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Research report

Event-related neural activity associated with the Stroop task

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Abstract

The time course of neural activity supporting performance during the Stroop task was investigated using event-related brain potentials (ERPs). Four spatially and temporally distinct modulations were observed differentiating the ERPs elicited by incongruent trials from the ERPs elicited by congruent, neutral, or word identification trials. Two of these modulations reflected increased negativity over the fronto-central region and positivity over the fronto-polar region for incongruent trials and may reflect conflict detection and resolution processes. The other modulations, distributed over the left parietal and temporo-parietal regions, may reflect the activity of a meaning-based conceptual level system active during congruent, neutral, and word identification trials; and the activity of a perceptual level system supporting task performance when only color information can guide an efficient response on incongruent trials.

Keywords: Stroop task; Event-related brain potential

1. Introduction

The Stroop interference effect [19] has been one of the most extensively studied phenomena in cognitive science. The effect refers to the increase in response latency observed when an individual is required to identify the color of a color-word when these aspects of the stimulus are incongruent (e.g., the word RED presented in the color blue) compared to the time required to name the color of a neutral (e.g., XXX in blue), or congruent (e.g., the word RED presented in the color red) stimulus. The Stroop effect has been utilized by researchers to explore the nature of automatic and controlled cognitive processes [9,16], disturbances in cognition resulting from various psychiatric and/or neurological disorders [13], the neuro-cognitive architecture of selective attention [14], and age-related declines in inhibitory processing [22].

Current computational [5] and mathematical [11,12] models of the Stroop task propose that color and word information are processed in independent pathways that converge on a shared or common response system. For congruent and neutral trials responding is relatively fluent, as the color and word pathways activate the same response level representation. Interference, or the Stroop effect, arises on incongruent trials when information from the color and word pathways activate competing response level representations. The activation of more than one response level representation requires additional time for input by the color pathway to accrue enough activation to become differentiated from input by the word pathway and guide a response.

Neuro-imaging studies incorporating the positron emission tomography (PET) technique have begun to identify the neural architecture supporting performance of the Stroop task. Increased regional cerebral blood flow (rCBF) has been observed in the anterior cingulate in a number of studies [4,15] and has been proposed to reflect cognitive processes supporting efficient selection between competing color and word information. Increased rCBF has also been observed in the frontal polar region [1], the inferior frontal gyrus [20], and the inferior parietal region [1]. These findings indicate that the anterior cingulate is part of a distributed network supporting task performance. While these studies have identified a number of brain regions active during performance of the Stroop task, little is known about the time course of these neural events.

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Scalp recorded event-related brain potentials (ERPs) offer real-time temporal resolution of neural processes, permitting a precise analysis of the time course of neural events supporting task performance. ERPs reflect event locked electrical activity generated by neural ensembles and consist of a series of positive (P) and negative (N) deflections above some pre-stimulus baseline level of activity that peak at particular intervals following stimulus onset. For instance, the third positive deflection in the waveform is generally labeled as P3, and a negative deflection occurring at 400 ms would be labeled N400.

In an early study, Duncan-Johnson and Kopell [7] reported that there were no differences in the latency or amplitude of the P3 elicited by congruent, neutral, or incongruent trials in the Stroop task. In comparison, there were large differences in response latency between the congruent and incongruent trials. Together these findings led them to suggest that interference was related to conflict in response selection rather than stimulus evaluation processes, consistent with dual-pathway models of the Stroop task. However, the conclusions of this study [7] were based upon findings of null results in the P3 modulation and a fairly conservative low-pass filter was used obscuring modulations other than the P3. Rebai et al. [14] also found no differences in the ERPs elicited by congruent and incongruent trials in the amplitude or latency of the P3. In comparison, significant differences between the ERPs for these two conditions did emerge over the central region in the range of 350 to 450 ms that were observed when the task required selection between competing color and word information. However, the enhanced N400 observed in this work for incongruent trials was greatest in a silent naming task making it difficult to determine exactly what individuals were doing in this condition. Also, both of these studies employed a very limited number of electrodes placed primarily over the midline of the scalp making it impossible to examine the topographic distribution of these ERP modulations.

In the current study, we recorded ERPs while individuals performed the Stroop task using a large array of electrodes in an effort to characterize the temporal and spatial patterns of neural activity associated with task performance. Based upon dual-pathway models and the findings of previous ERP studies we expected the ERPs reflecting early stages of perceptual processing and stimulus evaluation (i.e., P3) observed over the occipito-parietal regions to be similar for congruent, neutral, and incongruent trials. Given the findings of Rebai et al. [14], greater negativity for incongruent trials, relative to congruent trials, was anticipated over the fronto-central region possibly reflecting the activity of response selection or conflict resolution processes active when incompatible color and word information is encountered [3]. In addition to congruent, neutral, and incongruent trials we also included word identification trials in the task. These trials permitted us to examine patterns of neural activity supporting task performance when only color information could serve to guide a response on incongruent trials and neutral trials; and when word information could guide a response on congruent and word identification trials.

2. Method

2.1. Subjects

Twelve volunteers (six females) 24–31 years of age participated in the study. All participants reported normal or corrected to normal visual acuity, 10 reported a right hand preference and two characterized themselves as being ambidextrous.

2.2. Materials and procedure

In the Stroop task, participants were asked to identify one of four colors (red, blue, green, or yellow) or the names of these colors by pressing one of four keys (V, B, N, or M) on a computer keyboard using the index and middle fingers of the right and left hands. The experiment was divided into a color-to-key acquisition phase, a practice phase, and a test phase. The color-to-key acquisition phase consisted of 100 trials presented in a single block with each of the four colors presented 25 times in a series of X's equal in length to the color's name. This phase was designed to establish a strong mapping between the stimulus colors and response keys. The practice phase consisted of 40 trials representing the four types of stimuli that would be encountered in the test phase. Thirty of the trials were presented in the color red, blue, green, or yellow. In these trials there were 10 congruent (e.g., RED in red), 10 neutral (e.g., XXXX in blue) and 10 incongruent (e.g., GREEN in yellow) trials. For these trials the participant was instructed to identify the color of the stimulus by pressing the appropriate key. In the 10 remaining trials the words red, blue, green, or yellow were presented in light gray and the individual was instructed to identify the word by pressing the appropriate key.

In the test phase, participants were presented with congruent, neutral, incongruent, and word identification trials. The proportion of word identification trials was varied between blocks. The five 25% word identification blocks consisted of 96 trials. In these blocks, 25% of the trials were presented in light gray and the individual was instructed to press the key identifying the name of the word. In the remaining trials, equal numbers of congruent, incongruent, and neutral stimuli were presented in the colors red, blue, green, and yellow and the individual was instructed to press the key corresponding to the color of the stimulus. The five 50% word identification blocks consisted of 144 trials, the additional 48 trials in these blocks were all word identification trials. Presentation of the 25% and 50% word identification blocks was alternated over

the course of the task, beginning with a 25% word identification block then a 50% word identification block.

At the beginning of the acquisition and practice phases and before the start of each test phase block, a message appeared on the screen instructing the participants to press the space-bar to begin the block of trials. After the space-bar was pressed the screen was blank for 1000 ms. The stimulus was presented in the center of the screen for 400 ms, followed by a blank screen until 1000 ms after a response was made. Following this interval the stimulus for the next trial appeared on the screen. The task was programmed using the MEL Professional 2.0 (MEL) software [18].

2.3. Electrophysiological recording and analysis

The EEG (bandpass 0.05–30 Hz), digitized at 250 Hz, was recorded from an array of 47 electrodes based upon a modified 10/20 system. Vertical and horizontal eye movements were recorded from electrodes placed lateral to and below the right and left eyes. During recording all electrodes were referenced to Cz; for data analysis, they were re-referenced to an average reference.

ERP analysis epochs were extracted off-line and included 200 ms pre-stimulus activity and 1000 ms post-stimulus activity. Trials contaminated by excessive eye or movement artifacts, peak-to-peak deflections over 200 μV, were rejected before averaging. Eye movements and blinks not removed by the artifact rejection criteria were corrected using an ocular source components approach [2] through the Brain Electrical Source Analysis software [17]. ERPs were averaged for trials associated with a correct response as a function of stimulus type (i.e., congruent, neutral, incongruent, and word identification) and proportion of word identification trials (i.e., 25% or 50%).

All statistical tests were performed on normalized mean voltages averaged over 100 ms windows where modulations of interest were observed relative to the mean amplitude of the 200 ms pre-stimulus baseline activity. Statistical tests were performed using Greenhouse–Geisser corrected degrees of freedom over regions of interest where modulations differentiating the various conditions of the Stroop task were observed in a series of 3 (Stroop condition: congruent, neutral, incongruent) × 2 (proportion of word identification trials) × 2 (hemisphere) × electrode ANOVAs with a $p < 0.05$ level of significance. Throughout the paper the original degrees of freedom are reported with the adjusted p-value and relevant Greenhouse–Geisser Epsilon value (ε).

3. Results

3.1. Behavioral data

Group average response latency and proportion of errors for the congruent, neutral, incongruent, and word identification trials for the 25% and 50% word identification conditions are presented in Table 1. A 4 (Stroop task condition) × 2 (proportion of word identification trials) ANOVA performed on the response latency data revealed significant main effects of Stroop task condition ($F(3,33) = 87.24$, $p < 0.001$) and proportion of word identification trials ($F(1,11) = 21.15$, $p < 0.001$) and a significant interaction ($F(3,33) = 6.24$, $p < 0.002$). To obtain a clear understanding of the main effects and the interaction a series of single degree of freedom contrast were performed. The first contrast examined the Stroop effect by comparing response latency for congruent and incongruent stimuli collapsed across the proportion of word identification trials. This contrast was significant ($F(1,33) = 196.83$, $p < 0.001$) and accounted for 75% of the variance in the main effect of Stroop task condition. The second contrast was design to explore the effect of varying the proportion of word identification trials on the magnitude of the Stroop effect by comparing response latency for congruent and incongruent trials in the 25% and 50% word identification trials conditions. This contrast was marginally significant ($F(1,33) = 3.42$, $p < 0.08$) and accounted for 18% of the variance in the interaction, indicating that there was a trend for the magnitude of the Stroop effect to increase as the proportion of word identification trials increased. However, the larger Stroop effect observed in the 50% word identification trials condition resulted from a decrease in latency for congruent trials in this conditions relative to the 25% word identification condition ($t(11) = 2.41$, $p < 0.034$), while there was no effect of varying the proportion of word identification trials on the incongruent trials. A final contrast was design to determine the effect of varying the proportion of word identification trials on response latency for the word identification stimuli. This contrast was significant ($F(1,11) = 29.38$, $p < 0.001$) and accounted for 80% of the variance in the main effect of proportion of word identification trials. This finding is consistent with the idea that varying the proportion of word identification trials would modulate the fluency of word reading processes.

A similar ANOVA performed on the response accuracy data revealed a similar pattern with more errors being

Table 1
Means response latency and proportion of errors as a function of Stroop task condition and proportion of word identification trials

		Proportion word identification	
		25%	50%
Congruent	Latency	718	681
	Errors	0.04	0.04
Neutral	Latency	709	691
	Errors	0.05	0.07
Incongruent	Latency	946	942
	Errors	0.12	0.14
Word ID	Latency	814	739
	Errors	0.06	0.06

committed on the incongruent trials than congruent, neutral, or word identification trials ($F(3,33) = 18.12$, $p < 0.001$), and more errors being made in the 50% word identification condition than the 25% word identification condition ($F(1,11) = 5.67$, $p < 0.036$). In this analysis these variables did not interact ($F < 1$).

3.2. Electrophysiological data

Fig. 1 displays the group average ERPs elicited by congruent, neutral, incongruent, and word identification trials for correct responses collapsed over the 25% and 50% word identification conditions. All trial types elicited a series of negative–positive–negative deflections peaking respectively at 170 ms, 230 ms, and 300 ms post stimulus onset maximal over the occipital–parietal region (e.g., Pz). The P230 was enhanced for the neutral trials relative to the other trial types (e.g., Pz; Stroop condition, $F(3,33) = 13.06$, $p < 0.001$, $\varepsilon = 0.79$). In addition, all trials generated a late positive complex wave that was maximal over the midline parietal region.

There were four modulations that differentiated the ERPs elicited by incongruent trials from the ERPs elicited by congruent, neutral, and word identification trials (see Figs. 1 and 2). To quantify these modulations a series of 3 (Stroop condition: congruent, neutral, incongruent) × 2 (proportion of word identification trials) × 2 (hemisphere) ANOVAs were considered including symmetrical electrode locations over regions where the modulations were expressed. When significant main effects and interactions were observed these effects were decomposed using two orthogonal contrast. The first contrast compared neural activity associated with incongruent trials to that associated with congruent and neutral trials and reflects the

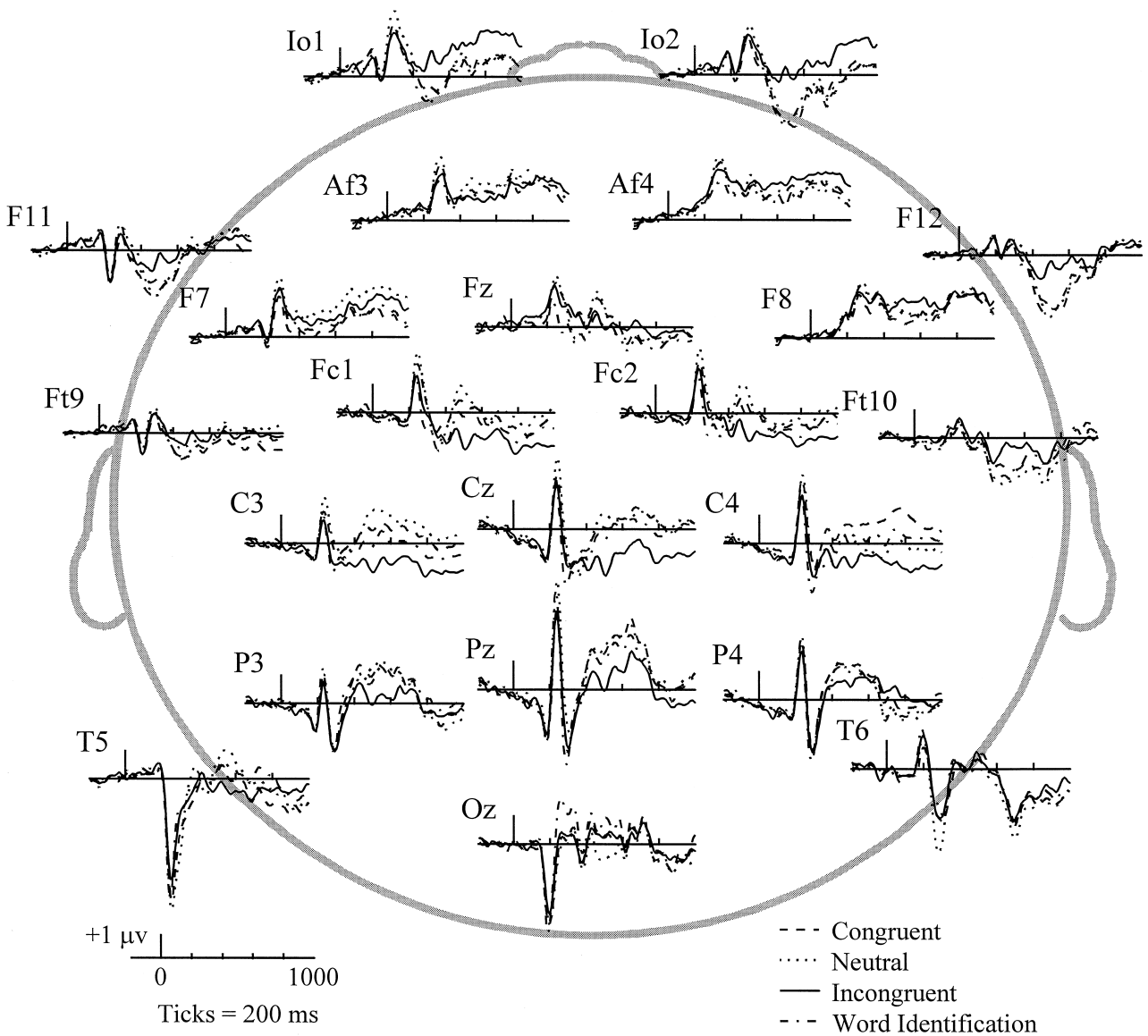

Fig. 1. Group average ERPs for selected electrode positions where modulations between the different Stroop trial types were observed collapsed over the proportion of word identification trials condition.

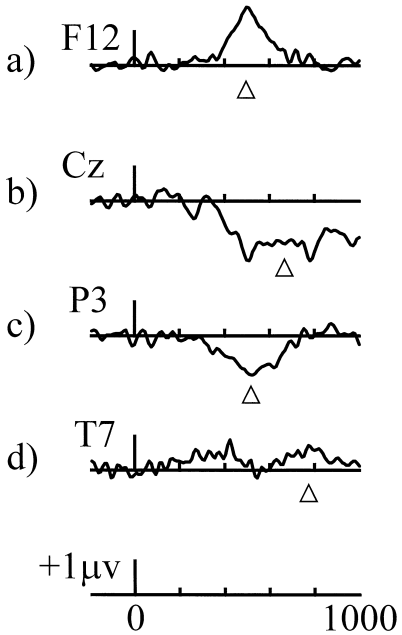

Fig. 2. Group averaged difference waves (incongruent–congruent) for four electrode positions demonstrating the four ERP modulations differentiating incongruent trials from other trial types: (a) phasic polar positivity, (b) fronto-central slow wave, (c) left parietal modulation peaking at 522 ms, and (d) left temporo-parietal positivity.

electrophysiological expression of the Stroop effect. The second contrast compared neural activity associated with congruent and neutral trials. This contrast was designed to determine the similarity of neural activity in these two conditions.

The first modulation was phasic in nature peaking at approximately 500 ms. This modulation was observed as a positivity over the lateral fronto-polar region, inverted in polarity over the fronto-central region, and was larger over the lateral polar regions than the fronto-central region (see Figs. 1, 2a and 3; Stroop condition × electrode interaction, $F(10,110) = 7.89,\ p < 0.002,\ \varepsilon = 0.24$). The first contrast was significant ($F(1,26.84) = 15.93,\ p < 0.001$) and accounted for 83% of the variance in this effect indicating there was a significant difference between incongruent, and congruent and neutral trials. The second contrast was not significant ($F(1,26.84) = 3.34,\ p > 0.07$), indicating that neural activity was similar on congruent and neutral trials. This modulation was also larger over the right fronto-polar and left fronto-central regions than the left fronto-polar and right fronto-central regions (Stroop condition × hemisphere × electrode interaction, $F(10,110) = 4.01,\ p < 0.04,\ \varepsilon = 0.25$). Again, the first contrast was significant ($F(1,26.84) = 8.77,\ p < 0.006$) and accounted for 99% of the effect variance, and the second contrast was not significant ($F(1,26.84) = 1.13,\ p > 0.28$).

The second modulation differentiating the ERPs elicited by incongruent trials from the ERPs elicited by congruent and neutral trials was a slow wave beginning at about 500 ms and persisting over the remainder of the trial. This modulation was observed as a negativity over the fronto-central region and positivity over the fronto-polar region (see Figs. 1 and 2b). This effect was larger over the right than left hemisphere (Stroop condition × hemisphere interaction, $F(2,22) = 5.73,\ p < 0.03,\ \varepsilon = 0.74$). The first contrast was significant ($F(1,16.28) = 8.32,\ p < 0.01$) and accounted for 72% of the effect variance indicating the presence of a Stroop effect in the slow wave. The second contrast was not significant ($F(1,16.28) = 3.18,\ p > 0.09$).

In Figs. 1 and 3 the distribution of the fronto-central slow wave appears to be more central in nature than the phasic fronto-polar positivity, not being observed at the lateral polar regions. This finding leads to the suggestion that different neural generators may contribute to these modulations. To explore this hypothesis further an analysis was conducted on the normalized mean voltages measured from 450–550 ms, the peak of the phasic positivity, and 600–700 ms. In this analysis, the Stroop condition × modulation × electrode interaction was significant ($F(10,110) = 4.01,\ p < 0.002,\ \varepsilon = 0.69$) consistent with the idea that different neural generators contributed to these modulations.

The third modulation reflected decreased positivity for the ERPs elicited by incongruent trials relative to the ERPs elicited on congruent and neutral trials and was distributed over the parietal region (e.g., P3; see Figs. 1, 2c and 3). This modulation peaked at approximately 522 ms. The amplitude of the modulation was larger over the left than right parietal region (Stroop condition × hemisphere interaction, $F(2,22) = 4.04,\ p < 0.05,\ \varepsilon = 0.80$). The significance of the first contrast was marginal ($F(1,17.52) = 4.06,\ p < 0.06$) and it accounted for 63% of the effect variance. The second contrast was not significant ($F(1,17.52) = 2.36,\ p > 0.13$). This modulation was largest at the P3/P4 electrode locations (Stroop condition × electrode interaction, $F(6,66) = 2.84,\ p < 0.05,\ \varepsilon = 0.52$). The first contrast was significant ($F(1,34.25) = 6.46,\ p < 0.02$) and accounted for 87% of the effect variance, while the second contrast was not significant ($F < 1$).

The fourth modulation reflected greater positivity for incongruent trials over the temporo-parietal region beginning at approximately 650 ms (see Figs. 2d and 3). The amplitude of this modulation was greater over the left than right hemisphere (Stroop condition × hemisphere interaction, $F(2,22) = 13.25,\ p < 0.002,\ \varepsilon = 0.85$). The first contrast was significant ($F(1,18.77) = 15.63,\ p < 0.001$) and accounted for 69% of the effect variance. The second contrast was also significant ($F(1,18.77) = 6.99,\ p < 0.02$) and accounted for 31% of the effect variance. This contrast reflected the greater positivity for neutral trials than congruent trials over this region.

The inclusion of word identification trials in the current design served two purposes: first, the inclusion of these trials was designed to increase the competition between color and word processing, thereby, enhancing the Stroop effect. Second, the inclusion of word identification trials

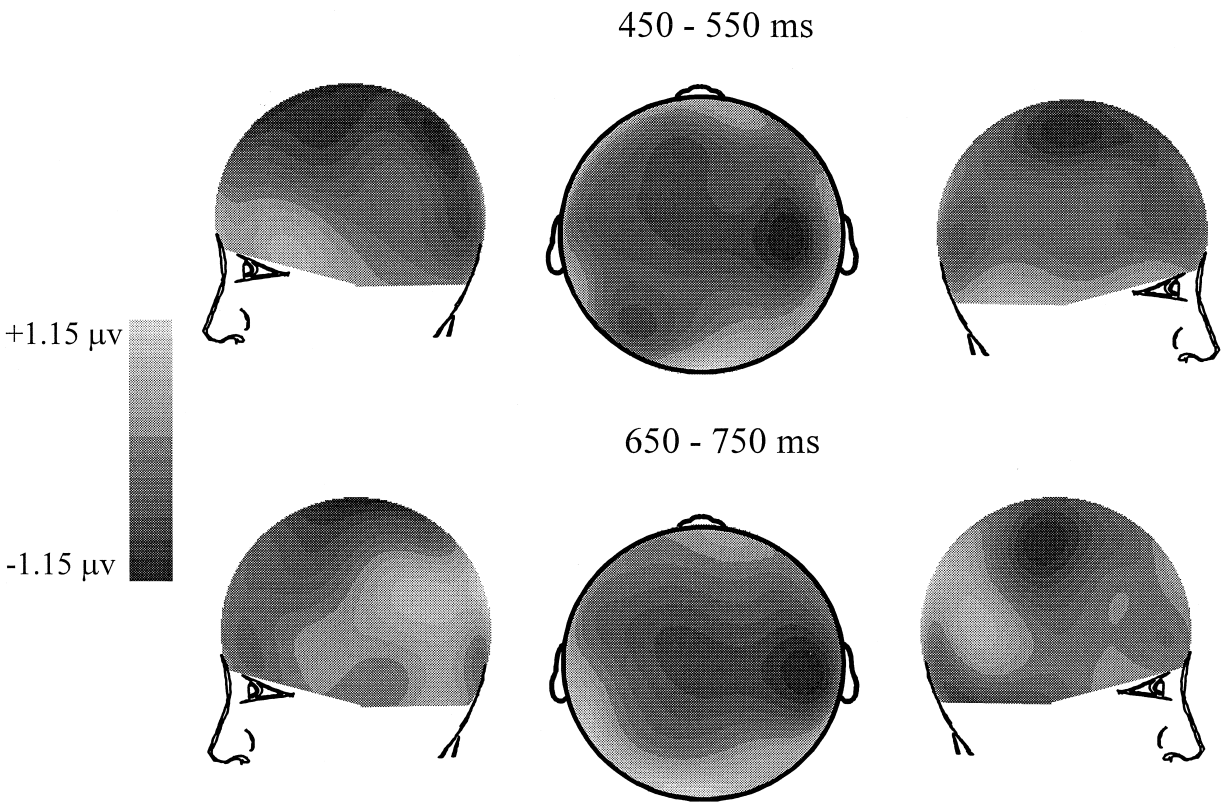

Fig. 3. Gray scale normalized difference voltage maps for incongruent minus congruent trials between 450 and 550 ms and 650 and 750 ms. Notice the area of positivity extending over left and right polar regions and negativity over the fronto-central region demonstrating the phasic polar positivity between 450 and 550 ms that is absent between 650 and 750 ms; the area of negativity over the left parietal region between 450 and 550 ms again absent between 650 and 750 ms, the fronto-central slow wave with its more right posterior distribution than the phasic polar positivity between 650 and 750 ms, and the left temporo-parietal modulation between 650 and 750 ms.

allows a comparison of the ERPs elicited when color information may guide a response, on neutral trials, and when word information may guide a response, on word identification trials. As noted earlier the ERPs elicited on neutral and word identification trials were generally quite similar. However, there was one notable exception to this general pattern reflecting increased positivity over the temporo-parietal region for the ERPs elicited on neutral trials relative to those elicited on word identification trials (see Fig. 4). This modulation was quantified in a 2 (task condition: neutral or word identification) × 2 (proportion of word identification trials) × 2 (hemisphere) × 4 (electrode) ANOVA performed on normalized mean voltage measurements taken between 400 and 600 ms post stimulus onset. This modulation was greater over the left than right hemisphere (task condition × hemisphere interaction, $F(1,11) = 11.34$, $p < 0.01$, $\varepsilon = 1.00$) and was largest at the T7 electrode location (task condition × hemisphere interaction, $F(3,33) = 4.75$, $p < 0.04$, $\varepsilon = 0.66$).

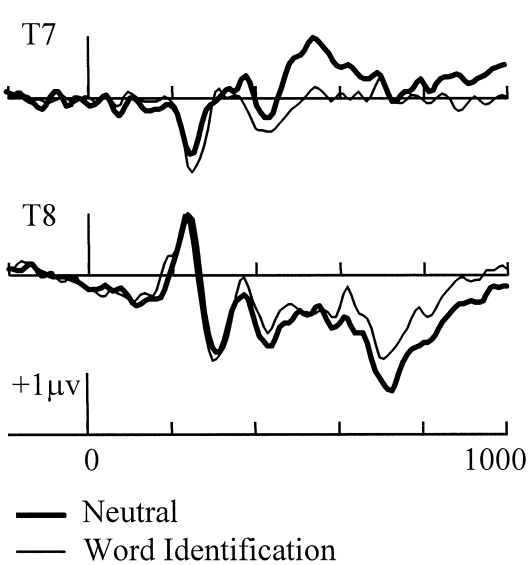

Fig. 4. Grand averaged ERPs for neutral and word identification trials demonstrating the left temporo-parietal positivity for neutral trials between 400 and 600 ms.

4. Discussion

In the study, a robust Stroop effect was observed in both the response latency and response accuracy data. As anticipated increasing the proportion of word identification trials served to enhance the fluency of word identification processes demonstrated by the faster word identification latencies in the 50% than 25% condition. Complementing

the behavioral data, four temporally and spatial distinct ERP modulations were observed reflecting differential neural processing for incongruent trials relative to congruent or neutral trials.

The first modulation represented a complex pattern of neural activity that peaked at 500 ms and reversed in polarity from the fronto-polar region to the fronto-central region. This modulation was larger over the fronto-polar region than the fronto-central region. It was also larger over the right fronto-polar and left fronto-central regions than the left fronto-polar and right fronto-central regions. Furthermore, this modulation was not observed at the electrode positions falling between the fronto-polar and fronto-central regions (see Fig. 1; F7, F8 and Af3, Af4). These findings suggest that the neural generators giving rise to this modulation may be located within the lateral prefrontal regions. This proposal is consistent with the findings of a PET study revealing enhanced rCBF in the right and left inferior frontal gyrus in an incongruent relative to a congruent task condition that was larger in the right than left hemisphere [21]. Given the time course and phasic nature of the effect we propose that this modulation indexes the activity of neural ensembles supporting the detection of incompatible color and word information on incongruent trials that serves to activate conflict resolution processes.

Contiguous with the peak of the phasic fronto-polar positivity was the onset of a slow wave that also reflected greater negativity over the fronto-central region and positivity over the fronto-polar region for incongruent trials relative to other trial types. This finding replicates and extends that of Rebai et al. [14]. In comparison to the phasic fronto-polar positivity the amplitude of this slow wave was greater over the fronto-central region than the fronto-polar region. It was also larger over the right than left hemisphere for the fronto-central region, and was distributed more along the midline at the fronto-polar region — not being observed at the lateral polar regions. As with the phasic fronto-polar positivity this modulation was not present at electrode positions located between the fronto-central and fronto-polar regions (see Fig. 1; Fz, Af3, and Af4), and was broadly distributed over the fronto-central region. This scalp topography suggests that the modulation reflects the activity of a relatively deep neural generator that may lie within the anterior cingulate or medial prefrontal cortex. This proposal is consistent with the findings of a number of PET and fMRI studies indicating that the anterior cingulate is activated to a greater extent on incongruent trials than congruent trials in the Stroop and similar tasks [1,3,15]. In these studies, the cingulate has been considered to be part of a conflict detection or resolution network that is active when multiple sources of information compete for access to a response selection system [3]. Based upon the results of the current study it seems that the fronto-central slow wave, possibly reflecting neural activity in the anterior cingulate, is more involved in conflict resolution than conflict detection as it persisted until a response had been made on incongruent trials.

For the left parietal modulation, the ERPs elicited by congruent, neutral, and word identification trials were virtually identical, while the ERPs elicited by incongruent trials were greatly attenuated between 400 and 600 ms. This finding is consistent with the recent proposal that similar conceptual level representations of word meaning are activated and guide a response on congruent and neutral trials [10] and in this case word identification trials. The decreased amplitude of the ERPs elicited by incongruent trials over the left parietal region reveals that this neural system is not as fully engaged and may even be suppressed when color and word information activate competing conceptual level representations [11].

At this point we have described a series of ERP modulations that reflect the neural events supporting task performance when a meaning-based conceptual level system can support responding, and the neural events involved in the detection and possible resolution of conflict between color and word information. However, a pattern of neural activity related to a correct response on incongruent trials when only color information can guide efficient task performance has not been identified. We propose that the left temporo-parietal modulation may reflect the activity of such a neural system that supports the processing of perceptual level color information. This modulation follows the time course of the fronto-central slow wave being most pronounced in the interval between the average response latency on congruent trials and incongruent trials. Therefore, this modulation would seem to emerge once incompatible color and word information has been detected indicating that information from the conceptual system cannot serve to guide a response. Also, a similar positivity was observed between neutral and word identification trials between 400 and 600 ms. The left temporo-parietal distribution of this modulation is consistent with the findings of a recent ERP study demonstrating that selective attention to color enhanced the amplitude of ERPs over the same region in a quite different task [8]. Also, enhanced rCBF has been observed in the left inferior parietal region when comparing incongruent and neutral trials in the Stroop task [1] and rCBF related to selective attention to color in the ventromedial occipital cortex is greater in the left than right hemisphere [6]. Together, the fronto-central slow wave and temporo-parietal positivity seem to reflect the interaction of neural systems that serve to enhance the activation of perceptual level color information that can guide a response when color and word information activate incompatible conceptual level representation(s) on incongruent trials.

The findings of the current study are generally consistent with dual-pathway models of the Stroop task [5,12]. We identified a number of ERP modulations reflecting differential neural activity when the word pathway could

support task performance on congruent and word identification trials and when the color pathway could support task performance on incongruent trials. The ERPs elicited by congruent, neutral, and word identification trials were quite similar indicating that similar neural processing supported task performance in each of these conditions. Based upon traditional dual-pathway models of the Stroop task, the similarity between the ERPs elicited by word identification and neutral trials was somewhat surprising as these models would postulate that the word pathway is not involved in neutral trials. However, these data are consistent with a recent proposal suggesting that similar conceptual level representations (e.g., the semantic meaning of the color and word red) guide task performance on congruent and neutral trials [10], and in this case word identification trials. The ERP modulations associated with incongruent trials give rise to two interesting proposals in relation to models of the Stroop task. First, the two frontally distributed modulations may indicate that conflict detection and conflict resolution are separate processes supported by different neural generators located within the lateral prefrontal and anterior cingulate regions, respectively. Second, increased activity over the left temporo-parietal region, reflecting processing in the color pathway, was observed over the same interval as the fronto-central slow wave. This finding leads to the suggestion that conflict resolution processes serve to modulate the color pathway on incongruent trials [5]. Furthermore, these findings indicate that modulation of the color pathway is a dynamic process arising with the detection of incompatible color and word information. These findings seem most consistent with a model of the Stroop task where perceptual level color and word pathways converge on a common conceptual level system that supports task performance on congruent, neutral, and word identification trials. On incongruent trials the activity of this conceptual level system may be attenuated or suppressed as suggested by the decreased neural activity observed over the left parietal region for incongruent trials [11]. Also, on incongruent trials, conflict detection (phasic fronto-polar positivity) and resolution processes (fronto-central slow wave) may be activated to modulate processing of information in the perceptual color pathway. Therefore, the time required to activate the color pathway to a level sufficient to guide a response gives rise to the increased response latency on incongruent trials (i.e., the Stroop effect).

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