ERROR-RELATED BRAIN POTENTIALS ARE ASSOCIATED WITH TRANSIENT INCREASES IN SPECTRAL POWER & PHASE ALIGNMENT OF ON-GOING EEG OSCILLATIONS

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BACKGROUND

In ERP research it is assumed that ERPs reflect the summation of activity in successive areas of the brain, where dipoles are fixed spatially and temporally [1], such that ERPs arises out of a baseline of 'absent' activity [2]. Event-related spectral perturbations (ERSPs) and inter-trial phase coherence (ITC) can be used in tandem with ERPs to more richly capture dynamic brain activity across time-frequency domains [2].

Not only have auditory evoked ERPs been explained in terms of phase-aligned EEG signals, where no power increases are observed [3], but there is evidence that visually evoked potentials manifest from a transient alignment of ongoing oscillatory EEG rhythms [2].

Furthermore, the amplitude of the error-related negativity (ERN) can be accounted for in terms of increases in phase and non-phase locked theta power at fronto-central sites [4], and following error/loss feedback there are increases in cross-trial phase coherence and spectral power [5], particularly in the theta frequency range [6].

HYPOTHESES:

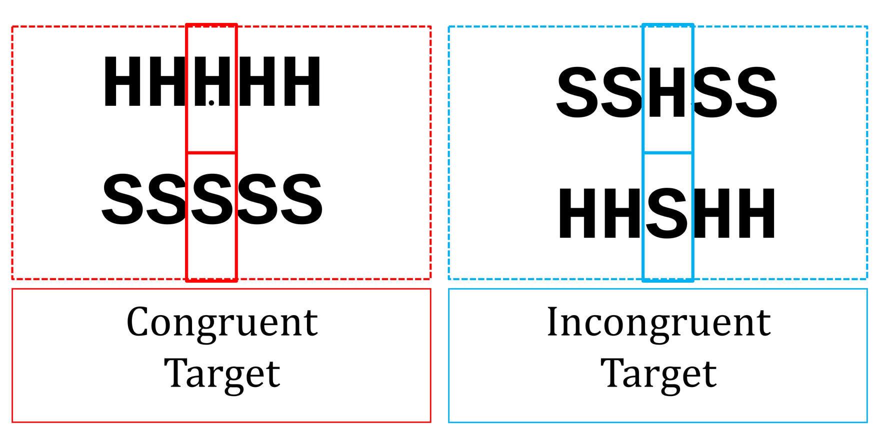
(1) ERP amplitude, peak power (ERSP), and ITC measures would be greater following errors as compared to correct responses.

(2) Greater peak power (ERSP) and ITC would be negatively associated with ERN amplitude; however, ITC would be a stronger predictor of unique variability in ERN amplitude.

LETTER-FLANKER TASK

TASK: Respond with index fingers to the central letter in a 5-string array. Letter-finger counterbalanced across participants.

- 480 trials, blocks of 160 trials, 50% congruent/incongruent
- Stimulus duration: 200 ms
- ISI: 1250 ms



METHODS

PARTICIPANTS:

- 11 Brock University students [7 Female, 4 Male; Age = 23.0 ± 4.5 years]

EEG RECORDING AND REDUCTION:

- Continuous EEG collected using 256-channel EGI system, analog filtering set at 0.1-100 Hz, and referenced to vertex.
- Offline 1-30 Hz bandpass filtered, re-referenced to common average.
- Epochs extracted -1500 ms to +1500 ms post-response at FCz, with -600 ms to -400 ms baseline for ERN amplitude.
- Peak amplitude, spectral power (ERSP), and ITC were extracted as the maximum value occurring between 0 and 200 ms post-response.
- ERSP and ITC scores were extracted between 3 and 20 Hz.

RESULTS

BEHAVIOURAL:
Mean # errors: 39 errors.
Average success rate: 92%

ERP [Figures 1A and 1B]:
Compared to correct trials (M = -0.94 µV, SD = 2.93), peak voltage was significantly more negative on error trials (M = -7.31µV, SD = 3.74) [t(10) = 4.91, p = .001].

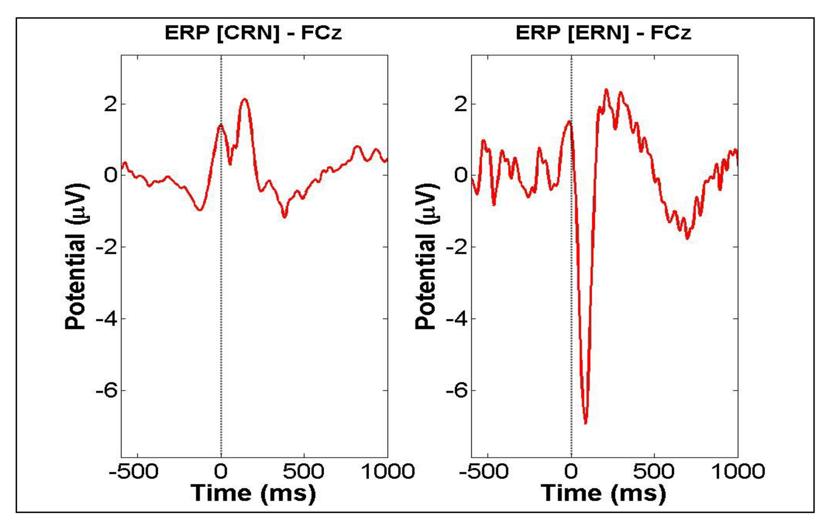


Fig. 1A Fig. 1B

ERSP [Figures 2A and 2B]:
Increases in spectral power were significantly greater on error trials (M = 5.93 dB, SD = 1.86), compared to correct trials (M = 2.94 dB, SD = 1.16) [t(10) = 6.66, p < .001].

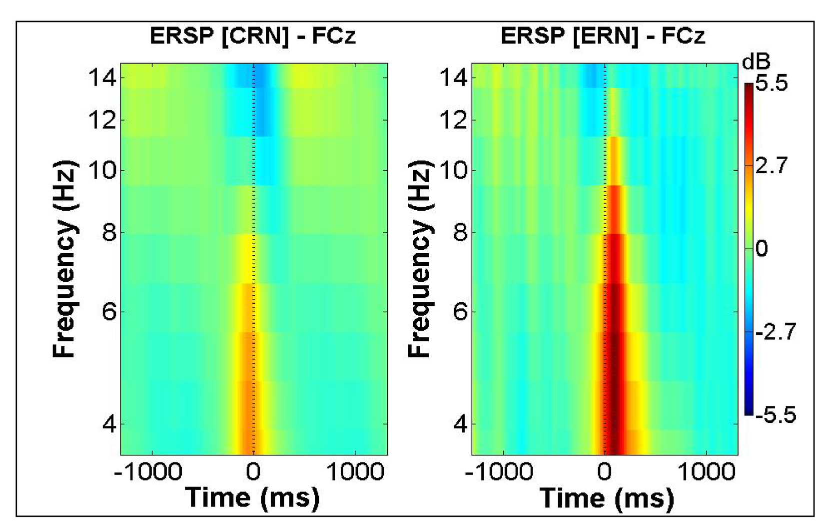


Fig. 2A Fig. 2B

ITC [Figures 3A and 3B]:
Increased phase angle coherence was significantly greater after erroneous responses (M = .62, SD = .15), as compared to successful responses (M = .45, SD = .17) [t(10) = 3.55, p = .005].

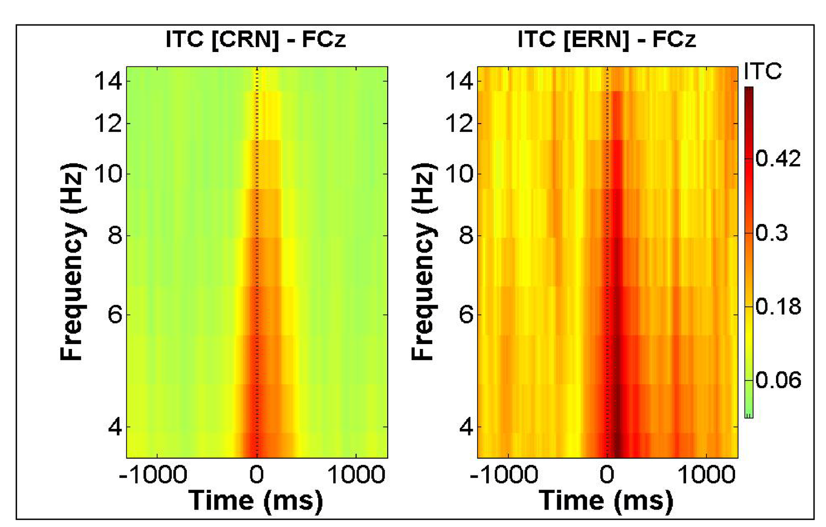


Fig. 3A Fig. 3B

ZERO-ORDER CORRELATIONS:
Peak power was negatively correlated with ERN amplitude [r(11) = -.68, p = .02 – **Fig. 4A**]. Similarly, ITC was negatively correlated with ERN amplitude [r(11) = -.80, p = .003 – **Fig. 4B**]. The relationship between peak power and ITC was not statistically significant [r(11) = .55, p = .08].

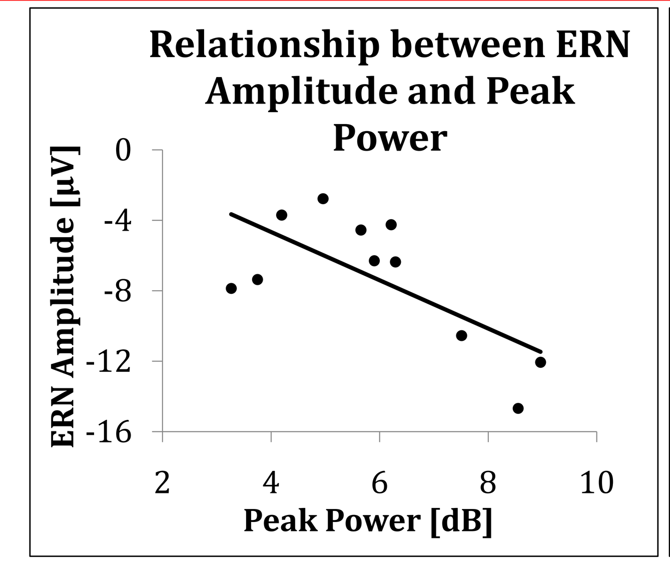


Fig. 4A

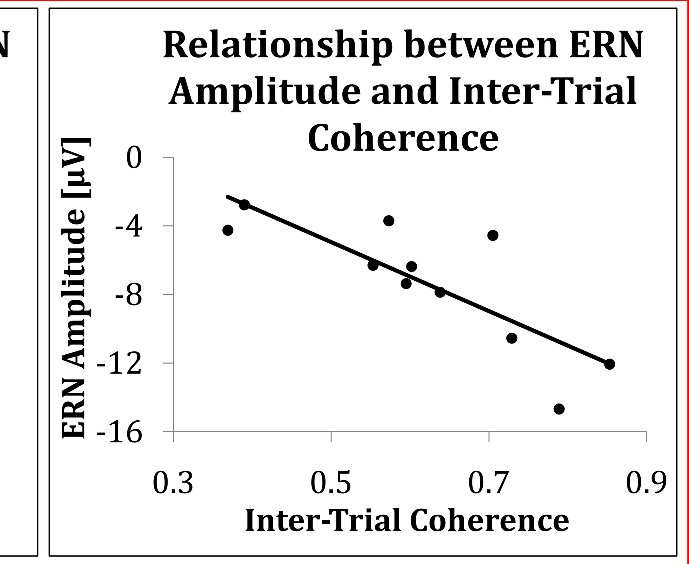


Fig. 4B

REGRESSION ANALYSIS:
Together, peak power and ITC accounted for 73% of the variance in ERN amplitude [F(2, 8) = 11.05, p = .005]. ITC was a significant predictor, contributing 27% unique variance in ERN amplitude [t(10) = 2.88, p = .02]; peak power contibuted 7% of unique variance to ERN amplitude [n.s., t(10) = -1.56, p = .16].

POST-HOC ANALYSES:
Pearson correlations indicate that neither amplitude [r (11) = -.47, p = .14] nor power [r (11) = .13, p = .71] were significantly associated with performance.
However, increases in ITC were associated greater overall accuracy in responding [r (11) = .68, p = .02 – **Fig. 5**].

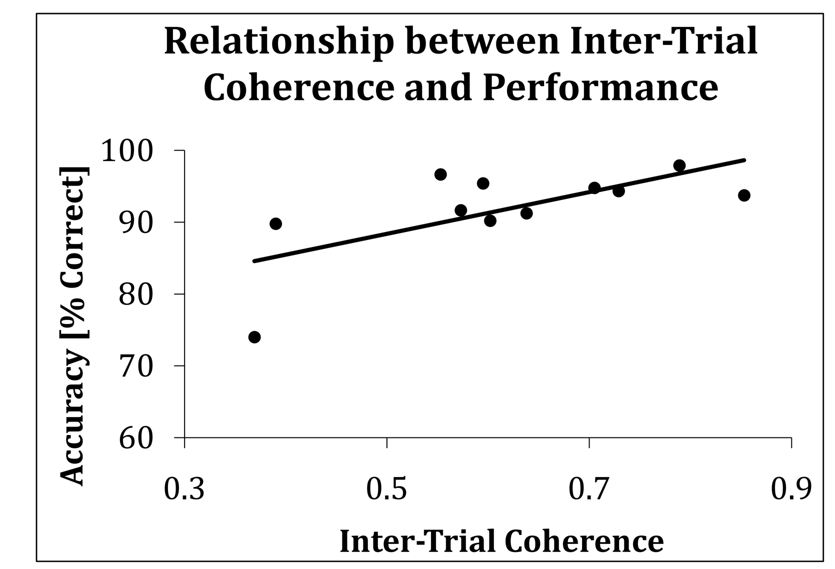


Fig. 5

CONCLUSIONS

- ERN emerges out of partial phase alignment of EEG oscillations over front-central sites [4,5] and is not due simply to an increases in voltage fluctuations.
- ITC uniquely predicts ERN amplitude and correlates with accuracy. Thus, phase coherence of theta following errors may reflect a mechanism of cortical and limbic coordination in support of adaptive self-regulation [4,7].
- Our results support the position that measures need to go beyond the single voltage dimension on which ERPs are typically considered to offer a fuller model of brain dynamics in relation to experimental events [1,2].

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