



DO PATIENTS WITH DAMAGE TO THE ANTERIOR CINGULATE SHOW AN ERROR RELATED NEGATIVITY (ERN)?

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Summary

Averaged EEG trials to erroneous responses consistently show a negative-going waveform which has been coined the error-related negativity (ERN) (for a summary see Falkenstein et al., 2000). Evidence points to the neural generator of the ERN to be distributed somewhere along the medial prefrontal cortex, most likely within the anterior cingulate. This suggests that patients with lesions in the anterior cingulate region should not produce an ERN. In order to test this hypothesis, we investigated five patients with a ruptured aneurysm of the anterior communicating artery (ACA) leading to damage of neural substrates in the anterior cingulate region. Four of the five patients did not produce an ERN in one paradigm, or they produced a highly deviant waveform. These results contrast with findings showing that patients with damage involving the lateral prefrontal cortex do produce an ERN (Gehring & Knight, 2000). This dissociation suggests that the anterior cingulate region is essential to initiate the ERN response. One patient showed an ERN in both paradigms possibly due to damage that differed from that of the other patients, or individual variation.

It has further been suggested that elicitation of the ERN is dependent on overt error awareness. Two of our patients showed relatively good cognitive functioning compared to the other patients, and during EEG recording they noticed when they had made an error as indicated by swearing, comments or gestures. Nevertheless, one of the two patient clearly did not show an ERN in both paradigms, and the other patient did show an ERN in one but not in the other paradigm. It thus seems that awareness of errors as signaled by overt error detection may be mediated by circuits outside of those necessary for ERN production.



The subjects

EM, female, 57 yrs, 20 wks post-onset



EZ, female, 47 yrs, 40 wks post-onset



RF female, 58 yrs, 32 wks post-onset



IE, female, 51 yrs, 8 wks post-onset



MH male, 36 yrs, 24 wks post-onset



9 healthy control subjects, 8 female, 1 male, age: 16 - 37

The stimuli

Eriksen flanker task: (1) A visual letter paradigm and (2) a form paradigm (similar to letter paradigm but instead of letters there were circles and squares) were presented on a screen.



The task: Press the button with the right finger if the letter (form) in the center is an H (a square) and with the left finger if the letter (form) in the center is an S (circle).

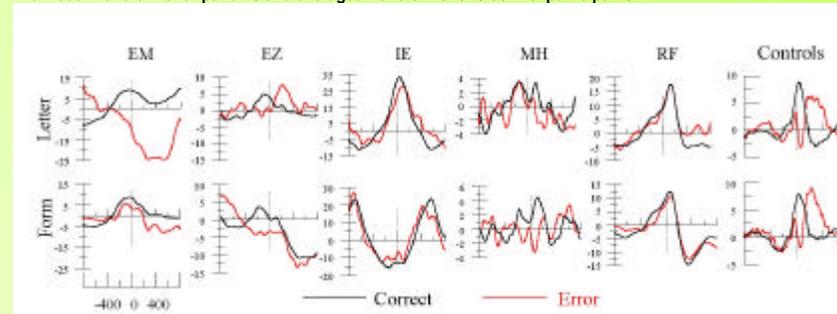
Presentation: 480 trials per paradigm, stimulus duration 250ms, ISI 1000ms.

EEG recording and analyses: 19 electrodes, 10-20 system, referenced to linked earlobes, Fpz as ground, sampling rate 250 points per sec., 70 Hz low pass filter, time constant of 5 s. EEG epochs (800 ms before and 800 ms after response) were corrected for eye-movement artifacts, signals > +/- 100 μ V in controls and +/- 200 μ V in patients were eliminated and a low pass filter of 20 Hz applied. The epochs were time-locked to the response on each trial and averaged separately for correct and incorrect trials.

Response times were calculated from stimulus onset to button press. **Neuropsychological procedures** involved attention battery by Zimmermann, d2 cancellation task, WMS-R, delayed recall, verbal fluency, TMT-A/B, WCST, Tower of Hanoi, office organization task, German version of WAIS.

The results

Individual waveforms for patients and averaged waveforms for 9 control participants.



Response trial	Controls		Patients		Post-response trials	Control		Patients	
	Form	Letter	Form	Letter		Form	Letter	Form	Letter
Mean error rate	8.9%	8.8%	9.8%	9.7%		Mean response time in ms			
Error range	3.2% - 18.5%	3.8% - 11.8%	2.5% - 15.6%	6.0% - 14.4%	Post-error response				
Rate of no-responses	4.1%	2.3%	29.7%	23.6%	correct trial (PEc)	348	356	511	575
Mean response time in ms					Post-correct response				
correct trials	343	341	486	531	correct trial (PCc)	341	340	486	526
incorrect trials	300	291	377	439	Diff. PEc minus PCc	+7	+16	+25	+49

- ★ The overall task performance on error rate and response times was similar in the two groups (no sign. diff.).
- ★ In accordance with previous findings, all participants showed faster response times to incorrect than to correct trials.
- ★ The controls produced a negative deflection (ERN) following incorrect but not correct trials in both paradigms. The ERN was followed by a sharp positive rise.
- ★ Patient MH produced an ERN in both paradigms, patient EZ produced an ERN in the letter but not the form paradigm, patients IE and EM clearly did not produce an ERN in one of the paradigms while in the other paradigm they produced a waveform for error trials that differed from the waveform in correct responses but which did not resemble an ERN. RF did not produce an ERN in either paradigm.
- ★ Patients IE and RF clearly showed signs (exclamations, whispered swearing, grimaces) of having noticed when they made an error. The other three patients' behavior was mixed.
- ★ Concerning the neuropsychological evaluation, patient IE performed within the average range on all tests. Although RF performed better than the other patients, she was impaired on all tests except for the WMS-R general memory and attention subtest. The other patients were impaired to various degrees on all tests performed.



Conclusion

- ✎ The dissociation between AACA patients not producing a proper ERN and patients with damage to the dorsolateral frontal cortex producing an ERN suggests that the anterior cingulate is essential to initiate the ERN response. Our data also speak against the SMA as being solely responsible for the ERN.
- ✎ The behavioral data (error rates of patients and explicit awareness of committing an error in two patients) suggest that the ERN may not simply represent an error detection. It has been suggested that the ERN (1) represents a response evaluation process which leads to error detection, or (2) is related to an emotional process associated with response conflict and/or errors. Our data showing that patients with no ERN can be aware of their errors seem to favor the latter view, and suggest that the ERN may not simply represent an obligatory stage in error detection.



Some selected references:
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