial with the closest response time

Induced spectral power (after EEG->CSD):

$$S^c(t,f) = \left\langle \left| S_n^c(t,f) \right|^2 \right\rangle_n - \left| \left\langle S_n^c(t,f) \right\rangle_n \right|^2$$

$S_n^c(t,f)$ – complex amplitude at time *t* and frequency *f* on *n*-th trial for condition *c*

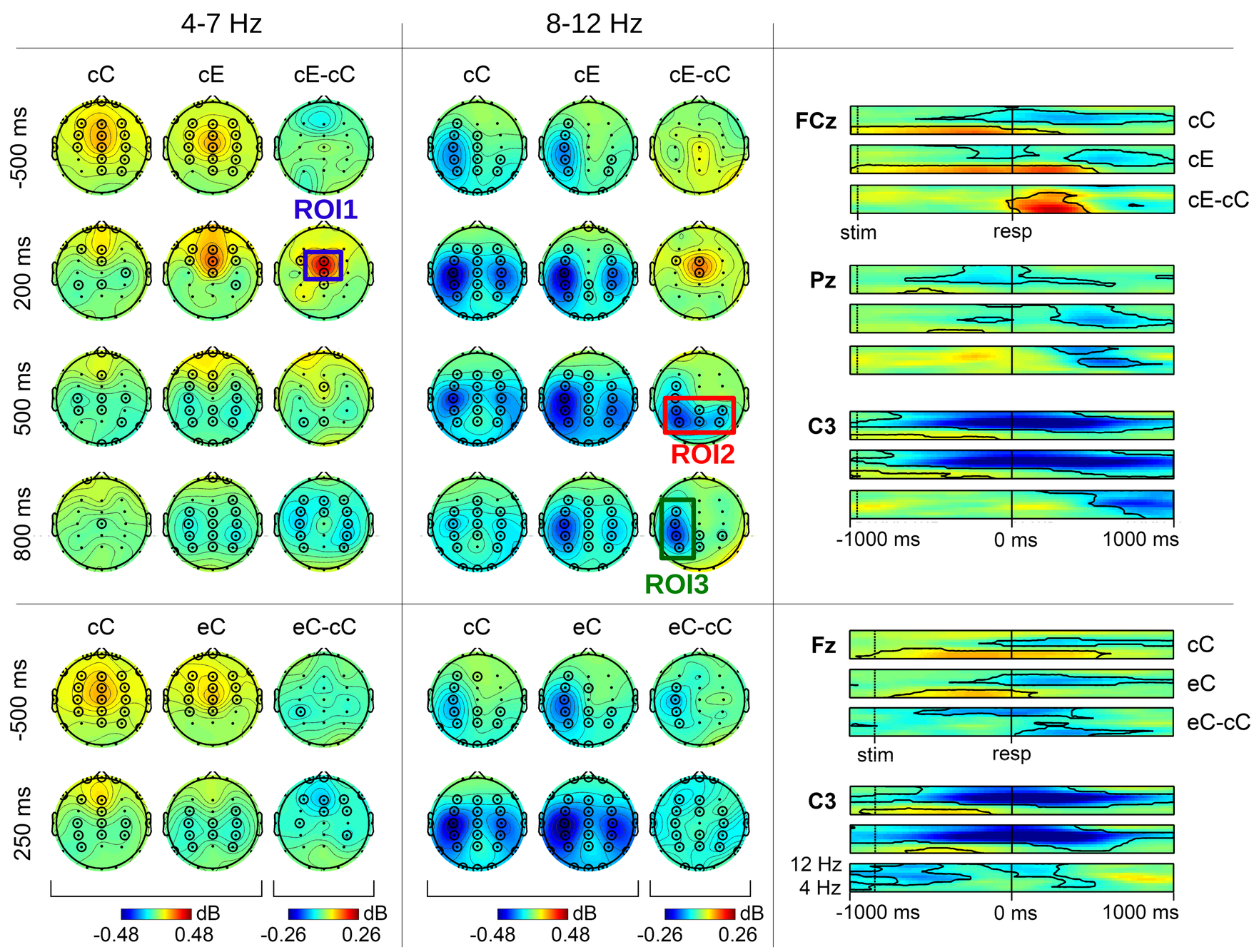
ERSP and difference:

$$ERSP_c(f,t) = \log S^c(t,f) - \log(\overbrace{S_{BL}^c(f)}^{\text{baseline}})$$

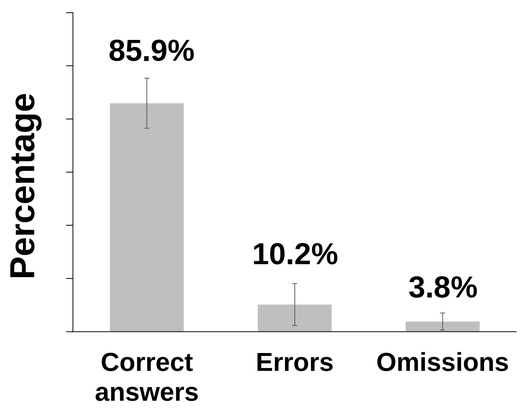
$$D_{12}(f,t) = \log S^1(t,f) - \log(S^2(t,f))$$

Statistics: minmax permutation-based statistics on TFCE-transformed 4-D maps (rostrality x laterality x time x frequency) of t-scores (t-test between ERSP or D and zero)

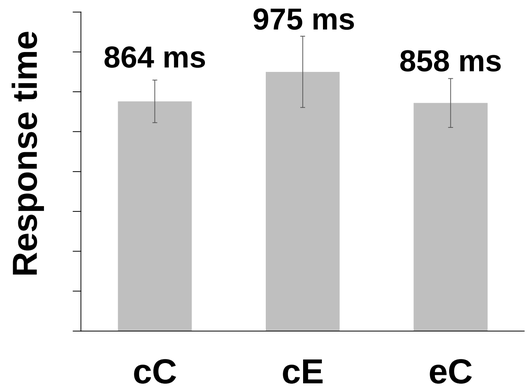
Event-related perturbations and cross-condition differences of induced spectral power



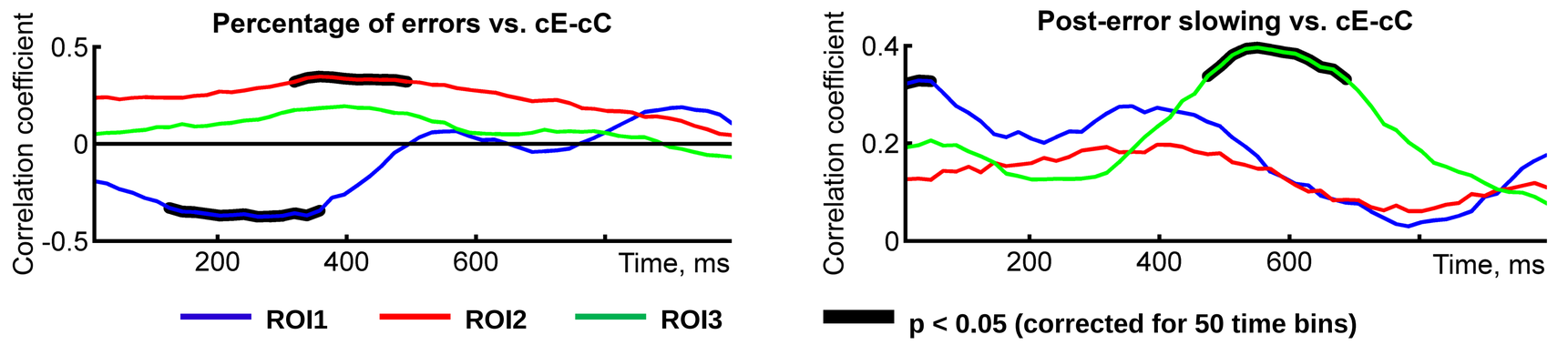
Percentage of response types



Mean response times (RT)



Spearman's correlation between behavior and spectral power difference averaged over ROI



Discussion

In this study, we described error-related modulations of theta and alpha band activity in the auditory version of the condensation task, that occur right after errors as well as on subsequent trial. We also found the relations between these modulations and behavioral measures of the task performance. We found post-error FMT power increase that positively correlated with both PES and successful performance; it was followed by posterior partial alpha suppression, which was related to good performance; then, sensorimotor alpha band suppression was observed, less pronounced for subjects with stronger PES. On a subsequent post-error trial, sensorimotor alpha band suppression ramped up faster, alpha suppression distributed over the entire scalp was observed after a response, and the post-response FMT power was reduced, reflecting jointly the state of increased cognitive control. Our results confirm the functional role of theta and alpha band oscillations in cognitive control and suggest that at least three brain networks exhibit error-related activity: the medial prefrontal performance monitoring network, the parietal attentional, and the sensorimotor network.

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