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Research Report

ERP—Correlates of response selection in a response conflict paradigm

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ABSTRACT

Neuroimaging and electrophysiological studies suggest that the anterior cingulate cortex (ACC) is involved in the cognitive control of response related action. A frontocentral negative ERP-component, the N2, which probably originates from the ACC, is usually enhanced in conflict-trials that demand an unexpected response. We here used stepped adjustment of response expectation in a response-cueing task, and measured how the N2 varied with global and local cue validity. Results showed that, irrespective of the current cue validity, response times, error rates, and the frontocentral components P2, N2 and P3 increased in unexpected trials. Nevertheless, a N2 was also seen in expected trials, and its latency correlated positively with reaction times, indicating that this potential does not express response conflict only. In line with roles suggested for the ACC, we here propose that the N2 is related to the process of response selection which influences subsequent processing stages reflected in the P3. Unexpected revisions of response programs enhance and delay the N2.

1. Introduction

Neuroimaging studies suggest that the anterior cingulate cortex (ACC) is involved in response conflict monitoring (see Botvinick et al., 2004 for a review). Conflict arises when incompatible response tendencies are simultaneously active. The frontocentral N2, an ERP component attributed to the ACC (e.g. van Veen and Carter, 2002), is especially prominent in rare conflict trials. When conflict and no-conflict trials are equiprobable, it is smaller (Braver et al., 2001), suggesting that the N2 is sensitive to response probability. Would rare compatible trials also elicit a N2?

While the ACC's role in conflict processing is widely accepted (see Botvinick et al., 2004 for a review), the ACC, in cooperation with other brain areas, also supports other functions. It is the crucial brain area involved in selecting and coupling perceptual information to motor action (Badgaiyan and Posner, 1998; Holroyd and Coles, 2002; Posner et al., 1988). Recent studies suggest that ACC takes part in response selection, i.e. the cognitive process of assigning a specific response to a specific stimulus category (Isomura et al., 2003; Paus, 2001; Picard and Strick, 1996; Turken and Swick, 1999). One line of evidence for the response selection account of the ACC stems from neuropsychological investigations. Turken and Swick (1999) evaluated a patient who had suffered a focal lesion affecting part of the right ACC. The authors tested the patient in a variety of executive control tasks. Reasoning that performance should be impaired regardless of the response modality if the ACC was responsible

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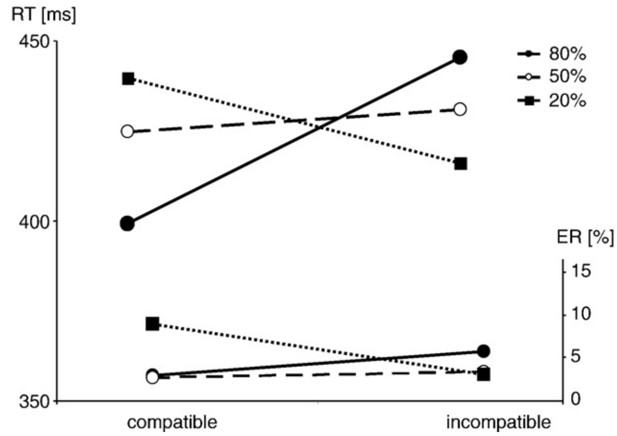

Fig. 1 – Mean reaction times and error rates for incompatible and compatible trials as a function of cue validity.

for general executive control, they requested both manual and vocal responses. Their results showed that performance was only impaired in manual response trials. Moreover, the impairment was most evident when response selection requirements were most demanding, that is in trials with a high level of conflict. A role for the ACC in response selection is also suggested by neurophysiological data. Reviewing the functional properties of the primate medial wall, Picard and Strick (1996) reported that the rostral zone of the ACC participated in tasks requiring movement selection and willful generation of many different types of motor behavior. Paus (2001) suggested that the lateral prefrontal cortex (PFC) computes and maintains information necessary for choosing the appropriate response, whereas the ACC facilitates implementation of action. Its overlapping motor, cognitive and arousal domains place the ACC in a unique position to translate intentions to action. More evidence for the response selection account of the ACC comes from single unit recordings in monkeys. Isomura et al. (2003) found that rostral cingulate motor areas (a homologue of a human ACC) participate in appropriate action according to an intention whereas dorsal and ventral ACC may be involved in motor preparation and execution. Consequently, the ACC responded only to stimulus classes that were associated with a particular response indicating an integrative role of the ACC in coupling of stimuli with a particular action. Finally, a recent fMRI study supported by computer simulations (Roelofs et al., 2006) challenged the conflict hypothesis of ACC in favour of the selection-for-action hypothesis. Roelofs and co-workers observed enhanced ACC activation in the absence of response conflict in a Stroop-like task. According to the regulative hypothesis of the ACC proposed by those authors, both Stroop facilitation (congruent vs. neutral) and Stroop interference (incongruent vs. neutral) have a common source and arise during response selection by selectively enhancing the activation of the correct response until a selection threshold is exceeded.

Finally, evidence relating the N2 to response selection also comes from the ERP literature. Ritter et al. (1982, 1983) first related the N2 to stimulus classification in choice tasks, which is close to our definition of response selection. Hohnsbein et al.

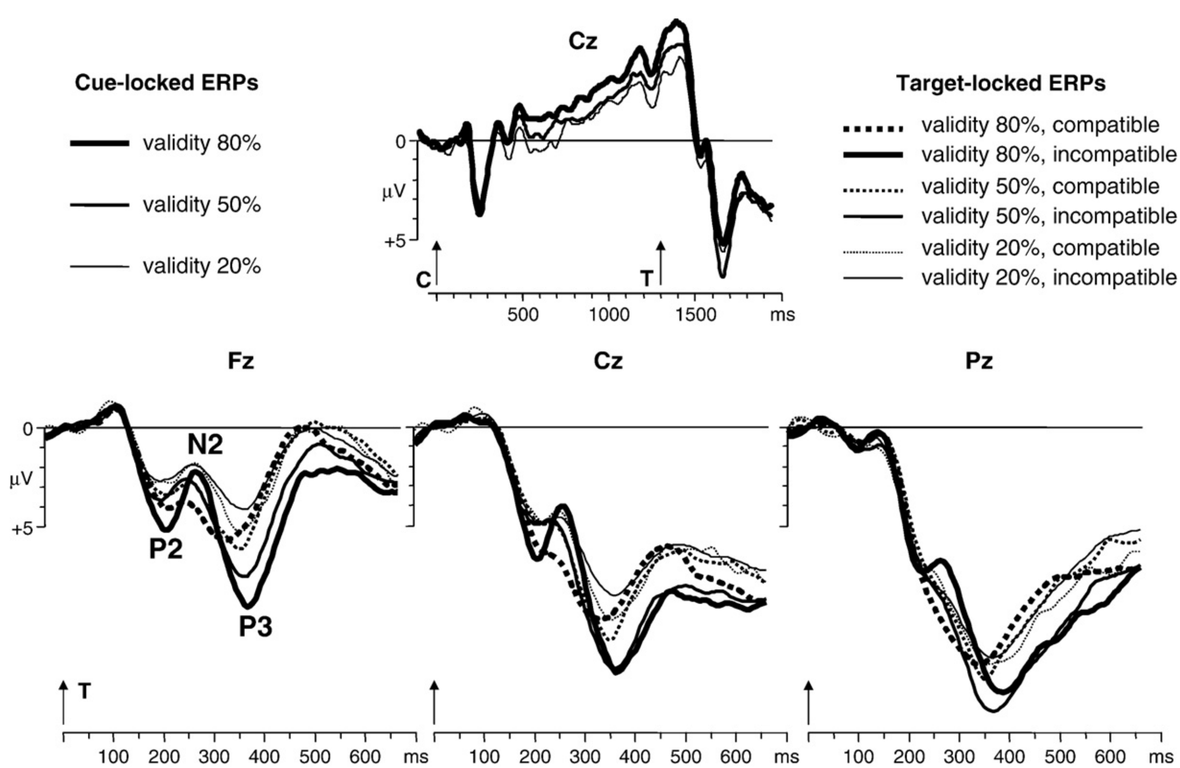

Fig. 2 – Top: cue-locked ERPs for 80% (thick line), 50% (intermediate line) and 20% (thin line) validity conditions collapsed over compatible and incompatible trials at Cz. Bottom: target-locked ERPs for 3 validity and 2 compatibility conditions at Fz, Cz and Pz. Thick lines — 80% validity, intermediate lines — 50% validity, thin lines 20% validity. Solid lines indicate incompatible, dotted lines compatible conditions. 'C' indicates cue-onset, 'T' target-onset.