Error related negativity (ERN): Error vs. Conflict generated?

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Abstract

Error related negativity (ERN) has received much attention due to its potential contribution to the study of executive control. However, considerable debate exists as to the specific cognitive processes responsible for its generation. Initial investigations suggested that ERN was produced during detection and compensation for task errors. Others proposed that ERN reflects activation of a general "conflict-monitoring" system responsible for detection of processing competition, independent of error commission. Data relevant to this debate are provided.

Participants performed a modified version of the Eriksen Flanker task. Each trial consisted of a string of 5 letters (H's and S's). Participants made forced choice responses to indicate the center target letter (H or S) while ignoring flanker letters surrounding the target. Flankers were compatible (match target; example: HHHHH) or incompatible (mismatch target; example: SSHSS), with compatible/incompatible trials equi-probable. A prepotent response was established by manipulating target letter frequency with one response more frequent (p=0.80) than the other (p=0.20).

Flanker compatibility and target frequency manipulations produced expected effects on task performance. Robust ERN was observed on error trials. However, sizeable variation in ERN was also observed on correct trials. Specifically, larger ERN occurred after correct response to infrequent vs. frequent targets. Moreover, the relationship between response time (an indirect index of processing competition) and ERN magnitude was greater among infrequent trials. Flanker compatibility did not affect ERN.

These results suggest interpretation of ERN as an index of error detection and/or compensation processes may be too narrow. Moreover, with respect to the conflict-monitoring hypothesis, differential effects of Target frequency vs. Flanker compatibility indicate ERN may be sensitive to response competition but not stimulus processing competition.

Methodology

Participants

- 32 university undergraduates (24 male/8 female)

Description of Paradigm

- Utilized a modified version of the Flanker Task (Eriksen & Eriksen, 1974)
- Stimuli consisted of a string of five letters (HHHHH; SSSSS; SSHSS; HHSHH)
- Center letter was designated as target in forced choice reaction time
- Flanker (surrounding) letters were distracters to be ignored

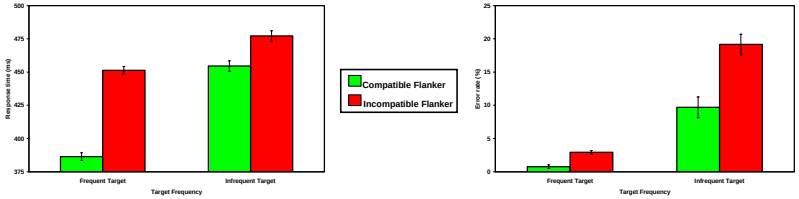
Primary Independent Variables

- **Flanker Compatibility (FC; Compatible vs. Incompatible):**
  - The flanker letters were compatible (HHHHH, SSSSS) or incompatible (SSHSS, SSHSS) with target letter
  - Equal numbers of compatible and incompatible trials were included
- **Target Frequency (TF; Frequent vs. Infrequent):**
  - The relative frequencies of the two target letters (H and S) were not equal
  - Frequent target was presented on 80% of trials (20% infrequent)

Paradigm Details

- Stimuli were presented for 500ms
- Intertrial intervals (ITI) varied from 1500ms to 2500ms
- Reaction times were collected in a 2000ms window starting with stimulus presentation
- 600 trials were included in three blocks (200 each with brief break between blocks)
  - 480 Frequent and 120 Infrequent targets
  - 300 Compatible vs. 300 incompatible flankers
  - 240 Frequent/Compatible, 240 Frequent/Incompatible, 60 Infrequent compatible, 60 Infrequent/Incompatible
  - Trial presentation was random with relative frequencies matched within blocks of 40 trials

Behavioral Measures



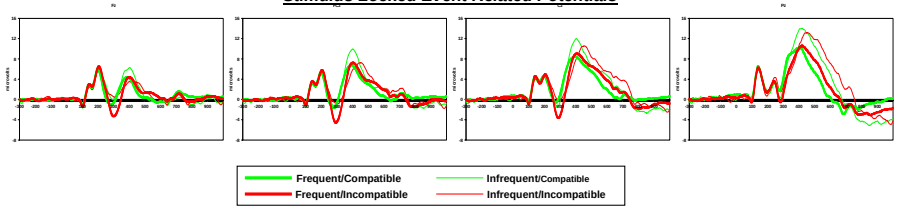
Response Time

Significant main effects of both Flanker compatibility, F(1,31)=302.44, p < .001, and Target frequency, F(1,31)=207.59, p < .001, were observed. In addition, a significant TF X FC interaction was observed, F(1,31)=87.00, p < .001, indicating that the interference resulting from Incompatible flankers was significantly greater for Frequent target trials.

Error Rate

Significant main effects of both Flanker compatibility, F(1,31)=47.94, p < .001, and Target frequency, F(1,31)=54.99, p < .001, were observed. In addition, a significant TF X FC interaction was observed, F(1,31)=24.95, p < .001, indicating that the increased error rate resulting from Incompatible flankers was significantly greater for Infrequent Target trials.

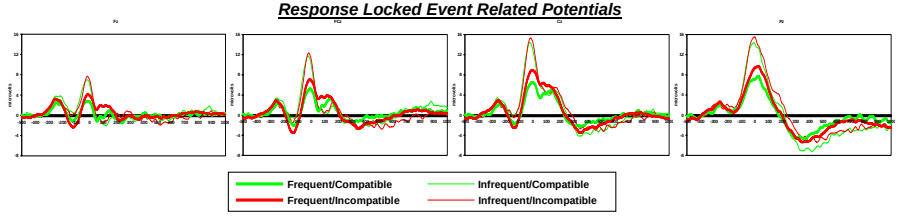
Stimulus Locked Event Related Potentials



N2 was indexed as the mean response (relative to 500 ms baseline) in a scoring window from 234 to 334 ms post stimulus onset. Significant TF X FC interactions were observed across all sites. Decomposition of the interactions indicated that N2 in the Frequent target/Incompatible flanker condition was significantly greater (more negative) than in all other conditions across all sites.

P3 was indexed as the mean response relative to baseline in a scoring window from 354 to 454 ms post stimulus onset. Significant TF X FC interactions were observed across all sites. Decomposition of the interactions indicated that P3 in the Infrequent target/Compatible flanker condition was significantly greater than all other conditions across all sites.

Response Locked Event Related Potentials



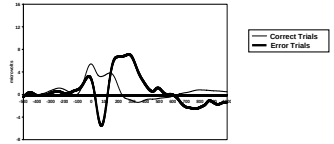
ERN was scored as the maximum negative deflection (relative to baseline between 500 and 300 ms pre-response) in a scoring window from behavioral response to 200 ms post response. To control for between condition effects in stimulus locked ERPs, only trials within a 100 ms window surrounding each participant's mean response time were included in waveform averages.

Significant main effects of Target frequency were observed at Fz and FCz sites. No significant effects of Target frequency were observed at Cz and no evidence of an ERN was exhibited at Pz.

The effect of Flanker compatibility was not significant across sites.

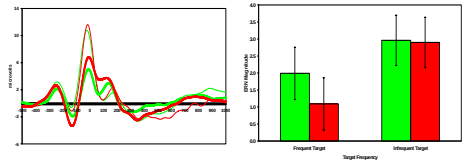
ERN on Error Trials

Consistent with previous investigations, a sizeable negative deflection in the response locked waveform subsequent to the commission of an error on the Flanker task was observed. The peak response is approximately 75 ms post behavioral response with a frontal/central distribution. The waveform depicted below represents average correct vs. incorrect trials across all conditions (i.e., collapsed across Target frequency and Flanker compatibility conditions)



ERN on Correct, Response time corrected Trials

Some manipulations which lead to processing competition (indicated by behavioral impairment) also produce variability in ERN among trials on which no error was made. Specifically, a Target frequency X Flanker compatibility analysis was conducted on ERN among "correct only" trials. A significant effect of Target frequency was observed with greater ERN on Infrequent target trials, F(1,31) = 5.35, p = .028. No significant effect of Flanker compatibility or TF X FC interaction on ERN was observed.



ERN Varies with Response Time to Infrequent Targets

As processing competition increases, response time should increase. In particular, this relationship between response time and processing competition should be noted among Infrequent targets, where prepotent priming of the incorrect Frequent target response is likely to exist even on correct trials. To test this, correct trials for Frequent and Infrequent targets were divided according to response time (median split into fast and slow response conditions). Analysis of Target frequency X Response time revealed significant main effects of Target frequency, F(1,31)=9.91, p=.004 and Response time, F(1,31)=27.97, p<.001. However a significant TF X RT interaction, F(1,31)=6.52, p=.016, indicated that the Response time effect on ERN was larger among Infrequent targets.