Looking for Emotional Interference in a Stroop-Like Paradigm: Behavioral and Event-Related Potential (ERP) Findings

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46th Annual Meeting of the *Society of Psychophysiological Research (SPR)* in Vancouver, BC, Canada, October 24 - 29, 2006

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Introduction

Behavioral interference (e.g., longer RT) for emotional content has been observed in Stroop-like paradigms (see MacLeod, Mathews, & Tata, 1986; McKenna & Sharma, 1995, 2004). This effect has been interpreted as an additional allocation of attentional resources when processing emotional versus neutral stimuli.

However, not all studies have revealed unambiguous emotional interference effects (e.g., Whalen et al., 1998; Compton et al., 2003; McKenna and Sharma, 1995). This may result from weak behavioral effects of the paradigm itself or differences in experimental methodology, possibly masking or mimicking emotional interference.

Although event-related potentials (ERPs) allow to directly measure task-related early sensory or attentional processes (e.g., P1 or N1) and differentiate these from later stages of information processing (e.g., categorization and evaluation as reflected by the N2-P3 complex), very few studies have investigated ERP correlates of emotional interference in a Stroop-like paradigm (e.g., Metzger et al., 1997; Perez-Edger & Fox, 2003). Enhancement of ERP components related to processing emotional stimuli, particularly within the N2/P3 complex, have been reported in studies that exploit the implicit emotional quality of a stimulus without requiring overt responses (Kayser et al., 1997, 2000) and those that blend cognitive and emotional processes (Cuthbert et al., 2000; Delplanque et al., 2005; Dietrich et al., 2001; Schupp et al., 2003a, 2003b).

Objective:

1. **Develop a paradigm that controls for (i.e., limits) unrelated cognitive processes (e.g., word recognition or stimulus habituation) that may confound emotional effects of interest.**
2. **Investigate the time course and the contribution of regional cortical activity related to different stages of information processing within an emotional Stroop paradigm by using advanced ERP methodology.**

Hypotheses:

1. **Emotional words would produce longer RTs than neutral words due to a greater amount of attentional load.**
2. **Emotional compared to neutral words would result in N2-P3 augmentations seen as:**
   a) Greater activity over ventroposterior and left temporal regions (N2)
   b) Greater midparietal activity (P3b)

Participants

- no history of psychopathology or neurological disorder
- Normal color vision
- Normal or corrected-to-normal visual acuity

	Healthy Adults (n = 28)
Gender (male/female)	15 / 13
Age (years)	27.8 ± 6.6 (20 – 41)
Education (years)	16.7 ± 1.8 (14 – 21)
Handedness (EHI)	83.3 ± 17.5 (42.9 – 100.0)

Stimuli and Procedure

- 192 words rated for affective valence, arousal, and dominance (selected from the Affective Norms for English Words [ANEW; Bradley & Lang, 1999])
- 48 Positive-Emotional words - upper ANEW quartile (positive valence)
- 48 Negative-Neutral words - lower ANEW quartile (negative valence)
- 96 Neutral words - second and third ANEW quartiles (intermediate valence), systematically matched to positive and negative words for word length (labeled positive-neutral and negative-neutral, respectively)

Mean (SD) ANEW Ratings for Positive-Emotional, Positive-Neutral, Negative-Emotional, and Negative-Neutral

		Emotional Content	
		Emotional	Neutral
Valence	Positive	2.5 (± .41)	4.9 (± .33)
	Negative	8.0 (± .29)	4.8 (± .53)

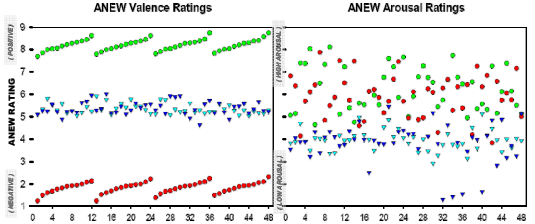


Fig. 1. Scatter-plot of ANEW Valence (**Left**) and Arousal (**Right**) ratings for Positive-Emotional (green circle), Positive-Neutral (cyan triangle), Negative-Emotional (red circle), and Negative-Neutral (blue triangle) words.

- Pseudorandomized (across participants) stimulus sequences (8 blocks of 12 word pairs):
  - **emotional content (i.e., emotional or neutral) did not occur more than twice consecutively**
  - **participants exposed to each word only once**
- Matched word pairs were in the same color (**blue**, **green**, **red**, **yellow**) under the following restrictions:
  1) the frequency of each color was equally presented to every participant
  2) the frequency of each color presentation was equal in every block
  3) no color was presented more than twice consecutively
- Color was indicated by a 4-choice button press (two buttons assigned to the left hand and two buttons assigned to the right hand, color assignment counterbalanced across participants)
- 150 ms stimuli exposure
- pseudorandomized across four stimulus onset asynchronies (1.700, 1.825,1.950, 2.075 ms)
- Instructions:
  - 1) indicate stimulus color as quickly and accurately as possible
  - 2) ignore meaning of words

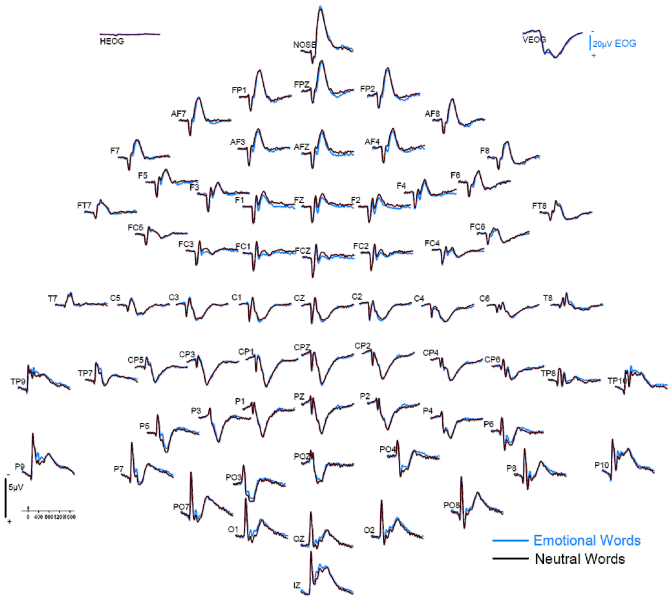
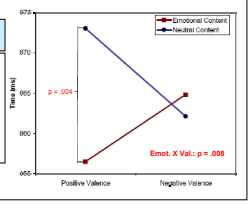


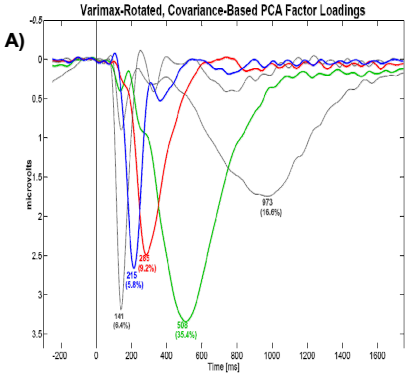
Fig. 2. Grand average ERP waveforms for all emotional (blue) and neutral (black) words. A clear, stimulus-specific (i.e., visual-verbal) component structure with a ventroposterior negativity at approximately 140 ms and a parietal positivity at approximately 500 ms is present across conditions. Components are comparable to average-referenced waveforms reported by studies investigating the traditional Stroop paradigm (Liotti et al., 2000; West & Alain, 1999) and emotional Stroop paradigm (Perez-Edgar & Fox, 2003).

Behavioral Results

Mean Log Transformed Response Latencies (SD) and Percentage Correct (SD) for Each Experimental Condition.

Condition	Response Latency (ms)	(SD)	% Correct	(SD)
Positive-Emotional	644.1	105.3	94.8	5.8
Positive-Neutral	660.6	101.0	94.2	6.4
Negative-Emotional	649.5	108.5	93.4	7.9
Negative-Neutral	648.2	98.0	92.8	7.2





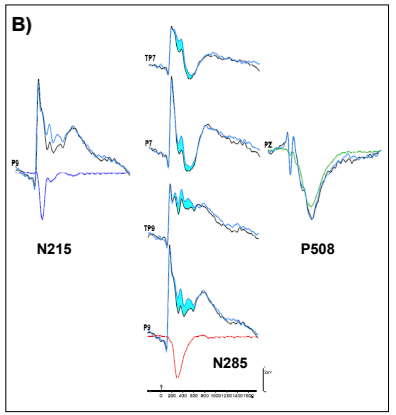


Fig. 3. **(A)** Time course of Varimax-rotated, covariance-based PCA factor loadings. Factors of interest (i.e., those within N2-P3 complex) were among the first 5 factors (74% total explained variance). These factors corresponded to peaks at around 215 ms (blue), 285 ms (red), and 508 ms (green). Factors are labeled according to peak latency. **(B)** ERP waveforms at selected left-hemispheric and midparietal sites and factor score topographies comparing emotional and neutral words. Factors are labeled according to peak latency and polarity. At around 300 ms, more negative-going ERP amplitudes can be seen for emotional than neutral words at scalp locations Tp7, P7, TP9, and P9.

ERP Recording and Data Analysis

- Continuous DC (24-bit A/D) EEGs using an electrode cap, 67 scalp sites (extended 10-20 system), active recording reference (BioSemi), 256 samples/s
- Bipolar horizontal and vertical EOGs; **blink reduction** (continuous EEG) **using spatial SVD**; horizontal eye artifacts (epoched EEG) using linear regressions of lateral EEG differences (Fp2-Fp1, etc.) then removing correlated activity (±beta weight / 2) of each lateral channel (Kayser et al. 2006)
- 2,000 ms epochs, 250 ms pre-stimulus baseline, ERP averages (artifact-free trials, correct responses) low pass filtered at 12.5 Hz (-24dB/oct.), 250 ms baseline correction
- Average-reference waveforms submitted to ***unrestricted* temporal principal components analysis (PCA)** derived from the covariance matrix followed by *unscaled* Varimax rotation (Kayser & Tenke, 2003), to identify and measure the temporal pattern and spatial distribution of underlying cortical activity
- Factor scores of meaningful PCA factors were submitted to repeated measures ANOVA with group (gender) as the between-subjects factor, and Valence (Positive, Negative), Emotional Content (Emotional, Neutral), and Response Hand as within-subjects factors. A conventional significance level ($p < .05$) was applied for all effects.
- Subsets of recording sites at which PCA factor scores are largest and most representative of the associated component structure were included as a within-subjects factor (e.g., Kayser et al., 2006).
- ***Behavioral data***: The percentage of correct responses and mean response time for each condition were submitted to repeated-measures analysis of variance (ANOVA) with emotional Valence (positive and negative), Emotional Content (emotional and neutral), and Response Hand (right and left) as within-subjects factors, and Gender as a between-subjects factor.

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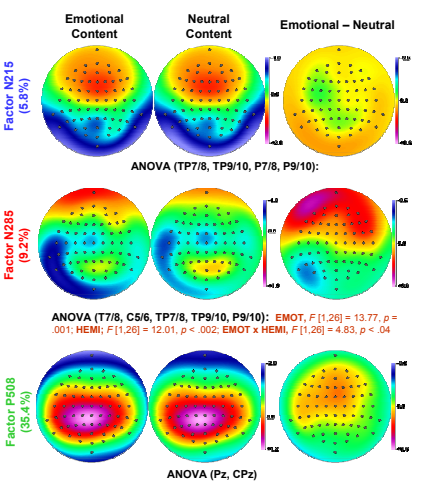

Fig. 4. Mean topographies of PCA factor loadings extracted from average-reference ERP waveforms for emotional content (left column), neutral content (middle column), and respective differences (right column). A uniform symmetric scale is used for difference maps, whereas other maps show an asymmetric scale optimized for score ranges between emotional conditions.

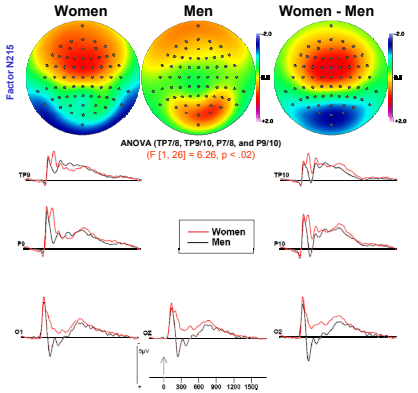

Fig. 5. Mean topography for Factor N215 comparing women and men at selected electrode sites revealing a significant negative-going ERP most prominently seen for women, which is markedly reduced or even absent for men

Summary and Conclusions

- Behavioral interference (e.g., longer RT) for emotional compared to neutral words was not observed.
- Significantly greater negativity over left ventroposterior and temporal sites was observed for emotional words around 285 ms (N285).
- This effect may be an electrtophysiological measure of increased allocation of attentional resources to emotionally charged words, possibly indexing active inhibition of motivational significance.
- Whereas the lack of behavioral emotional interference effects casts doubt on the generalizability of the phenomenon for healthy adults, the difference between emotional and neutral words as indexed by N285 may reflect physiological processes preceding overt behavioral interference.

UNPREDICTED FINDINGS:

- A significantly greater negativity over bilateral inferior temporoparietal electrode sites most prominent in women, which was greatly reduced in men.

Acknowledgments

*This research was supported by **National Institute of Mental Health Grant No. MH36295***