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REPUBLIC OF TURKEY

HACETTEPE UNIVERSITY

GRADUATE SCHOOL OF HEALTH SCIENCES

COMPARATIVE INVESTIGATION OF EVENT-RELATED POTENTIALS ELICITED BY THE STROOP EFFECT AND EVENT-RELATED POTENTIALS ELICITED BY COLOR CONFLICT

Gamze DOĞAN

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Supervisor: Assoc. Prof. Dr. Babur ŞAHİNOĞLU

This thesis study has been approved and accepted as a Master dissertation in "Biophysics Program" by the assesment committee, whose members arelisted below, on 05/08/2019.

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07 Ağustos 2019

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YAYIMLAMA VE FİKRİ MÜLKİYET HAKLARI BEYANI

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Tezin kendi orijinal çalışmam olduğunu, başkalarının haklarını ihlal etmediğimi ve tezimin tek yetkili sahibi olduğumu beyan ve taahhüt ederim. Tezimde yer alan telif hakkı bulunan ve sahiplerinden yazılı izin alınarak kullanılması zorunlu metinlerin yazılı izin alınarak kullandığımı ve istenildiğinde suretlerini Üniversiteye teslim etmeyi taahhüt ederim.

Yükseköğretim Kurulu tarafından yayınlanan ***"Lisansüstü Tezlerin Elektronik Ortamda Toplanması, Düzenlenmesi ve Erişime Açılmasına İlişkin Yönerge"*** kapsamındatezim aşağıda belirtilen koşullar haricince YÖK Ulusal Tez Merkezi/ H.Ü. Kütüphaneleri Açık Erişim Sisteminde erişime açılır.

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06/08/2019

Gamze DOĞAN

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i "Lisansüstü Tezlerin Elektronik Ortamda Toplanması, Düzenlenmesi ve Erişime Açılmasına İlişkin Yönerge"

(1) *Madde 6. 1. Lisansüstü tezle ilgili patent başvurusu yapılması veya patent alma sürecinin devam etmesi durumunda, tez **danışmanının** önerisi ve **enstitü anabilim dalının** uygun görüşü üzerine **enstitü** veya **fakülte yönetim kurulu** iki yıl süre ile tezin erişime açılmasının ertelenmesine karar verebilir.*

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Tez **danışmanının önerisi ve **enstitü anabilim dalının** uygun görüşü üzerine **enstitü** veya **fakülte yönetim kurulutarafından karar verilir.***

ETHICAL DECLARATION

In this thesis study, I declare that all the information and documents have been obtained in the base of the academic rules and all audio-visual and written information and results have been presented according to the rules of scientific ethics. I did not do any distortion in data set. In case of using other works, related studies have been fully cited in accordance with the scientific standards. I also declare that my thesis study is original except cited references. It was produced by myself in consultation with supervisor Assoc. Prof. Dr. Babur ŞAHİNOĞLU and written according to the rules of thesis writing of Hacettepe University Institute of Health Sciences .

Gamze DOĞAN

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This thesis is especially dedicated to my family Meryem, Metin and Yasin DOĞAN, without their endless support and patience this study would not have been possible.

ABSTRACT

DOĞAN, G., Comparative Investigation Of Event-Related Poteniıals Elicited By The Stroop Effect And Event-Related Potentials Elicited By Color Conflict. Hacettepe Unıversity Graduate School Of Health Sciences, Biophysics Master Thesis, Ankara, 2019. Main interest of cognitive and experimental psychology is the human behavior system. Cognitive control is the key aspect of this system and investigating its neural mechanisms is an important objective method in such studies. One of the prominent methods of studying cognitive control is the Stroop effect. The studies we have met in the literature used different sets for congruent and incongruent stimuli, which could cause habituation effects at various ERP components. The aim of this thesis was to examine the cognitive control in the context of the Stroop task by recording event-related potentials with a standard oddball paradigm. Amplitudes and latencies of the seven ERP components were examined in the averaged data and compared between stimulus types. N1 was not different for four stimuli in terms of amplitude and latency. Latencies of P2, N2 and P3b were significantly longer for incongruent words than that of incongruent bars. These findings suggest that Stroop conflict is processed at early stages of stimulus evaluation. Incongruent bars and words enhanced significantly longer and larger P3b responses than congruent bars and words, respectively, as expected from a standard oddball paradigm. N450-LPC complex was recorded only for incongruent words as a reflector of post-perceptual mechanisms. Among the stimulus types, only congruent bars did not evoke an LPN response since they did not have any semantic dimension or a color conflict.

Key Words: Cognitive control, ERPs, Stroop effect, Oddball paradigm.

ÖZET

DOĞAN, G., Stroop Etkisi İle Ortaya Çıkan Olay-İlişkili Potansiyellerin Renk Çelişkisi İle Ortaya Çıkan Olay-İlişkili Potansiyellerle Karşılaştırmalı İncelenmesi. Hacettepe Üniversitesi Sağlık Bilimleri Enstitüsü, Biyofizik Programı Yüksek Lisans Tezi. Ankara, 2019. Bilişsel ve deneysel psikolojinin temel ilgi alanı, insan davranış sistemidir. Bilişsel kontrol bu sistemin temel özelliğidir ve bu özelliğin nöral mekanizmalarını incelemek bu tür çalışmalarda önemli ve objektif yöntemdir. Bilişsel kontrolü incelemek için önde gelen yöntemlerden biri de Stroop etkisidir. Literatürde karşılaştığımız çalışmalar, çeşitli Olaya İlişkin Potansiyel (OİP) bileşenlerinde alışkanlık etkilerine neden olabilecek, uyumlu ve uyumsuz uyaranlar için farklı setler kullanılarak gerçekleştirilmiştir. Bu tezin amacı, bilişsel kontrolü, Stroop testi bağlamında, standart *oddball* paradigması ile OİPleri kaydederek incelemektir. Yedi OİP bileşeninin genlik ve latansları, ortalaması alınmış verilerde incelenmiş ve uyaran tipleri arasında karşılaştırılmıştır. N1 genliği ve latansı dört uyaran için farklı değildi. P2, N2 ve P3b latansları uyumsuz kelimeler için uyumsuz çubuklarınkinden anlamlı olarak daha uzundu. Bu bulgular, Stroop çelişkisinin uyaran değerlendirmesinin erken aşamalarında işlendiğini göstermektedir. Uyumsuz çubuk ve kelimelerin P3b cevapları, standart bir *oddball* paradigmasından beklenildiği gibi, sırasıyla uyumlu çubuk ve kelimelerden anlamlı olarak daha uzun ve daha büyüktü. N450-LPC kompleksi algı sonrası mekanizmaların bir yansıtıcısı olarak sadece uyumsuz kelimelerde kaydedildi. Uyaran çeşitleri arasında, sadece uyumlu çubuklar, herhangi bir anlamsal boyuta veya renk çelişkisine sahip olmadıkları için LPN yanıtı oluşturmadı.

Anahtar Kelimeler: Bilişsel kontol, OİP, Stroop Etkisi, Oddball Paradigması.

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1.INTRODUCTION

Behavioral control is one of the most distinctive features of the human cognitive system. It enables humans to attend to relevant information about the stimuli that we encounter in our everyday life and to resolve the conflict if an inconsistency exists between the dimensions of a stimulus. Cognitive control studies are generally based on the automatic-control processing approach and Stroop task is one of the classic tasks to investigate these processes in terms of conflict between these two processes (1). In a standard Stroop task, participants are to name the font-color of a color-word, the controlled process, and not to read the word, inhibition of the automatic process. The conflict between the word and the font color (incongruent condition) leads a delay in response time (RT) as compared to a neutral stimulus (control condition) and the "Stroop effect" refers to the longer RT in the incongruent condition.

In Stroop studies, Event-Related Potentials (ERPs) have been used to reveal if the color-word interference is initiated early at stimulus processing or later at the response selection stage (2). A considerable amount of literature has been published by numerous modifications of the color-word Stroop task. It has been reported that proportion of the incongruent stimuli in the presented sequence and the response type requested from subjects affected the degree of the Stroop effect (3-5). Although extensive research has been carried out on Stroop effect no single study exists which used a standard oddball paradigm.

This thesis was designed to investigate the Stroop effect by a standard oddball paradigm and we hypothesized that since our paradigm prevented the habituation effect on the incongruent stimuli, it provided us to examine the full effect of the color-word conflict in cognitive processes.

2.LITERATURE REVIEW

2.1. Automatic and Controlled Processes

As in all living beings, the behavior of humans is based on the stimulus-response relationship. The sensory information received from the environment is encoded and transmitted to the central nervous system for evaluation to give an appropriate response. In the information-processing system, all cognitive processes take place either automatically or controlled; or with the collaboration of both processes. Automatic processes require none or little conscious effort and are usually developed with practice. However, the controlled processes involve short-term memory mechanisms, therefore they require conscious effort for their execution. Controlled processes are relatively slow compared to automatic processes. If a task involves a competition between these two processes, there arises the possibility of the automatic response overriding the controlled; and inevitably the response would be slower or the possibility to make an error would increase (6).

When a person encounters a two-dimensional stimulus contradicting with each other in a certain way and is forced to make a choice between them, her/his reaction time is slowed down; because the controlled action must first overcome the tendency of giving an automatic reaction in order to give the correct response. This is an example of interference, a time-lag caused by the competing functions in the cortex.

Cattell (7) conducted one of the earliest psychological experiments in 1886 and reported that saying “horse” to a picture of a horse or “blue” to a blue colored patch required more time compared to reading the words “horse” and “blue”. He explained this situation as follows; since we associate words and letters frequently; reading becomes automatic, however naming objects and color required a voluntary effort. Cattell’s automatic/voluntary (controlled) distinction paved the way for the Stroop Effect; one of the most effective and widely known experiments in both cognitive and experimental psychology (1). Amongst the numerous paradigms used to examine the nature of automatic and controlled processes, the most prominent is the Stroop task (8).

2.2. The Stroop Effect

In 1935, John Ridley Stroop compared the RTs of naming the colors of incongruent stimuli (a color word printed in a mismatched ink color such as “BLUE” displayed in red ink) and colored patches. Incongruent stimuli consist of two dimensions; a word dimension and a color dimension whereas colored patches only have a color dimension. When presented with an incongruent stimulus, individuals process both dimensions of the stimulus despite being asked only to name the font color without reading it. He showed that naming the colors of incongruent stimuli took 47 s longer than colored patches The difference between the response times to these two types of stimuli is defined as the Stroop interference effect (or the Stroop effect).

Since Stroop's milestone study, color-word Stroop test and its various forms have become the efficient tools for increasing our understanding of the selective attention, interference, automaticity, cognitive flexibility, and inhibition in experimental psychology (8,9).

A core assumption of virtually all theoretical accounts is that the Stroop interference effect is a result of the conflict between automatic and controlled processes. Posner and Snyder (10) have assumed that word reading was automatic while color naming was controlled and when the responses of these two processes contradict each other, one of them is slowed down, in other words, an interference occurs.

In the Stroop test, above all, the automatic process of word-reading should be suppressed, only when this automatic process is suppressed can the controlled process of naming the color could occur.

Previous studies have shown that the tendency to read a word and to evaluate the meaning of it are difficult to suppress even if one is instructed not to do so since reading is an automatic process (11-13). Objective response time measurements have clearly revealed that naming the color of the incongruent stimulus requires more time than that of the congruent stimulus (8).

Stroop studies are generally in the form of speed reading of congruent and incongruent words written on cards and measuring reaction times (1). With the introduction of computers in the scientific researches, the cards were replaced by the screens; subject's reactions are measured by pressing a button, according to the font-color of the congruent or incongruent words they see on the screen (5). Whether it is a card or a screen reading, such measurements are mostly based on psychophysics. Measurement of galvanic skin resistance, cortical and cardiac electrical activity of subjects provide an objective evaluation of the Stroop effect. However, the neural mechanisms in resolving the conflict have not been clearly revealed yet. At this point, ERPs come into use in the Stroop effect studies since they provide a high temporal resolution for a comprehensive understanding of the neural mechanisms underlying the Stroop effect (2).

2.3. Event-Related Potentials

Transient electrical activities recorded from the brain as a result of the presentation of a controlled sensory stimulus, usually acoustic or visual, to the subject under laboratory conditions are called Evoked Potentials (EPs). An EP is the response of the subject to the physical properties of the stimulus (such as intensity, color, frequency, etc.). However, if a stimulus is of importance to the subject, in other words, if the stimulus has a psychological dimension, additional electrical activities are also recorded and called Event-Related Potentials (ERPs). Like EPs, ERPs are the field potentials that are due to the synchronized postsynaptic activity of a neuron population and reflect the time-locked EEG changes to cognitive, sensory, and motor events (14-16). ERPs allow the neuroscientist to investigate the cognitive processes from before the onset of a stimulus until after an appropriate response is given, and from the point of view of temporal resolution they offer the best information in investigating the timing of cognitive processes. In the literature, the N1 and P2 are called the early (sensory) components of ERPs and they are enhanced in response to the physical properties of a stimulus having a psychological dimension. These components are generally followed by N2, P3, N4, LPC and LPN waves, which are categorized as late (cognitive) components since they are sensitive to psychological dimensions of a stimulus. The main components of a standard ERP complex are given in Figure 1. The temporal information provided by ERPs and interactions between ERPs are helpful to enlighten the neural mechanisms underlying the cognitive processes (17).

Oddball paradigm has been introduced in the cognitive studies for the first time by Squires et al. (18) in an auditory-ERP study and since its discovery, this paradigm and its several forms have also being used in visual studies (19). A standard oddball paradigm is based on the technique of using standard and deviant stimuli within a single session; in such a way that deviant stimulus, usually 10% of the total stimuli, distributed among the standard stimulus in a random manner. The deviant stimulus differs from that of the standard stimulus in a certain aspect such as color, size, frequency, etc. The subject is asked to attend these deviant stimuli; thus this stimulus becomes an important factor for the subject, that is, the stimulus bears a psychological dimension.

However, we have seen that such an ERP strategy has not been fully implemented in the ERP studies on Stroop paradigm (20-23). In these studies, different sessions were generally used for congruent and incongruent stimuli. The purpose of this study was to examine the Stroop effect with a standard ERP strategy.

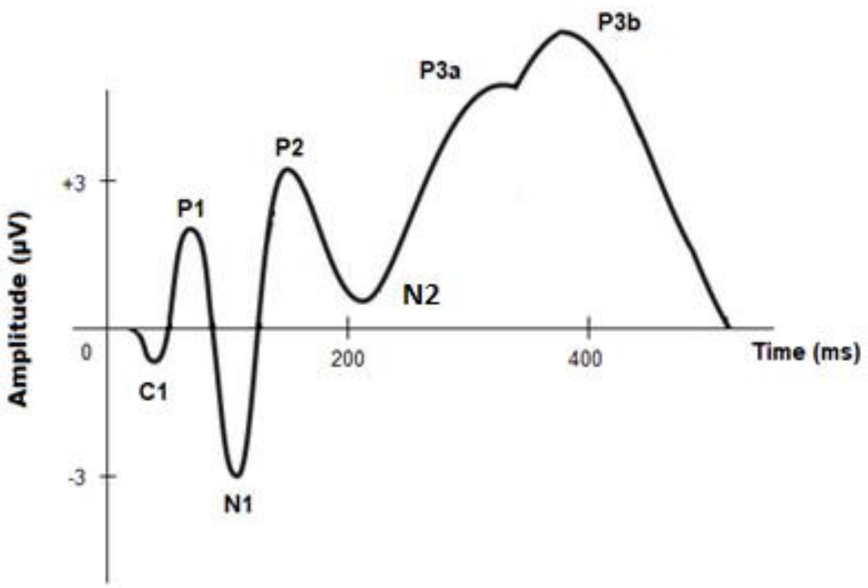

Figure 2.1. An ERP complex showing its typical components.

2.3.1. N1

Our nervous system, besides other sensory modalities, processes a myriad of visual-sensory stimuli in everyday situations and processing stages differs with the "expectancy of the stimuli". It has been shown that reaction time to expected (attended) visual stimuli was shorter than the reaction time to unexpected (unattended) visual stimuli (24). In addition to psychophysical studies, researches by ERPs have also been conducted to investigate the difference between attended and unattended stimuli processes. A negative response, called N1, was reported to be greater when stimuli are presented at attended locations than stimuli presented out of spatial attention (25). This study suggests that the early stages of visual processing are affected by attention. N1 can be elicited by both auditory and visual stimuli over multiple cortical areas such as occipital, parietal, and frontal areas in a latency range from 150 -200 ms (26,27).

2.3.2. P2

N1 wave is followed by a positive-going wave peaking around 200 ms after stimulus onset over parieto-occipital areas (28). P2 has been associated with both basic-level sensory processes such as evaluation of size, color, luminosity, etc. of the stimulus; and higher-level cognitive operations such as attention or language context (29). Detecting a simple target or complex visual stimulus, identifying pictures or reading words enhanced the P2 wave and the word-evoked P2 is called Recognition Potential (RP) (30).

It has been reported that meaningful words evoked larger RP than a random sequence of letters and response time is longer for difficult words compared to easy words (31-34). P2 may reflect neural processes that occur when a visual stimulus is compared with an internal representation or expectation in memory or language (35). Taking into account of all these, P2/RP can be considered as the first indicator of higher cognitive functions and a convenient tool in assessing cognitive evaluation time.

2.3.3. N2

N2 is a negative ongoing ERP wave which occurs in 200 – 350 ms time range after a deviant stimulus is presented, and it is thought to be reflecting the stimulus evaluation processes since it is observed before a motor response is made (36). It is also associated with language processing, contextual information and mismatch detection (37). Jackson et al. (38) have reported that N2 amplitude was attenuated with repetitions suggesting that this wave is sensitive to habituation. Several studies have investigated the sub-components of N2 such as N2a, N2b, N2c, and N2pc (39, 40). They have been characterized according to the type of stimulus they were sensitive to and/or to their distribution over the scalp. Amongst them, N2b has a fronto-central or central topography and it is associated with color selection and general detection processes (39, 41). Because this component is also evoked in focal-attention required tasks, it has been suggested as an indicator of the response conflict and controlled processes (39, 42, 43). In the flanker task, which has been accepted as an appropriate tool to investigate conflict mechanisms, in which only one-dimensional stimulus has been used, the N2 observed was larger compared to that of the congruent stimulus (44, 45).

2.3.4. P3

The most featured and most studied ERP component was described by Sutton et al. (46) in 1965. They reported a relatively larger “late positive component” (P3) was evoked to target or expected stimulus. The P3 wave is a positive deflection occurring from 250 to 500 ms after stimulus onset and it is most pronounced at central electrode sites (47, 48). The P3 is most clearly observed during the oddball paradigm. In this paradigm, the low-probability (target) stimuli are randomly scattered between the high-probability (non-target) stimuli and subjects are asked to focus their attention on the low-probability stimuli. The amplitude of the P3 is larger to the low-probability stimuli than that of the high-probability stimuli (49). The sensitivity of the P3 to psychological aspects of stimuli and its independence from physical characteristics of stimuli (50) enables to investigate the mechanisms related to selective attention (51). It has been reported that the P3 latency is proportional to discriminability of low-probability stimuli from its high-probability counterparts, therefore P3 latency is an appropriate tool to determine the stimulus evaluation time and to separate evaluation stage from response selection (52).

In literature, two P3 subcomponents have been described (48). The first component is novelty P3 or P3a and the second component is classic P300 or P3b. P3a is evoked by attention or detection of novelty, on the other hand, it is also said to be produced independently of attention. It is frontocentrally distributed and reaches its maximum value in the 250 - 280 ms range after the stimulus onset. Although differentiated from P3b, its amplitude and latency may depend on the activities which also affect its neighboring component P3b (53).

The P3b is evoked around 280 - 500 ms time range and its amplitude is maximal over the parietal regions of the scalp. When the subject directs her/his attention to the stimuli and when memory processes are involved in the stimulus evaluation a P3b is elicited (47, 54, 55, 51). On the other hand, Sutton et. al. (46) proposed that the P3b appeared when an uncertainty in the stimulus was resolved, in other words, the difficulty in eliminating a conflict in the stimulus is reflected as an increase in its latency. Therefore the P3b latency can be interpreted as an index of uncertainty resolution. The theories proposed by Donchin (56) and Kok (57) has one thing in common: P3b is evoked as the result of making a decision about whether a stimulus matches with an internal representation of a specific category. This process of categorization involves mechanisms such as attention, perception and working memory.

P3 wave has been the most powerful tool to investigate the cognitive abilities such as intelligence, selective attention, memory, and neurological or psychiatric diseases since its discovery (58). In the studies investigating the inhibition processes or selective attention mechanisms through the Stroop effect, P3 is the most preferred ERP component since the first Stroop-ERP research conducted by Duncan- Johnson and Kopell (59). ERP findings in further studies reported no significant latency difference between congruent and incongruent stimuli. It has been concluded that the Stroop effect occurs during the response production stage, not in the stimulus evaluation stage (2).

2.3.5. N450-LPC Complex

In Stroop studies, two relatively late components were reported which were sensitive to incongruency, namely N450 and LPC (60-62). In Stroop-ERP studies, a more negative wave occurring within 300-550 ms after stimulus onset for the incongruent stimuli as compared to congruent or control stimuli has been reported over the fronto-central regions (63-66). N450 has been considered as reflecting the inhibition mechanisms of the neural system during evaluating the incongruency (63).

The second Stroop-related ERP wave in this complex is LPC (also labelled as Slow Potential). It is a positive-going component peaking between 600-900 ms post-stimulus (20, 60, 64). LPC has been reported to be sensitive to color-word conflict since it was more positive to incongruent stimulus than to congruent stimulus in Stroop studies. Liotti et al. (60) suggested that this late positivity may be associated with semantic re-activation of the word.

In the light of these studies, N450 and LPC have been proposed to reflect the stimulus conflict and/or the response selection during the color-word conflict processing (63, 61, 67-69).

2.3.6. LPN

In the experimental paradigms that subjects were required to retrieve contextual information to accomplish the task, a negative deflection recorded between 600-2000 ms is called the Late Posterior Negativity (LPN) (70). Various kinds of experimental paradigms such as; item recognition and lexical decision revealed enhanced LPN (71). Since different paradigms, stimuli types (word, voice, picture), and tasks evoked LPN, there is no consensus about its function. One of the theories about the LPN suggested that it is associated with the retrieval of perceptual information from the stimulus context such as color (72).

3.PARTICIPANTS and METHOD

3.1. PARTICIPANTS

The study protocol was approved by the Hacettepe Univesity Faculty of Medicine Ethics Committee (Decision Number: GO 17/118-49). This study was carried out in the EEG-1 Laboratory of the Biophysics Department of Hacettepe University Faculty of Medicine. 19 healthy volunteers (8 females) with a mean age of 26.68 ± 4.56 participated in the study. Volunteers have been informed that they can terminate the study at any time. A signed consent form was obtained from all the volunteers (see Appendix-3). The inclusion criteria of the participants are as follows: having at least a high school education; no neurological or psychological disorders; normal or corrected to normal vision; no achromatopsy and no fear of darkness or claustrophobia.

3.2. METHOD

3.2.1. Stimulus

As mentioned earlier, the Stroop paradigm is based on word-color conflict. The stimulus in a Stroop paradigm consists of a color-word (e.g., RED) and the color of the font the word is written, that is, the stimulus used in such a paradigm is a two-dimensional stimulus, namely a meaning and a color. On the other hand, the bar stimulus, which is used as the control in this thesis has only the color dimension. Therefore, when the subject is met with an incongruent bar, she/he has to deal with the change of color, only. However, for a word stimulus, the subject, besides dealing with a color change, she/he also has to overcome the color-word conflict to give the appropriate response. In this thesis, we based our paradigm to investigate the Stroop Effect by examining the differences between the parameters of the responses to the incongruent bar and word stimuli.

Our Stroop paradigm was developed by using the Psychtoolbox-3 (PTB-3) software which ran under a licensed MATLAB program (R2016a). In this study, four Turkish color-words, in upper-case letters, written in bold Arial fonts with a font size of 40 were used: "KIRMIZI" (red), "MAVİ" (blue), "YEŞİL" (green) and "SARI" (yellow). The RGB color codes chosen for these colors were "255,0,0" for red; "1,152,255" for blue; "58,198,58" for green and "255,219,1" for yellow. The color codes were chosen in such a way to ensure the subjects to see the words and bars clearly over a black background. The frame rate of the screen used was 60 Hz.

The horizontal angles that hold on the retina when subjects sat 1 m away from the screen were 4°48′, 3°09′, 3°47′, 3°02′ for KIRMIZI, MAVİ, YEŞİL, and SARI respectively; the vertical angle, 55′, being the same for all words. For the control session, four bar stimuli which bear no contextual meaning and having the colors of the four words were prepared (e.g., green bar instead of the word YEŞİL, i.e., green). The same dimensions were used for the bars which corresponded to the words they replaced. A small grey circle, holding an angle of 34.4′, used as a fixation point, was continuously visible on the center of the screen to discourage the eye movements.

Participants were presented with four consecutive sessions; each session consisted of word or bar stimulus. For the word session, the word “KIRMIZI” written in red fonts was used as the congruent word stimulus and the word “KIRMIZI” written in blue fonts was used as the incongruent word stimulus. The word “YEŞİL” in green fonts and the word “YEŞİL” in yellow fonts were used as congruent and incongruent stimuli, respectively. As for the bar sessions, the same paradigm was used; red colored bar vs. blue colored bar and green colored bar vs. yellow colored bar. The stimulus sequences displayed to the subjects are given in Figure 3.1. Participants were required to vocalize the color of the bars and words on the screen and to ignore the meaning of the word, that is, not to read the word. To familiarise with the task, participants underwent two training sessions of 25 trials.

Figure 3.1. Stimulus sequences used in the study.

In each session, the ratio of the number of incongruent stimuli to the total number of stimuli was 1:10, in line with a standard oddball paradigm. The incongruent stimuli were interspersed between the congruent randomly. For every session, forty-five congruent and five incongruent stimuli were used. The pre-stimulus interval was 200 ms, and the stimulus and blank interval durations were each 750 ms.

The reason for using an oddball paradigm is that the studies, which used separate sessions for congruent (standard) and incongruent (deviant) stimuli, reported a habituation effect causing a decrease in N2 and P3 responses (38, 47). Therefore, in order to eliminate this habituation effect, which arises by the repetitive stimulus, we have chosen to intermix congruent and incongruent stimuli in one session, in line with a standard oddball paradigm. In this manner, the subject is met with a word-color conflict stimulus infrequently and gives a full response. However, our paradigm differs from a standard oddball paradigm in one point: subjects are required to attend to all stimuli, not to attend only to incongruent ones.

3.2.2. EEG Recording

Subjects were taken into a dimly lit sound-attenuated and electrically shielded room and sat on a comfortable chair 1 m away from the screen. Three gold electrodes were placed on the scalp of the subjects at Fz, Cz and Pz positions according to the 10-20 international system. All electrodes were referenced to A1/A2 and subjects were grounded by another electrode placed on their forehead. Electrode impedances were kept below 5 kΩ. EEG signals were recorded using the MICROMED SD plus Polygraphic Acquisition System and digitized at a 250 Hz sampling rate with a band-pass of 0.1-100 Hz and a 50 Hz notch filter.

For analysis, epochs were visually inspected for artifacts and the artifact-free epochs were averaged with the MICROMED software. The ERPs were averaged off-line from 200 ms before to 12000 ms after stimulus onset. The peak latencies and the amplitudes of the ERP waves; and the time-positions of these peaks within the time-windows where they were expected to appear were determined by a code written in Matlab. Peak amplitudes of the waves were measured with respect to the averaged EEG baseline in the 200 ms pre-stimulus period. Then the averages and the standard errors of the mean amplitudes and latency were calculated.

3.2.3. Statistical Analysis

Latencies and amplitudes of the ERPs were analyzed with a licensed IBM SPSS Statistics 23 software package. Data were expressed as means ± standard error (SE). A one way ANOVA was conducted on the ERP latency and amplitude measures for the following factors; color (red-blue, green-yellow), electrode derivations and stimulus type (bar-word, congruency-incongruency) and ANOVA followed by the Scheffe multiple-comparison posttest. A value of $p < 0.05$ was considered statistically significant.

4. FINDINGS

Since we have found no significant difference between the parameters of the ERP components recorded for both red-blue and green-yellow sessions, we have combined data of these two sessions within the one data.

We summarise which ERP components evoked by congruent and incongruent stimuli types in Table 4.1. Mean amplitudes and latencies of ERPs in response to all stimulus types are given in Appendix-1.

Table 4.1. The presence of waves according to stimulus types**.**

	N1	P2	N2	P3a	P3b	N450-LPC	LPN
CB	+	-	-	+	+	-	-
CW	+	-	-	+	+	-	+
ICB	+	+	+	-	+	-	+
ICW	+	+	+	-	+	+	+

C: Congruent, IC: Incongruent, B: Bar, W: Word.

The ERP responses to bars and words for congruency and incongruency conditions are given in Figure 4.1.

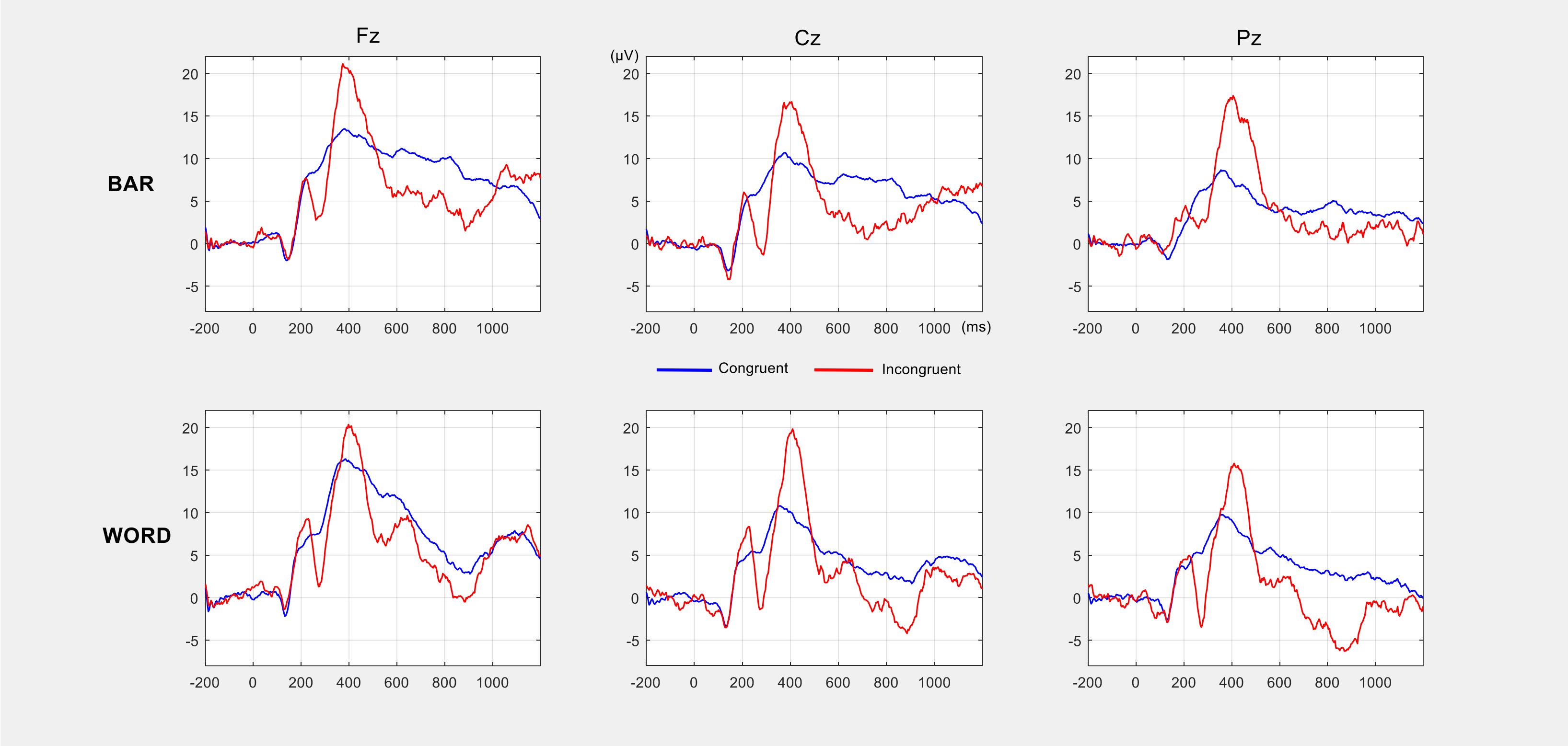

Figure 4.1 Grand-average ERPs at Fz, Cz, Pz for the congruent/incongruent conditions in response to bars and words.

Figure 4.2 and Figure 4.3 give the ERP responses of bars and words for congruent and incongruent stimuli types, respectively.

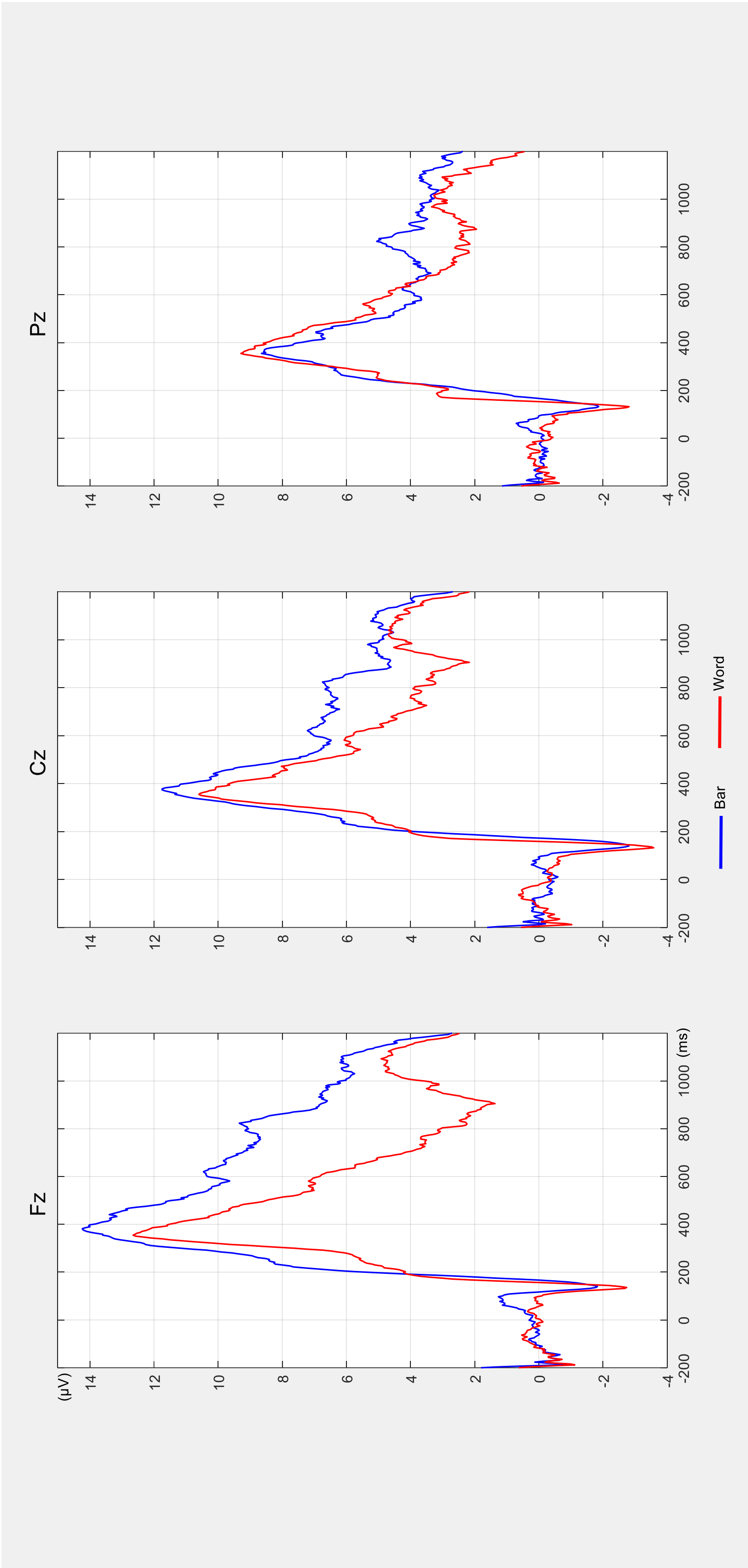

Figure 4.2. Grand-average ERPs at Fz, Cz, Pz for the congruent bars and words.

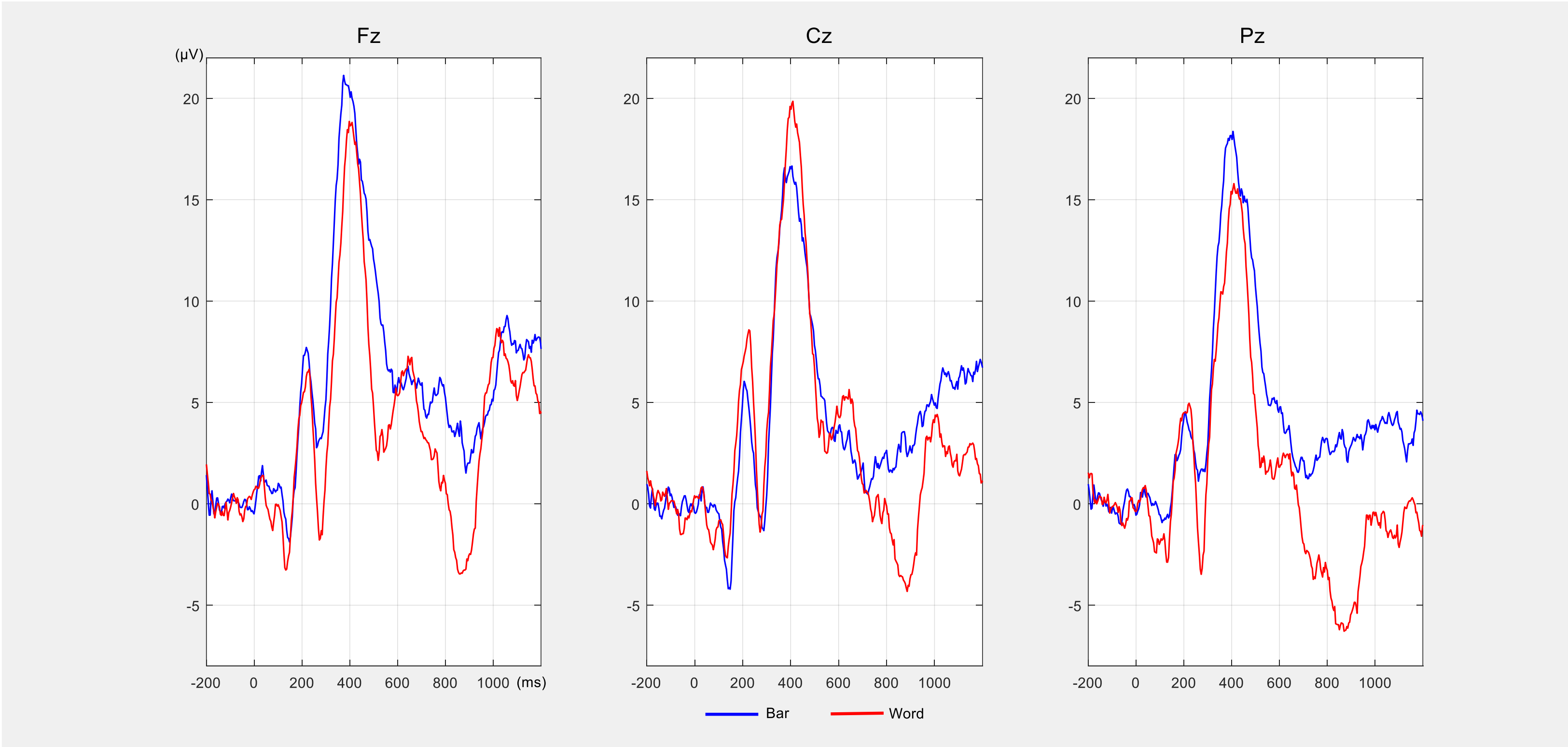

Figure 4.3. Grand-average ERPs at Fz, Cz, Pz for the incongruent bars and words.

4.1. N1

The latency and amplitude of the N1 did not manifest any significant difference for bar-word and congruent –incongruent and electrode site interactions.

4.2. P2

Congruent stimuli did not evoke any P2 response. The amplitude and latency of P2 did not show significant difference between electrode sites. The amplitudes of P2 did not manifest any significant difference betwen incongruent bar and word, whereas the latency of the word was longer than the latency of the bar significantly at Fz ($F(1,25) = 9.31$, $P < 0.05$), Cz ($F(1,27) = 11.42$, $P < 0.005$), Pz ($F(1,22) = 5.90$, $P < 0.05$).

4.3. N2

Congruent stimuli did not evoke any N2 response. No statistically significant difference was found in terms of N2 amplitude and latency for incongruent stimuli between electrode sites. N2 amplitude did not differ significantly between incongruent bars and words. The analysis of N2 latency at the Fz ($F(1,20) = 5.45$, $P < 0.05$) and Pz ($F(1,21) = 5.93$, $P < 0.05$) electrode sites yielded a significant difference between incongruent bars and words with earlier peaks for bars than words.

4.4. P3

All stimulus types evoked P3b response, whereas P3a response was observed for only congruent stimuli. For congruent bars, latency of P3a at Cz was significantly earlier than Pz ($F(2,43)= 4.51$, $P < 0.05$). No significant difference was found between the electrode sites for both congruent and incongruent stimuli in terms of P3b parameters. Incongruent bars evoked significantly longer (at Fz, $F(1,19) = 10.94$, $P < 0.00$); Cz, $F(1,18) = 11.79$, $P < 0.005$; Pz, $F(1,21) = 22.01$, $P < 0.001$) and larger (at Fz, $F(1,17) = 9.98$, $P < 0.05$; Cz, $F(1,15) = 5.05$, $P < 0.05$; Pz, $F(1,20) = 5.33$, $P < 0.05$) P3b responses than congruent bars. Also we found significant differences between latencies and amplitudes of P3b for the congruent and incongruent words. As in the case of bar stimuli, incongruent words evoked longer (at Fz, $F(1,27) = 9.69$, $P < 0.005$; Cz, $F(1,26) = 10.21$, $P < 0.005$; Pz, $F(1,26) = 12.60$, $P < 0.005$) and larger (at Fz, $F(1,24)$

= 10.63, $P < 0.005$; Cz, $F(1,25) = 14.19$, $P < 0.005$; Pz, $F(1,25) = 13.85$, $P < 0.005$) P3b response.

Amplitudes and latencies of P3a and P3b were not significantly different between congruent bars and words. On the other hand, although there was no significant difference between incongruent bars and words in terms of P3b amplitude, the latency of incongruent words was longer than incongruent bars at Fz ($F(1,18) = 18.53$, $P < 0.001$), Cz ($F(1,16) = 19.56$, $P < 0.001$) and Pz ($F(1,20) = 8.45$, $P < 0.05$).

4.5. N450-LPC Complex

Only incongruent words evoked N450 and LPC at Fz and Cz electrode sites. There was a significant main effect of site with Cz being longer in latency than Fz for N450 response ($F(1,18) = 6.69$, $P < 0.05$). No significant difference was found between the electrode sites for LPC.

4.6. LPN

Congruent bars did not evoke any LPN. An LPN response was observed at all three electrode sites for incongruent words, whereas incongruent bars and congruent words evoked this component only at Fz and Cz sites. There was a significant main effect of site with Cz being earlier in latency than Fz for incongruent bars ($F(1,20) = 25.48$, $P < 0.001$). Although no significant latency difference was found between congruent words and incongruent words, LPN amplitude was significantly greater for incongruent words at Cz ($F(1,26) = 4.92$, $P < 0.05$). The latency of the LPN difference between incongruent bars and words significantly different at the Cz electrode, being longer for words (($F(1,18) = 10.10$, $P < 0.05$).

5. DISCUSSION

5.1. N1

N1 was the first peak of the ERPs we have recorded. We observed that all of our bar and word stimuli, whether congruent or incongruent, produced N1 wave. But we found no significant difference between them in terms of amplitudes and latencies and between the derivations. The reason of this invariability may be that the peak around 140 ms after the stimulus onset was nothing but the sensory component of the time-locked EEG and insensitive to contextual changes therefore it can be considered as a component of the Visual Evoked Potentials (VEPs). On the other hand, contrary to the first suggestion, if the N1 was a cognitive component, then we have to turn our attention to our experimental paradigm. All of the presented stimuli were in the range of spatial attention and as mentioned in the literature review, N1 has been reported as being sensitive to spatial attention. In their study, Vogel and Luck (73) found no significant N1 effect difference in response to choice-easy and choice-hard tasks, despite the fact that more cognitive effort was required in the choice-hard task. Furthermore, Atkinson et al. (21) revealed that N1 was not significantly different between the conditions of the Stroop paradigm. In conclusion, we suggest that N1 does not reflect high-level cognitive processes, such as the semantic evaluation of a stimulus, and can not be considered as an indicator of the Stroop effect.

5.2. P2

We have observed no P2 in our data for congruent stimuli, be it word or bar, the possible explanation for this insensitivity can be that congruent stimuli have a repetition effect on subjects since they are more frequently presented than incongruent stimuli. The repetition causes a decrease in attention, hence a decrease or a complete attenuation of the P2. Moreover, since all stimulus types evoked N1 whereas congruent ones did not evoke P2, we suggest that higher executive functions are initiated around 200 ms after stimulus onset. On the other hand, we have clearly observed a P2 response in our data for both incongruent bars and words, in such a way that the latency of the P2 produced by the words being longer than that of the bars. We propose that such a delay may indicate the first step in processing the Stroop conflict and Stroop delay arises in the early processes of the stimuli identification. As for the amplitudes of the P2 waves for both stimuli types, there was no significant difference between them indicating that the same amount of mental energy is spent in evaluating these two stimuli.

5.3. N2

As in the case of P2, congruent stimuli did not evoke an N2 wave, which is line with the study of the Jackson et al. (38) revealing that N2 was attenuated in amplitude with repetitions. Our findings have shown that N2 was elicited only for the incongruent stimuli and the latencies of these two stimuli (bar and word) were statistically significant. The longer evaluation time of the incongruent word, relative to the incongruent bar, suggests that the Stroop effect which is caused by the response conflict and controlled processes is reflected by N2 latency. Various brain regions involved in the Stroop conflict processing have been identified with the functional magnetic resonance imaging (fMRI) studies and the most prominent one among them is the anterior cingulate cortex (ACC) (13). In their dipole source localization study, Veen and Carter (74) revealed that the source generator of N2 is ACC and N2 reflects the conflict detection. Combining these findings with our latency results N2 is a stronger index of Stroop effect than P2.

5.4. P3

In our study, the P3a wave was enhanced only by congruent stimuli, but as can be seen, its time course is interrupted and a half-wave is observed. This can be explained by the overlapping time-windows of P3a and P3b: the decreasing phase P3a coincides with the rising phase of the relatively large P3b. P3a is related to attention and since attention is required all through the sessions, the existence of a P3a is also expected for the incongruent stimuli, too. For the absence of P3a in incongruent response we suggest that although P3a tends to rise, its presence is occluded by the incongruent-specific N2 wave. We know that the time windows of these two waves overlap considerably and their polarities are in opposite directions. As a result, the relatively larger N2 attenuated and prevented the further rise of the P3a wave. A significant difference between the latencies of P3a for bar responses at Cz and Pz electrode sites was found indicating that the evaluation of the bar stimulus first took place at Cz and then at Pz electrode sites. This may explain the frontocentral distribution of the P3a.

When we compare the responses to the bar and word stimuli within themselves, we have seen that congruent bar parameters (latency and amplitude) were significantly different from their incongruent counterparts, incongruent parameters being longer in latency and greater in amplitude, and the same is also valid for the parameters of the word responses. These results show that when the cortex is met by a deviancy and/or a conflict, it expends more energy and spends more time in evaluating the stimulus.

As for the P3b component, a robust P3b was observed for both congruent and incongruent stimuli. No significant differences were found between the congruent bar and word latencies and amplitudes indicating only attentional mechanisms are involved in evoking the P3b. On the other hand, although no differences were found between the incongruent bar and word amplitudes, the differences between the bar and word latencies were significant, word latencies being longer. This shows that for the bar stimulus P3b is evoked only by a color conflict whereas the word, besides having a color dimension, it also has a contextual dimension that harbors a word-color conflict. Therefore the cortex must first resolve this uncertainty before arriving a conclusion, which means that it needs extra time in evaluating this kind of stimulus.

Our findings are in line with the literature which showed that P3 amplitude and latency are proportional to cognitive demands and stimulus evaluation time (48, 75).

5.4. N450-LPC Complex

In our study, we observed the N450 and LPC components only for the incongruent word over the fronto-central regions. No N450-LPC complex was recorded either for congruent words or congruent/incongruent bars. We reported P2, N2 and P3b waves for both incongruent bars and words with a longer latency for words which indicate that more time was required in evaluating the conflict in incongruent words. However, we recorded N450-LPC complex for only incongruent words, which revealed additional post-perceptual mechanisms reflecting the Stroop conflict or the re-emergence of inhibited automatic processes. As mentioned in the literature review, previous Stroop studies reported that congruent words, too, enhanced N450 and/or LPC with small amplitudes. The lack of this complex for congruent words in our data can be explained by the repetition effect. In our paradigm, the number of congruent stimuli is 90% of the total stimuli, that is, the subject is met with congruent stimuli sufficiently enough to be habituated. We can assert that at each repetition of the stimulus, the semantic processing is eased and subsequently the activity ceases. There was a significant N450 latency difference between Fz and Cz sites, Fz leading the Cz, indicating that the N450 is transmitted in a frontocentral direction. This finding is in line with the results of Qui et al. (76) who reported that a negativity in this time range was observed over prefrontal regions.

5.6. LPN

All four stimulus types, but the congruent bar, enhanced a late negative deflection around 900 ms after stimulus onset in our study. For the incongruent word stimulus, this peak can be explained by the fact that it is enhanced by high-level conflict, retrieval of color information and lexical decision. Although a congruent word stimulus does not include a high-level conflict and retrieval of color information, since it bears a lexical dimension we also have observed an LPN for this stimulus type. A latency difference between Fz and Cz sites has been observed, the LPN at Cz being shorter for the incongruent bars. We assume that different source generators of the LPN were included in the processing stages.The amplitude of the LPN for the incongruent word was found to be significantly larger than that of the congruent word at the Cz electrode site. This indicates that high-level conflict and retrieval of color information required additional energy compared to lexical decision alone. The latency of incongruent words was longer than incongruent bars at the Cz electrode site, but there was no significant difference at Fz. We suggest that although Fz is sensitive to both stimuli types, it is indifferent to higher executive functions such as discrimination between patterns

6.CONCLUSION

In this thesis, we described the relationships between the relevant ERP components and the Stroop effect. Basing on the electrophysiological findings, we discussed various aspects of the conflict processes.

We have observed the N1, P3b and LPN components for all types of stimulus whereas, P2, N2, N450 and LPC waves only for the incongruent stimulus types. The existence of these four waves reflected additional energy proportional to increased cognitive demands. Furthermore, incongruent words evoked N450-LPC complex in addition to P2 and N2 waves which suggested that increased cognitive demands were also reflected between incongruent bars and words. In our paradigm, incongruent bars led to only physical deviation however incongruent word led to both physical and semantic deviations. We concluded that processing of this semantic deviation has been mirrored at N450-LPC complex.

Since N1 was elicited for all stimulus types we cannot relate this wave to higher cognitive functions such as detecting or resolving a conflict. Stroop effect was first observed at P2 and N2 waves, with a longer latency for incongruent words than incongruent bars, thus we interpreted that the Stroop conflict is initiated at early stages of the stimulus processing. As far as we know, no study in the literature reported such a conflict processed as short as 200 ms after the stimulus onset. For example, although Ergen et al. (77) recorded these early components, they found no significant difference in ERP components of congruent and incongruent words. Since the first Stroop-ERP study in 1981 (59), researchers have not associated the P3 wave with the Stroop effect; however, this situation was reversed in our results. Since we found a latency difference between incongruent bars and words, we suggest that Stroop conflict is also being reflected at P3. We suggested that whereas P2 and N2 waves can be considered as related to conflict detection, N450-LPC complex may indicate the conflict resolution processes since they are relatively late components.

Stroop tasks are used in linguistic sciences, cognitive functions or clinical studies (78-82). Standard oddball paradigm has enabled to investigate the neural mechanisms of

Stroop interference explicitly, the findings presented in this thesis may lead to new approaches for these studies. In the future, using our experimental design in various forms of Stroop task may be advantageous in understanding neurophysiological and/or psychiatric disorders.

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8. APPENDICES

Appendix-1. Mean ERP latencies and amplitudes with standard error.

		N1			
		CB	*CW*	*ICB*	*ICW*
Latency	*Fz*	143 (0.004)	140 (0.002)	145 (0.003)	139 (0.000)
	Cz	138 (0.003)	139 (0.002)	146 (0.005)	138 (0.003)
	Pz	137 (0.004)	134 (0.002)	128 (0.007)	134 (0.003)
Amplitude	*Fz*	-1.95 (1.272)	-2.66 (1.216)	1.78 (1.885)	-1,68 (1.548)
	Cz	-2.84 (0.861)	-3.75 (1.116)	4.24 (2.153)	-2,90 (1.239)
	Pz	-1.76 (1.244)	-2.57 (0.664)	0.49 (2.971)	-2,89 (1.666)

		P2		N2	
		ICB	*ICW*	*ICB*	*ICW*
Latency	*Fz*	217 (0.003)	235 (0.005)	263 (0.006)	279 (0.003)
	Cz	216 (0.004)	233 (0.004)	280 (0.007)	277 (0.003)
	Pz	219 (0.004)	234 (0.005)	266 (0.007)	279 (0.006)
Amplitude	*Fz*	7.73 (1.553)	9.13 (1.803)	2.66 (2.077)	0.20 (3.184)
	Cz	6.14 (2.035)	8.79 (2.200)	-1.51 (2.591)	-1.77 (3.201)
	Pz	5.53 (2.702)	4.68 (1.778)	1.91 (0.995)	-3.14 (2.629)

		P3a		P3b	
		CB	*CW*	*CB*	*CW*
Latency	*Fz*	251 (0.006)	253 (0.006)	378 (0.007)	358 (0.009)
	Cz	246 (0.005)	250 (0.007)	368 (0.008)	357 (0.009)
	Pz	265 (0.005)	255 (0.007)	353 (0.008)	354 (0.009)
Amplitude	*Fz*	8.46 (1.491)	5.60 (0.771)	14.34 (3.65)	12.52 (2.28)
	Cz	6.14 (1.026)	5.24 (0.828)	11.73 (2.18)	10.69 (1.91)
	Pz	6.13 (1.038)	5.08 (0.710)	8.53 (1.851)	9.49 (1.67)

		P3b		N4	LPC
		ICB	*ICW*	*ICW*	*ICW*
Latency	*Fz*	378 (0.007)	419 (0.007)	518 (0.009)	652 (0.015)
	Cz	375 (0.008)	418 (0.007)	559 (0.011)	643 (0.017)
	Pz	379 (0.007)	419 (0.011)	-	-
Amplitude	*Fz*	21.65 (3.52)	20.35 (3.74)	4.63 (3.848)	8.63 (2.480)
	Cz	16.48 (2.81)	19.29 (2.05)	2.56 (3.009)	5.54 (3.704)
	Pz	19.27 (3.85)	16.33 (2.53)	-	-

Latencies are in milliseconds and amplitudes in micro-volts.

C: Congruent, IC: Incongruent, B: Bar, W: Word.

Appendix-1. (Continued) Mean ERP latencies and amplitudes with standard error.

		LPN		
		CW	*ICB*	*ICW*
Latency	*Fz*	905 (0.008)	880 (0.014)	864 (0.012)
	Cz	906 (0.006)	718 (0.033)	874 (0.017)
	Pz	-	-	870 (0.013)
Amplitude	*Fz*	2.76 (0.926)	1.82 (2.317)	-0.57 (4.530)
	Cz	1.51 (1.114)	0.81 (3.001)	-4.87 (3.719)
	Pz	-	-	-6.84 (3.082)

Latencies are in milliseconds and amplitudes in micro-volts.

C: Congruent, IC: Incongruent, B: Bar, W: Word.

Appendix-2. Approval of the Ethics Committee of Hacettepe University

T.C.
HACETTEPE ÜNİVERSİTESİ
Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu

Sayı : 16969557 – 382
Konu : ARAŞTIRMA PROJESİ DEĞERLENDİRME RAPORU

Toplantı Tarihi	: 28 ŞUBAT 2017 SALI
Toplantı No	: 2017/06
Proje No	: GO 17/118 (Değerlendirme Tarihi: 07.02.2017)
Karar No	: GO 17/118- 49

Üniversitemiz Tıp Fakültesi Biyofizik Anabilim Dalı öğretim üyelerinden Doç. Dr. Babür ŞAHİNOĞLU' nun sorumlu araştırmacı olduğu ve Gamze DOĞAN' ın yüksek lisans tezi olan, GO 17/118 kayıt numaralı, ***"Stroop Etkisi ile Ortaya Çıkan Olay-İlişkili Potansiyellerin Renk Çelişkisi ile Ortaya Çıkan Olay-İlişkili Potansiyellerle Karşılaştırmalı İncelenmesi"*** başlıklı proje önerisi araştırmanın gerekçe, amaç, yaklaşım ve yöntemleri dikkate alınarak incelenmiş olup, etik açıdan uygun bulunmuştur.

1.Prof.Dr.Nurten AKARSU (Başkan)	10 Prof. Dr. Oya Nuran EMİROĞLU (Üye)
2. Prof. Dr. Sevda F. MÜFTÜOĞLU (Üye)	11 Yrd. Doç. Dr. Özay GÖKÖZ (Üye)
3. Prof. Dr. M. Yıldırım SARA (Üye)	12. Doç. Dr. Gözde GİRGİN (Üye)
4. Prof. Dr. Necdet SAĞLAM (Üye)	13. Doç. Dr. Fatma Visal OKUR (Üye)
İZİNLİ 5. Prof. Dr. Hatice Doğan BUZOĞLU (Üye)	İZİNLİ 14.Yrd. Doç. Dr. Can Ebru KURT (Üye)
İZİNLİ 6. Prof. Dr. R. Köksal ÖZGÜL (Üye)	15. Yrd. Doç. Dr. H. Hüsrev TURNAGÖL (Üye)
7. Prof. Dr. Ayşe Lale DOĞAN (Üye)	16. Öğr. Gör. Dr. Müge DEMİR (Üye)
8. Prof. Dr. Elmas Ebru YALÇIN (Üye)	17. Öğr. Gör. Meltem ŞENGELEN (Üye)
9. Prof. Dr. Mintaze Kerem GÜNEL (Üye)	18. Av. Meltem ONURLU (Üye)

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Ayrıntılı Bilgi için:

Appendix-3. Consent Form

ARAŞTIRMA AMAÇLI ÇALIŞMA İÇİN AYDINLATILMIŞ ONAM FORMU

Değerli Katılımcı,

Gönüllü olarak katılmayı kabul ettiğiniz bu çalışma "*Stroop Etkisi ile Ortaya Çıkan Olay-İlişkili Potansiyellerin Renk-Çelişkisi ile Ortaya Çıkan Olay-İlişkili Potansiyellerle Karşılaştırmalı İncelenmesi*" adını taşımaktadır. Bu çalışmanın amacı, insanda renk ve kelime algılarının beyinde oluşturduğu elektriksel faaliyetleri incelemek ve beklenenden farklı bir renkle karşılaşıldığında beynin vereceği elektriksel tepkiyi kaydetmektir. Bir başka deyişle, algı olarak adlandırdığımız bilişsel faaliyeti fizyolojik bir temele oturtmayı hedeflemekteyiz.

Olay-İlişkili Potansiyel terimi, görsel ya da işitsel bir uyaran dizisinde bir aksama olduğu zaman kişinin bu aksamayı fark etmesi sonucu beyninde ortaya çıkan elektriksel faaliyete verilen teknik bir terimdir. Bu ölçümün, yöntem olarak, çok daha yaygın olarak bilinen ve kalbin elektriksel faaliyetlerini kaydetmeyi hedefleyen elektrokardiyografiden hiçbir farkı yoktur ve EEG (elektroensefalografi) temeline dayanmaktadır. Bu tür çalışmalarda saçlı deride ilgili bölgelere yüzeyel elektrodlar yerleştirilir ve bir EEG cihazıyla kayıt alınır.

<u>Bu çalışmada izlenecek yöntem aşağıdaki aşamalardan oluşur</u>:

- **Kayıtlar Hacettepe Üniversitesi Tıp Fakültesi Biyofizik Anabilim Dalı'nın EEG-1 laboratuvarında yapılacaktır.**
- **Katılımcının saçlı derisi üzerine bir jel aracılığıyla üç adet elektrot yerleştirilir. Ayrıca alına ve iki kulak memesine de birer elektrot yerleştirilir ve elektrotlar bir EEG cihazına bağlanır.**
- **Katılımcı sesten ve ışıktan yalıtılmış bir izole odaya alınır ve bir bilgisayar ekranından 1 m uzaklığa oturtulur.**

- **Ekranda belirli aralıklarla bir renk-kelimesi (örneğin, kırmızı) gösterilir ve katılımcıdan bu kelimeyi değil, renk-kelimesinin yazıldığı *fontun rengini* içinden söylemesi istenir.**
- **Bir seans için aynı kelime belirli aralıklarla 100 kez gösterilecek ve her birinde farklı bir renk-kelimesinin kullanıldığı dört ya da beş seans yapılacaktır. Her bir seans yaklaşık 2 dakika sürecektir. Kayıtlara başlamadan önce deney stratejisine alışması için katılımcıya bir prova seansı yaptırılacaktır.**
- **Prova seansı ve elektrot yerleştirilmesi süreci dahil, ölçümlerin bitimine kadar geçecek tüm süre yaklaşık 45 dakika dolaylarında olacaktır.**

<u>Katılmayı gönüllü olarak kabul ettiğiniz bu çalışmada</u>:

- **Hiçbir zararlı radyasyona maruz kalmayacaksınız.**
- **Size ağız yoluyla ya da damardan herhangi bir kimyasal madde verilmeyecektir.**
- **Vücudunuzdan elektrik akımı geçirilmeyecektir.**
- **Ölçüm elektrotlarını monte etmek için kullanılacak olan jel deride hehangi bir tahrişe ya da alerjiye neden olmaz, deride kalıntı bırakmaz ve kolayca temizlenebilir niteliktedir.**

<u>Çalışmanın size getireceği zorluklar</u>:

- **Kayıtların dış etkilerden arındırılması için ölçümler ses ve ışıktan yalıtılmış karanlık bir odada (izole oda) alınacaktır.**
- **Her bir seans süresince (yaklaşık 2 dakika) kelimelerin üzerinde bulunan küçük daireden gözünüzü ayırmayacak (odaklanacak), renge konsantre olacak ve dikkatinizi ses, ışık vb gibi başka şeylere yöneltmeyeceksiniz.**
- **Her bir seans süresince sizden hareket etmemeniz (özellikle boyun bölgesi), ekranla kendiniz arasındaki mesafeyi korumanız ve gözünüzü kırpmamanız istenecektir. Göz kırpmaktan kaçınma ve bir noktaya odaklanma göz sulanmasına neden olabilir.**

<u>Size verilen tüm bu bilgilerin ışığında, eğer çalışmamıza gönüllü olarak katılmaya karar verirseniz</u>,

- **Size herhangi bir ücret ödenmeyecektir.**

- **Sizden herhangi bir ücret talep edilmeyecektir.**
- **Sizinle ilgili tüm bilgiler gizli tutulacaktır.**
- **Araştırma sonuçları bilimsel ve eğitim amaçlı olarak yayınlandığında kişisel bilgileriniz özenle korunacaktır.**
- **Kayıtlar sırasında yukarıda belirtilen zorluklardan herhangi biriyle karşılaştığınızda (karanlıktan bunalma, kas ağrıları, göz sulanması vb) seansı sonlandırabilir ve dinlenme süresi talep edebilirsiniz.**
- **Kayıtlara başlamadan önce ya da kayıtların herhangi bir aşamasında araştırmadan tümüyle çekilebilirsiniz. Bu size maddi bir yükümlülük getirmeyecektir.**

HACETTEPE ÜNİVERSİTESİ TIP FAKÜLTESİ AYDINLATILMIŞ ONAM FORMU

1. Sorumlu araştırmacı tarafından çalışmanın konusu ve araştırmanın yürütülmesi ile ilgili ayrıntılı açıklama yapıldı. Çalışmanın sağlığım açısından hiçbir risk taşımadığı konusunda bana güvence verildi. Yine de, çalışmadan kaynaklanan herhangi bir sağlık sorunu ortaya çıkması durumunda her türlü tıbbi bakımın yapılacağı ve bu durumun bana parasal bir yük getirmeyeceği bildirildi.
2. Şahsımla ilgili kişisel bilgilerin gizli kalacağı ve özenle korunacağı konusunda bana güvence verildi.
3. Çalışmaya gönüllü olarak katılıyorum. Çalışmanın başarıyla yürütülmesi için sorumlu araştırmacı tarafından bana iletilen ilkelere uyacağımı taahhüt ediyorum.
4. Çalışmaya katılmamla ilgili parasal bir talepte bulunmuyorum.
5. Çalışma için yapılan harcamalarla ilgili herhangi bir parasal sorumluluk altına girmiyorum.
6. Çalışmanın herhangi bir aşamasında araştırmadan çekilebilirim, bunun bana hiçbir parasal sorumluluk getirmeyeceğini biliyorum.
7. Acil bir durumda ya da daha fazla bilgiye gerekseme duyduğumda sorumlu araştırmacıya nasıl ulaşabileceğimi biliyorum.

TARİH:

Gönüllü Katılımcı

Ad ve Soyad	
Adres	
Telefon	
e-mail	
İmza	

Sorumlu Araştırmacı / Yardımcı Araştırmacı

Ad ve Soyad	
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Appendix-4. Report for Originality of Thesis Study

turnitin

Dijital Makbuz

Bu makbuz ödevinizin Turnitin'e ulaştığını bildirmektedir. Gönderiminize dair bilgiler şöyledir:

Gönderinizin ilk sayfası aşağıda gönderilmektedir.

Gönderen:	Gamze Doğan
Ödev başlığı:	Yüksek Lisans Tez
Gönderi Başlığı:	COMPARATIVE INVESTIGATION O..
Dosya adı:	JURY-THESIS-PDF.pdf
Dosya boyutu:	1.95M
Sayfa sayısı:	50
Kelime sayısı:	10,937
Karakter sayısı:	58,092
Gönderim Tarihi:	07-Ağu-2019 10:54AM (UTC+0300)
Gönderim Numarası:	1158302602

Thesis Title: COMPARATIVE INVESTIGATION OF EVENT-RELATED POTENTIALS ELICITED BY THE STROOP EFFECT AND EVENT-RELATED POTENTIALS ELICITED BY COLOR CONFLICT
Student Name and Surname: Gamze DOĞAN
Total Page Number: 50

COMPARATIVE INVESTIGATION OF EVENT-RELATED POTENTIALS ELICITED BY THE STROOP EFFECT AND EVENT-RELATED POTENTIALS ELICITED BY COLOR CONFLICT

ORIJINALLIK RAPORU

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BENZERLIK ENDEKSI	İNTERNET KAYNAKLARI	YAYINLAR	ÖĞRENCI ÖDEVLERI

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9. CURRICULUM VITAE

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