Error-related negativity is associated with resting hemispheric asymmetry

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Abstract

- Previous research has shown that negative affect is associated with larger error-related negativity (ERN) amplitudes. Resting frontal brain asymmetry, also a correlate of individual differences in affective and motivational tendencies, might thus moderate ERN amplitudes.
- Relatively greater left frontal activity is proposed to be associated with approach-motivated behaviors while greater right frontal activity is hypothesized to index withdrawal-motivated behaviors. Such findings suggest that frontal brain asymmetry might predict variance in affective and cognitive responses during error-monitoring.
- In this study, a sample of undergraduates was selected over a range of obsessive-compulsive (OC) symptoms – a known correlate of both negative affect and heightened error monitoring. Greater relative right frontal and frontal central activity at rest was associated with larger ERN amplitudes in a probabilistic learning task.
- However, comparable effects were not observed for frontal or parietal asymmetry on ERN amplitude from a standard flankers task. These results suggest that frontal brain asymmetry may moderate response monitoring processes in implicit learning tasks but not explicit forced-choice paradigms.

Background

- Several studies have shown that relative right frontal activity is a correlate of negative affect when watching fearful film clips (Tomarken et al., 1990; Wheeler et al., 1993), and when making fearful or sad facial expressions (Coan et al., 2001), and that relative right frontal activity characterizes individuals with depressive or anxious symptoms (for a review, see Coan and Allen 2004).
- Likewise, there is tentative evidence that the ERN may also be associated with negative affect. Luu and colleagues (2000) showed that college students with high levels of negative affect and negative emotionality had larger ERN amplitudes during the first block of trials. Furthermore, Hajcak et al. (2004) also found that participants who had high negative affect showed enhanced ERNs.
- However, the studies mentioned relied on subjective measures of negative affect. Frontal asymmetry could provide a complementary method that might provide a more sensitive index of trait and state motivational tendency. Thus, in the current study, frontal asymmetry is used as an alternative index to further explore the relationship between negative affect and ERN.

Methods

Participants

- Participants included 29 undergraduates with high, medium, and low obsessive-compulsive scores on the Obsessive-compulsive Inventory (range = 0-58).
- Participants included in analysis were not on medication, produced at least 30 errors, and were able to learn the easiest symbol pair in the first and second task.

Task

- Six minutes of baseline resting EEG was recorded prior to the tasks.
- Participants completed a Flanker task which is an explicit forced-choice paradigm that provides direct feedback on performance. No significant correlations were found with this task and this is not discussed further.
- Participants also completed a probabilistic learning task where the participant must choose between two Japanese characters (see figure below). This task is an implicit learning forced-choice paradigm in which feedback reinforces the correct choice only 80%, 70% or 60% of the time depending on the stimulus pair (Frank et al., 2007). During the test phase, participants must rely on previously learned associations to make the correct choice without feedback.

EEG recordings and ERN quantification

- EEG data were acquired with the 64-Channel Ag/AgCl Quick-Caps and the NeuroScan SynAmps² using the 10-20 placement system.
- References included Cz recorded online while linked mastoids were derived offline for ERN and Average Reference was derived for EEG asymmetry.
- Vertical eye-movement artifacts were corrected with a regression algorithm for ERN analyses, and were rejected for resting EEG analyses.
- ERN data were filtered between 1.5 Hz and 15 Hz, 96 dB/octave. Response-locked waveforms were created for trials with optimal choices and trials with suboptimal choices, the latter reflecting the ERN, with peak negativity identified 0-120 msec following response and compared to the previous positive peak. Difference scores were computed (dERN) such that a larger positive value reflected a larger ERN.

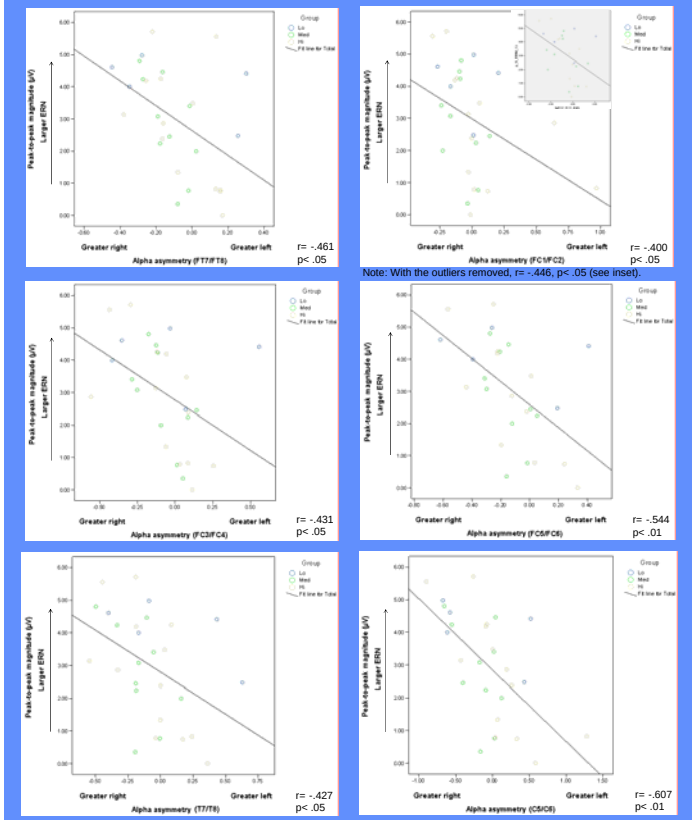
Methods continued…

Frontal asymmetry measurement

- EEG data were converted to an average reference, and spectral power was extracted from 2 second epochs that overlapped by 75%, using a hamming window.
- Frontal alpha asymmetry scores were obtained using the natural log of 8-13 Hz power at each homologous pair of electrodes, ln(R/L), with higher scores indicating greater relative left activity (greater relative right alpha power).

Frontal asymmetry and ERN

Larger ERN amplitudes during a probabilistic learning task are associated with greater resting right fronto-central activity.



Note: With the outliers removed, r= -.446, p< .05 (see inset).

Figure 1: Panels 1-6 show a significant negative correlation between ERN amplitude and left frontal asymmetry for six homologous electrode pairs: FT7/FT8, FC1/FC2, FC3/FC4, FC5/FC6, T7/T8, and C5/C6.

- These results show that relatively greater right hemispheric activity was associated with larger ERN amplitudes during the probabilistic learning task.
- As shown in the plots, the effect was not dependent on level of OC symptoms
- Note that there were no significant correlations between frontal asymmetry and ERN amplitude during the Flanker task.
- The correlation between Flanker ERN and PL ERN was not significant (r = .17, p>.05).
- Results using Alpha-power derived under linked mastoids reference produced a generally similar pattern of results, with significant fronto-central effects at regions: F5/6, F7/8, FC3/4, FC5/6.

Results continued…

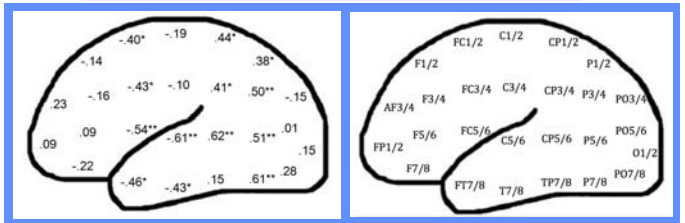


Figure 2: Left panel shows correlation coefficients plotted on a diagram of the brain's left hemisphere; positive coefficients indicate relatively greater left activity while negative coefficients indicate relatively greater right activity which was associated with larger ERNs. Right panel shows the location of each homologous electrode pair is plotted on the left hemisphere.

- The finding of greater right frontal-central activity associated with larger ERN amplitudes was found across the range of obsessive-compulsive scores using the whole head average as reference.
- Additionally, this hemispheric activity pattern reversed in the posterior regions (Figure 2).

Discussion

- These results support, in part, the findings reported by Luu, Collins, and Tucker (2000) and Hajcak, McDonald, and Simons (2004) who also found enhanced ERN amplitudes associated with increased negative affect.
- Although this study was able to show a relationship between larger ERN amplitudes and greater right hemispheric activity as predicted, enhanced ERN was only found during the probabilistic learning task and not during the Flanker task as in these other studies. Moreover, the effect was hypothesized to encompass a range of frontal regions, whereas the effect was confined to the fronto-central region.
- This discrepancy may be related to participant motivation as Luu, Collins, and Tucker (2000) provided a monetary incentive for correct responses on the Flanker task; no monetary rewards were provided for the Flanker task in the current study. However, most ERN studies use the Flanker task without monetary rewards. Furthermore, participants were given an incentive during the probabilistic learning task (the top scorer received a $30 gift certificate).
- The dissociation between the Flanker ERN and PL ERN suggests that these ERPs may not be identical. It is possible that the ERN elicited during the Flankers task results from punishment sensitivity (external motivation) while the ERN found during the probabilistic learning task is a result of self-regulated error monitoring (internal motivation).
- Another possibility is that negative affect as measured by self-report questionnaires is not identical to the negative affect associated with frontal asymmetry. Some studies have found a correlation between negative affect questionnaires and relative right frontal activity (Tomarken et al., 1992; Jacobs and Snyder, 1996) while others have not found clear support (Hagemann et al., 1999).
- A limitation of this study is that a subjective measure of negative affect was not included. Future studies should compare frontal asymmetry and self-report measures of negative affect to determine whether they provide comparable indices of negative affect.

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