# RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS, FEELING OF KNOWING AND CONFIDENCE JUDGMENTS IN SEMANTIC MEMORY: AN ERP STUDY

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**İSTANBUL, 2020**

# RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS, FEELING OF KNOWING AND CONFIDENCE JUDGMENTS IN SEMANTIC MEMORY: AN ERP STUDY

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## ABSTRACT


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The present study aims to investigate feeling of knowing (FOK) judgments in semantic memory by considering its neural correlates and also its relationship with executive functions. For purposes of the study, semantic memory task consisted of 93 general knowledge questions created with a norming study. In the study, classical recall, judgment and recognition paradigm was used. The neural correlates of FOK and confidence judgments for recognition (CJRs) were examined in semantic memory task by using ERPs for Fz, Cz, Pz and Oz for 0-100, 100-200, 200-300, 300-400 and 400-650 ms time windows, and levels and overall amplitude values of FOK and CJRs were analyzed. Additionally, shifting ability and cognitive flexibility were evaluated to understand underlying mechanisms of FOK and specific contributions of executive functions to metacognitive decisions. It was found that there were significant relationships in terms of FOK with set shifting ability and CJRs.

Participants' FOK judgments were significantly differentiated according to recall and recognition performances. For ERP findings, not FOK judgments, but amplitude values of central electrodes during CJRs were significantly different. Cz and Pz electrodes had respectively higher amplitude values than Fz and Oz. For FOK judgments, only difference was found for late components in overall condition as higher amplitude values of Fz than Cz. Findings of the presents study indicated that FOK and CJRs were separated from each other and amplitude values supported the familiarity and accessibility accounts.

*Keywords:* FOK, metacognition, set shifting, cognitive flexibility, confidence judgments, ERP

## ÖZ

SEMANTİK BELLEKTE BİLME HİSSİ, BELLEĞE DUYULAN GÜVENİN YÖNETİCİ İŞLEVLER İLE İLİŞKİSİ: OLAY İLİŞKİLİ POTANSİYEL ÇALIŞMASI

Güler, Berna

Yüksek Lisans, Bilişsel Nöropsikoloji

Tez Danışmanı: Prof. Dr. Metehan Irak

Ağustos, 2020

Yapılan çalışmanın amacı semantik bellekte bilme hissi paradigmasının, bilme hissinin nöral mekanizmaları göz önünde bulundurularak incelenmesidir. Amaç doğrultusunda norm çalışması ile oluşturulan 93 genel kültür sorusu klasik hatırlama, yargı ve tanıma paradigması ile semantik bellek görevinde kullanılmıştır. Bilme hissi yargısının semantik bellek görevindeki nöral mekanizmaları, bilme hissi ve tanıma yargıları değerlendirilerek incelenmiştir. Ek olarak, bilme hissi yargısına yönetici işlevlerin katkılarını ölçmek amacı ile set değiştirme becerisi ve bilişsel esneklik değerlendirilmiştir. Sonuçlar doğrultusunda bilme hissi yargısı ile set değiştirme becerisi ve tanıma görevi sırasındaki eminlik yargıları arasında anlamlı ilişki gözlenmiştir. Ek olarak, katılımcıların hatırlama ve tanıma görevleri sırasındaki performanslarına göre bilme hissi performansları anlamlı olarak değişmiştir. Olay ilişkili potansiyel sonuçlarına göre, bilme hissi yargıları olmasa da, tanıma sırasında verilen eminlik yargıları açısından sırasıyla Cz ve Pz kanalları Fz ve Oz kanallarına göre yüksek genlik değeri göstermiştir. Bilme hissi yargıları değerlendirildiğinde ise tek anlamlı bulgu, Fz kanalının Cz kanalına göre geç zirvelerde daha yüksek genlik değeri göstermesi olmuştur.

*Anahtar kelimeler:* Bilme hissi, üstbiliş, set değiştirme, bilişsel esneklik, eminlik yargısı, olay ilişkili potansiyel

*To my dear family*

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# CHAPTER 1

## INTRODUCTION

Memory consists number of different interrelated systems, classified complex of operating components, neural substratum, and their cognitive and behavioral correlates (Tulving, 1985). It is also known that memories do not existed in emptiness; however, they continually interrupt each other (Greene, 1992 cited in Loftus & Pickrell, 1995). It may be assumed in a sense that human beings are capable of retrieving any information in any necessity; however, it is not the case that retrieval is a perfect process and retrieved information usually is the same as the stored piece of information. If human being is perfect with infallible memories and able to retrieve information perfectly in any time, then most of the concepts such as feeling of knowing (FOK), a type of metacognitive decision, would be meaningless (Hart, 1965). In fact, people can be consciously aware that they know a piece of information, but unable to retrieve it. As stated by William James (1893), when a person tries to remember a name which is currently forgotten, there is an active gap that points us to a direction to search and bring us a sense of closeness to the searched item. This active phase in memory processes also includes metacognitive processes.

Metacognition is defined as the ability to supervise and control person's own cognitive system which can be either retrospective or prospective during different stages such as retrieval, acquisition or retention. To clarify, metacognition includes cognitive processes such as beliefs, thoughts that are bounded to control and evaluate personal cognitions, and having an active control over cognition usually needs active monitoring of present conditions within the mind to decide an appropriate answer (Hertzog & Dunlosky, 2011). In that sense, monitoring can be explained as personal assessment of individuals' own knowledge; however, control includes the processes which use the products of monitoring to manage cognitive processes and behavioral output (Koriat, 2000). The general way of studying metacognition and its monitoring role is appealing of person's subjective reports by personal introspections (Nelson & Narens, 1990). One of the main motivation to investigate metacognition is related to memory systems and metamemory. The concept of metamemory is mainly defined as knowledge of control and monitoring memory processes and learning (Nelson & Narens, 1990). According to Hart (1965) memory monitoring defines the intrusive and also descriptive process between recall and recognition. In most of the situations, memory performance depends both on what might possibly be termed as memory, and on control and monitoring processes that get involved the concept of metamemory (Mazzoni & Nelson, 2014). One of the concepts related and searched with the metamemory is FOK. It is mainly defined as a metacognitive judgment regards to having a belief to recognize an item or an event in the future that has not been remembered at that moment (Koriat & Levy-Sadot, 2001). In that sense, FOK has contributions to understanding the mechanisms of human metamemory systems (Kikyo, Ohki, & Miyashita, 2002).

The concept of FOK was first studied by Hart (1965) by the recall- judgment-recognition (RJR) paradigm. In this paradigm, individuals are either asked to remember a general knowledge information which is a semantic memory measurement (e.g. “What is the capital of France?”) or to recall a recently learned material such as an image or word pairs as an episodic memory measurement. For classical FOK assessment, if people are not able to recall the previously presented item or give an answer, then they are instructed to make a FOK judgment regarding their belief that whether they will be able or not to remember the target in the future among distractors in a recognition test (Koriat & Levy-Sadot, 2001). In that sense, episodic FOK judgments include context and self-dependent remembrances, however, semantic FOK judgments comprise predictions for factual cues which are independent from context (Reggev, Zuckerman, & Maril, 2011). When FOK judgments for unrecalled items on a task are related to performance on recognition, then FOK accuracy appears (Mazzoni & Nelson, 2014). It was supported by the findings that FOK judgments made after retrieval failures are quite valid while predicting the success of remembering the target among incorrect alternatives (Hart, 1965; Schwartz & Metcalfe, 1992). Sometimes it can be difficult to remember a piece of information, however, in such cases people may have a strong FOK and able to monitor the emergence of ambiguous target into consciousness (Koriat, 1998). As might be expected, this process consists of also subjective experience itself (Koriat, 2000). By meaning, FOK itself includes direct experience which a person can feel the existence of a searched item rather than inferring its existence (James, 1893). Therefore, it was assumed that individuals are quite accurate while making a FOK judgment regarding their future performance. However, contrary conditions should be considered too, because memory processes which are involved during FOK performance such as recall and recognition differentiated from each other even though they share common cognitive processes (Postman, Jenkins, & Postman (1948).

Different hypotheses have been proposed while explaining FOK judgments. One of the main theoretical explanations is the cue familiarity account. According to this account, FOK judgments are based on the familiarity of the cue which helps to probe memory and early motivation to search and retrieve information depends on this effect (Reder, 1987). In that sense, rather than retrievability of the item, familiarity of the pointer actually matters for FOK judgments. Reder (1987) mainly argued that FOK judgments before the retrieval of the item are automatically formed in relation with familiarity of the question whether searched item exists in the memory. Metcalfe, Schwartz and Joaquim (1993) also proposed that FOK judgments are based on cue familiarity as an indirect assessment, and evaluating the familiarity of the pointer can be named as cue familiarity heuristic. When familiarity of the cue increases then there is an increase in FOK judgments even without the existence of actual retrieval, and this heuristic can be assessed mostly useful in conditions where judgments are needed to be quick and based on outer features of the question (Reder & Ritter, 1992).

Alternatively, accessibility account proposed by Koriat (1993) assumes that mnemonic cues are used to decide whether the target is in the memory and whether it will be answered in the criterion test. According to this theoretical perspective, accessible amount of information in the memory influences FOK judgments (Koriat, 1998), and monitoring does not pre-exist before retrieval, but it follows the retrieval process (Koriat, 2007). By meaning that an individual can evaluate whether the searched item is in memory with the use of partial information related to the target and continue to search for it. Even though people can assume they know the answer, they may not retrieve the target from memory or answer in a wrong way. Accessibility account explains this in the way that individuals are confident about their performance by giving a FOK judgment with the help of accessed information, and this situation is consistent irrespective of whether remembered item is true or not in the criterion test (Koriat, 1993).

Another and more recent theoretical perspective related to FOK judgments proposed the combination of accessibility and familiarity accounts (Koriat & Levy-Sadot, 2001). According to this view, both accessibility and familiarity are quite related to each other and they are parts of the FOK judgments. In one part of the process, remembered information with the memory pointer works as a cue for subjective sense of familiarity. On the other part, familiarity designates accessibility of the process (Koriat & Levy-Sadot, 2001). To clarify, familiarity of the cue promotes the starting for memory search, and accessibility of the retrieval process is evaluated with the help of familiarity. When familiarity is high, then the effect of accessibility is observed even they are both parts of the process, and in that sense accessibility is moderated by familiarity effect.

### 1.1. Neuropsychology and neuroimaging of FOK judgments

Current study focused on semantic memory while studying FOK and confidence judgments for recognition (CJRs) as metacognitive judgments to understand formation of metacognitive decision when retrieval failures occur. When individuals attempt to reach a piece of information from memory which is already learned, they rely on semantic retrieval processes that depend on conscious recollection of general knowledge about world and realistic information (Tulving, 1972). It was stated that level of general knowledge is linked with structural brain network connectivity (Genç et al., 2019). Moscovitch (1992) stated that semantic events and related signals are automatically linked to the hippocampal components. It is also known that left inferior prefrontal cortex (IPFC) associated with tasks that measure semantic decisions (Poldrack et al., 1999) and semantic processing (Vandenerghe et al., 1996). In addition, it was stated that medial PFC is involved in semantic retrieval (Addis et al., 2004 a, b; Gilboa et al., 2004; Levine et al., 2004 cited in Burianova et al., 2010).

When semantic and episodic judgments are evaluated, activations in right inferior PFC, left middle temporal gyrus, and posterior medial regions were observed for both judgments that revealed memory domain and memory prediction (Reggev et al., 2011). Additionally, they found an increased activation in left PFC, anterior cingulate cortex (ACC), and left parietal cortex (PC) during positive FOK judgments compared to negative judgments regardless of distinction between semantic and episodic memory. They also mentioned the activation in lateral PC activation for both semantic and episodic retrieval, indicating PC contribution to retrieval process in general. Therefore, there are both common and separate regions contribute to semantic and episodic FOK judgments, and these common regions engage in more general subjective metamemory monitoring. Kikyo and colleagues (2002) focused to decompose the neural correlates of FOK during semantic memory task and found activations in the bilateral inferior frontal gyrus (IFG), left dorsal PFC, ACC, left medial frontal gyrus (MFG) and bilateral caudate nuclei during greater FOK. It is also stated that activation in left IFG is associated with FOK and successful semantic recall (Kikyo et al., 2002). When frontal region contribution is considered with an episodic task, it was found that left dorsal, left IPFC and medial regions of frontal cortex have a role on FOK (Maril et al., 2003). Kikyo et al. (2002) emphasized that activations in PFC are not just related to response latencies in FOK judgments, however, due to intensity of the FOK itself. Moreover, they stated that parts of bilateral IFG, which known as subdivisions of FOK, were not found to be related to successful recall. These findings suggest that these regions should be related to metamemory system. On the other hand, Maril and colleagues (2003) found activation in left frontal regions related to successful recall during episodic task (know condition) when FOK judgment is evaluated in three rating scale as know, do not know, and FOK instead of six point Likert scale.

There is a scarce in studies of FOK via ERP analyses and one of the known study is by Paynter, Reder and Kieffaber (2009). In their study they used unfamiliar math problems which were shown several times during the task and they asked participants whether they directly know the answer ("retrieve") or solve the problem immediately ("calculate"), and in that sense, familiar questions created higher FOK. Their results indicated that retrieval trials with high familiarity are linked with high positivity in P2 (180-280 ms) and P3 (300-500 ms) components. They also stated that FOK activation was especially observed in fronto-central regions of the scalp. They concluded that neural correlates of FOK appeared 200 ms after the question was seen. There is also a current study conducted by Irak, Soylu, Turan and Çapan (2019), and they measured FOK phenomenon in episodic memory to compare high and low FOK via word pairs and they found that FOK judgments are related to positivity in P2 component at frontal, central, parietal and frontocentral regions and negativity in N2 component at parietal region. Their findings revealed that level of FOK judgments affected the ERP components saying that higher FOK judgments were associated with higher amplitude in P2 component at frontal, central and frontocentral sites, and low FOK judgments were related to higher amplitude in N2 component at parietal regions. Another study by Turan, Irak and Soylu (2017) measuring FOK judgments in semantic memory task and they found P2 component at parietal and occipital regions and N2 component at fronto-central site with link to FOK judgments. In studies of FOK judgments with different stimuli, Irak, Soylu and Turan (2020) investigated both FOK and judgment of learning (JOL) with face-name recognition task and also compared neural correlates of high versus low judgments. They found that FOK judgments appeared 200 ms after the stimulus presented, and high FOK judgments generated greater amplitude for N1, P1, P2 and P3 components compared to low FOK judgments.

### 1.2. Relation between executive functions and FOK: Shifting and cognitive flexibility

It is known that FOK, as a metacognitive process, is related to other cognitive processes and especially frontal lobe functions such as focused and divided attention and inhibition (Irak, 2005). Therefore, it is valuable to search which executive functions are involved in FOK as one of the metacognitive judgments, because discovering such contributions may explain how FOK appears and what kinds of cognitive processes are involved during FOK judgment. Some of the well-defined neuropsychological tests such as Tower of Hanoi (TOH) and Wisconsin Card Sorting Test (WCST) are quite much studied in the literature to examine executive functions (Lezak, 1995; Shallice & Burgess, 1991; Souchay, Isingrini, Clarys, Taconnat & Eustache, 2004; Stuss & Benson, 1986). These tasks are defined as primary tasks for studying the roles and organization of executive functions in the brain (Miyake et al., 2000), even though they are quite complex and reasons of poor performance on them cannot be defined very well. For instance, studies which were conducted with patients with frontal lobe damage revealed contradictory results that some patients performed well on WCST, however, performed poor on TOH, and such results suggest that executive functions are not unitary (Miyake et al., 2000). It is emphasized that shifting has a link with WCST, however, inhibition has a link with TOH task (Huizinga, Dolan, & van der Molen, 2006). Rather than assessing executive functions, WCST is also studied in the literature when evaluating FOK judgments (Perrotin, Tournelle & Isingrini, 2008; Souchay et al., 2004). Baran and collegues (2009) found a significant correlation between episodic FOK accuracy and WCST in older adults. Also, it was found that WSCT is one of the best task to evaluate its contributions to the FOK judgments, however, it is not clear which underlying mechanisms of executive functions are partly responsible for the FOK since WCST comprises more than one frontal ability such as set shifting, inhibition, planning and so on (Souchay et al., 2004). Therefore, it was considered as valuable to search metacognitive judgments with simpler rather than complex tasks. Since it was not clear what WCST measures, contributions of shifting, updating, monitoring, and inhibition were measured and it was found that especially WCST has specific connection with shifting ability (Miyake et al., 2000). Perrotin and collegues (2008) also found that shifting was only predictor among different executive function tasks when accuracy of FOK judgments is considered with episodic memory. Shifting between intellectual sets or tasks is a crucial cognitive ability in the concept of executive control. Moreover, it was speculated about the reason why shifting was found as highly associated with FOK that it is opening a gate to shift between possible mechanisms which are accessibility heuristic and cue-familiarity (Perrotin et al., 2008). Additionally, Boduroglu, Tekcan and Kapucu (2014) used a task switching task in the prediction of FOK accuracy and they found no significant correlation between mixing cost (reflects higher working memory demand; RT for non-switching trials in mixed trial minus control block trial) and FOK accuracy, but found a significant correlation between switch cost (RT for switching trials minus non-switching trials) and FOK accuracy. They concluded that shifting may not play a global role, but play a partial role on FOK accuracy, and common mechanisms can have a role in both set shifting ability and FOK judgments. It is known that shifting is related to FOK accuracy, but how and in which stages of production of FOK judgments and shifting are related and whether this relation is differentiated depending on the task are not searched well-enough. Cognitive shifting ability, when examined independently via different tasks, might play a considerable role in the explanation of FOK accuracy.

When individuals try to shift between tasks or cognitive sets, they also rely on different intellectual capacities. In the requirement of set shifting, individuals need to consider related alternatives and while doing this, cognitive flexibility is one of the required ability. Even though it is quite difficult to define cognitive flexibility, it can be explained as a person's readiness to selectively choose a response from concept system in the appearance of an environmental stimulus (Scott, 1962). When it is evaluated from a broader perspective, cognitive flexibility can be summarized in four concepts which are set shifting ability, cognitive control, features of mental states and way to measure divergent thinking (Ionescu, 2012). It was also mentioned that most of the studies use the terms of cognitive flexibility and set shifting as synonyms, and it is found quite difficult to separate shifting ability from cognitive flexibility that decomposition of any kind of flexible behavior reveals shifting as a crucial component of it. In physiological manner, it was found that basal ganglia and frontal lobe are associated with neural correlates of cognitive flexibility, and frontal region was found as a mediator between access to knowledge systems and production of various ideas (Eslinger & Grattan, 1993). Also, the role of set shifting in different forms of cognitive flexibility was evaluated (Kim, Johnson, Cilles, & Gold, 2011), and it was found that cognitive set shifting ability is associated with lateral and medial PFC. Since the cognitive flexibility and set shifting are quite interrelated concepts, it is considered significant to evaluate them together while measuring metacognitive judgments.

### 1.3. Goal of the study

A major motivation of research in the field of metamemory is to ensure that there are links between knowing about memory and actual memory performance (Mazzoni & Nelson, 2014). This motivation basically shed light on the main aim of this study which is to explore neural correlates of FOK and confidence judgments in semantic memory with a different methodology. Also, relation between FOK, confidence judgments and executive functions in terms of cognitive flexibility and set shifting were evaluated in the current study to understand different contributions of frontal lobe functions to occurrence of such metacognitive judgments. Even though there are sufficient behavioral findings in the literature related to FOK judgments, there is still scarce information related to neural systems underlying FOK and such findings can provide support for behavioral measures. Since considering the complexity of measuring metacognition and executive functions on behavioral analyses, neuroimaging studies take an important role in understanding emergence of such decisions and evaluations. In that sense, there are discovered neural mechanism in spatial resolution by the help of fMRI studies (e.g., Maril et al., 2003, 2005; Kikyo et al., 2002), however, temporal dynamics of FOK judgments may broaden the current perspective and sustain new information in the sense of memory accessibility, assessment of familiarity or connection between metacognitive judgments.

While measuring FOK judgments to understand neural correlates behind them, studies evaluated accurate or inaccurate FOK (Maril et al., 2003), high or low FOK judgments (Kikyo et al., 2002) with fMRI, however, there is not much evidence comes from ERP study that compared high and low FOK and confidence judgments while measuring their accuracy (Irak et al., 2019; Turan et al., 2017) or using different methodology. Also, studies investigated neural underpinnings of FOK judgment use episodic memory tasks (Irak et al., 2019; Irak et al., 2020; Maril et al., 2003), arithmetic problems (Reder & Ritter, 1992), and there is not much of an evidence in terms of semantic memory tasks (e.g., Kikyo et al., 2002) especially on ERP studies. In that sense, it is important to search neural components of FOK and confidence judgments with novel stimuli and different methodology to understand the mechanism behind the creation of such evaluations.

Addition to the understanding of neural correlates of familiarity and recollection, it is also important to evaluate similarities and differences between FOK and CJRs regarding memory source, since they are both metacognitive processes. Familiarity and recollection are temporally linked to different ERP components in memory tasks (Woodruff, Hayama, & Rugg, 2006). Frontal N400 (300-500ms) component is linked to familiarity and it has a pattern of escalation with the increase in recognition confidence, however, late positive component (LPC, 500-800ms) (left parietal effect) is associated with recollection and it is correlated with high confidence recognition responses (Addante, Ranganath, & Yonelinas, 2012). Recognition based on familiarity is linked to variability in response confidence, but recognition based on recollection is associated with responses with high confidence and it is evaluated as an all-or none process (Curran, 2004; Yonelinas, 2001, 2002 cited in Wynn, Kessels, & Schutter, 2020). In that sense, it is assumed that familiarity is more continuous and related to strength, however, recollection is reported as a threshold, and judgments based on recollection commonly produced with high confidence compared to variability on familiarity judgments (Woodruff, Hayama, & Rugg, 2006). However, it was recently stated that recollection process operates as some-or-none rather than operating as binary that output of the recall may vary when recollection is successful (Murray, Howie, & Donaldson, 2015). It was also found that individuals can accurately recognize an item even their CJRs are not high, and in this situation LPC was not observed, however, late and distributed negative ERP component was observed (Addante, Ranganath, & Yonelinas, 2012). In that sense, it is considered to be valuable to search differences between metacognitive judgments in specific time windows, since confidence judgments regarding memory source vary while individuals depend on recollection, familiarity or both.

Additionally, behavioral measurement of set shifting ability and cognitive flexibility can help to understand the contribution of executive function to FOK and confidence judgments. With the help of such analyses, importance of studying executive functions with metacognitive judgments was emphasized.

### 1.4. Hypotheses of the study

1. FOK judgments are changed according to answers during recall and recognition phases (e.g. correct and incorrect).
2. FOK judgments are positively correlated with recognition confidence judgments.

3. There are positive correlations between cognitive flexibility, set shifting and FOK judgments and CJRs.
4. Amplitude values of ERPs during general FOK and CJRs phases vary according to electrode sides ( e.g. Fz, Cz, Pz and Oz) at different time windows (e.g. 0-100, 100-200, 200-300, 300-400 and 400-650 ms). These relationships would be affected by degree of FOK judgments (know, FOK and do not know) and CJRs (high and low).

# CHAPTER 2

# METHOD

## 2.1. Participants

35 subjects (19 females) who aged between 20 and 29 (*M* = 23.79, *SD* = 2.46), participated in this study. EEG recording was collected from 26 of the participants. Data from 4 among these participants was removed due to EEG artifacts. ERP analyses were conducted for 22 participants aged between 20 and 29 (*M* = 23.90, *SD* = 2.56). Participants were right-handed and native Turkish speaker university students. All participants were volunteers, reported themselves to be in a good mental and physical health and free from medication that may affect central nervous system. Participants had normal or corrected-to-normal vision. Informed consent was provided to the participants in a manner approved by the Bahçeşehir University Ethics Committee.

## 2.2. Materials

### 2.2.1. Norming Study

The current version of general information question database in Turkish was outdated. Thus, as a first phase of the present study, general knowledge questions were created called ‘norming study’. Questions’ difficulty was determined by answers of 354 people (199 female) aged between 17-54 ($M$ = 27.70, $SD$ = 7.96). Education level of participants were mainly undergraduate (26.6%), graduate (23.3%), master (12.1%) and post graduate (6.8%). Questions were asked to participants in Turkish via an online platform. Total of 154 questions were selected from three main sources: the norm generated by Nelson and Narens (1980), its updated version by Tauber, Dunlosky, Rawson, Rhode and Sitzman (2013), and Turkish version of Trivial Pursuit (2011) questions (Haney, 1979). The main inclusion criterion was having a particular answer which consists of at least two words. Additionally, questions with answers of proper noun were mostly eliminated to avoid spelling errors, and commission errors were accepted with controlling manually. To give a basic example from questions: “What is the name of the long speech of actors in a theater?”. Questions were chosen from different areas; geography (34%), science (31.2%), history (13%), culture (15%) and sport (7.1%). The main criterion behind this process was to determine good questions with different levels of difficulty for the average undergraduate and graduate students.

Questions were presented in the same way as they asked during norming study in the semantic memory FOK task. However, mainly short questions (e.g. what is the capital of France?) were preferred due to design of the semantic memory FOK task. Difficulty level was determined by the percentage of correct answers. To determine difficulty level, number of correctness of questions were sorted as percentage. Three groups were determined; 1$^{st}$ quartile (25% correctness, difficult questions), 2$^{nd}$ quartile (25-75% correctness, medium questions) and 3$^{rd}$ quartile (75% correctness, easy questions). Questions from different difficulty levels were selected from the top percentages within each category. Therefore, plainness of the questions for each difficulty level was ensured. The questions used during semantic memory FOK task were 93 general knowledge questions (30 easy, 30 medium, 30 difficult and 3 buffer from each category). Also, distractor words (3 alternatives) for recognition phase were selected from the most frequently reported wrong answers.

### 3.1.2. Semantic Memory Feeling of Knowing Task

In the current task, RJR paradigm was used (Hart, 1965). Figure 2.1 indicates the flow diagram of semantic memory FOK task. Considering all phases, there was no time limitation except presentation of the questions. Additionally, three buffer questions (easy, medium, difficult) were displayed in the beginning of the task for all subjects in the same order to prevent priming effect about difficulty of questions, however, 90 general knowledge questions were presented in randomized order for each subject. In the recall phase, participants were first given questions which were displayed for 5 sec, and after question was disappeared participants were asked to type the answer for each question using screen keyboard. On the next screen, participants were instructed to make confidence judgment by using 6-point Likert-type rating scale (1: definitely not sure, 6: definitely sure). If they felt like not able to answer, they were informed to write “1” as an answer and to select “1” as confidence judgment on the next screen. In this case, omissions were not allowed as an answer. The second phase of the task was FOK judgment phase and all questions were presented again in the same order without considering whether participants’ answers were right or wrong in the recall phase, since FOK resolution is found higher when all items were presented rather than unrecalled ones (Schwartz, Boduroglu, & Tekcan, 2016). Participants were asked to make an evaluation for their recognition performance considering the following question: “Even though I do not remember the answer right now, do I able to choose to correct answer among alternatives in the future?”. Their FOK judgments were collected by three options: successful retrieval (Know: I will definitely find the correct answer), unsuccessful retrieval without FOK (Do not know: I will not definitely find the correct answer), or unsuccessful recall with FOK (FOK: I feel that I can find the correct answer among alternatives) (Maril et al., 2001). In this part, questions were displayed again for 5 sec then disappeared for FOK judgment, and confidence evaluation was not asked to participants. Lastly, third phase was recognition (criterion test), and all questions were presented again. Participants were asked to choose the answer that they think was correct among four alternatives after question disappeared and they were instructed to choose an answer even if they had to guess. After selecting an answer, confidence screen was presented same as in the recall phase.

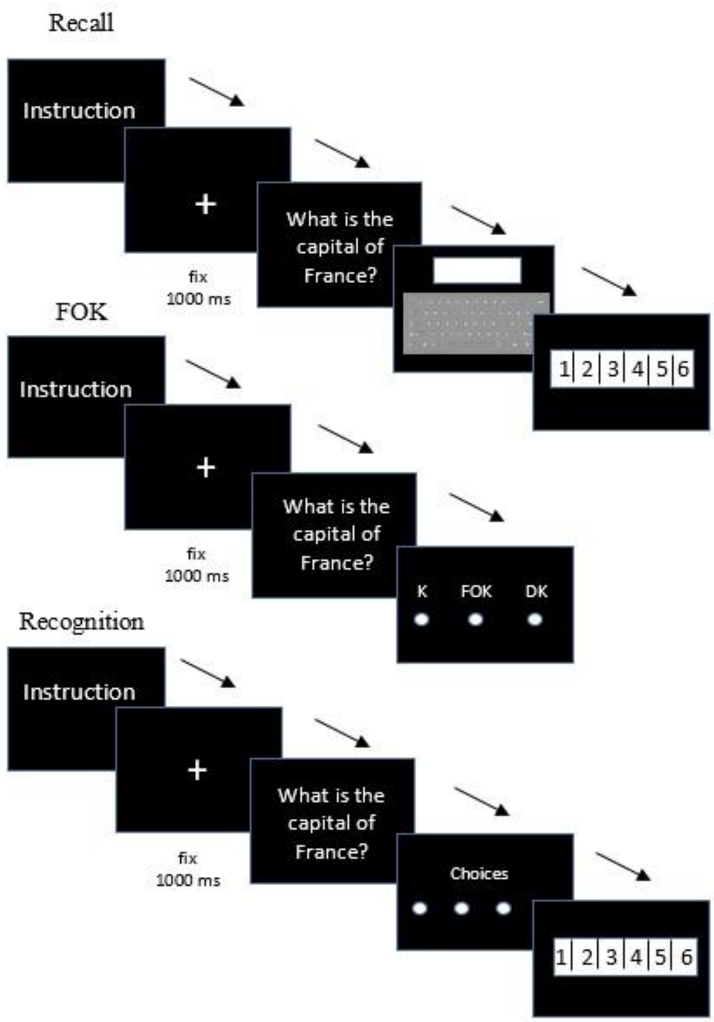


*Figure 2.1*. Flow diagram of semantic memory FOK task.

### 2.2.3. Concept Shifting Test (CST)

Concept Shifting Test (CST) (Vink & Jolles, 1985) was used to measure set shifting ability and it was developed by the inspiration of Trail Making Test (TMT) which was originally introduced as a part of Army Individual Test Battery (1944) and it was added later into the Halstead-Reitan Battery (Reitan & Wolfson, 1985). TMT is used to measure scanning, speed of processing, visual search, mental flexibility and executive functions (Tombaugh, 2004). TMT consists of Part A (counting numbers in an order) and Part B (switching between numbers and letters in an order). Especially Part B makes able to measure mental flexibility in executing more than one stimuli and shifting ability during an ongoing activity (Lezak, 1995 cited in Giovagnoli et al., 1996). It is known that TMT is sensitive to measure executive functions. However, CST was developed to prevent uncertainty in the interpretation of results in TMT (Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006). CST includes four parts and layout is identical for all parts which consists small 16 circles in a one big circle. Parts include numbers, letters, both number and letters, and an empty circle, respectively. Participants are needed to cross numbers in numerical order (Part A), cross letters in alphabetic order (Part B), both numbers and letters in an order (Part C), and lastly needed to cross twice empty circles as quickly as possible in a clockwise fashion (CST zero). Part A consists of numbers from 1 to 16, Part B consists of letters from A to P, and Part C consists both letters (A-H) and numbers (1-8). CST zero condition was included to ensure correction of basic motor speed. The time needed in completion for Part C is compared with the average time needed for Part A and B to gain information related to executive functioning or concept shifting (Van der Elst et al., 2006). Additionally, errors during trials were recorded, and CST was individually conducted in paper-pencil.

#### 2.2.4. Number-Letter Task (NLT)

The task was included to measure set shifting ability with the permission from Boduroglu and colleagues (2014). The original version of the task was developed by Rogers and Monsell (1995). In NLT, used in the present experiment, a number-letter pair (e.g., 16 A) was presented in the center of the computer screen, and participants were instructed to decide whether the letter was consonant or vowel, or the number was odd or even. NLT included three blocks, and RT was recorded during each block for each answer. First and second block have 30 pairs (60 in total) with 10 examples for each block. Third block has 60 pairs with 10 examples, and it requires shifting between rules compared to first two blocks. By meaning, participants are needed to shift while rules are changing on the screen. Shifting cost was calculated by the difference between the average RTs of third block and first two blocks. The rule to be followed appeared on the top of the screen (odd- even or vowel-consonant) with the number-letter pair, and the rule disappeared after 1 sec while the pair remained on the screen. Participants gave answer with keyboard by using "K" (vowel, even) and "D" (consonant, odd) buttons, and next stimulus was presented after 150 ms when participant gave answer. Participants had 3 sec to answer after the rule was appeared for 1 sec. If they were not able to answer, then answer was recorded as a missing value.

### 2.2.5. Cognitive Flexibility Inventory (CFI)

CFI was originally developed by Dennis and Vander Wal (2010), and it was standardized in Turkish by Gülüm and Dağ (2012). Inventory was developed to measure how people produce alternative, compatible and balanced thoughts when they encounter a difficult situation. It comprises twenty items with two sub-scale which are control (7 items) and alternatives (13 items). Alternatives sub-scale measures individuals' comprehension and problem solving ability when they encounter possible alternatives of a condition. Besides, control sub-scale measures individuals' tendency to perceive difficult situations as controllable or not. Answers were collected via a 5 point Likert-type rating scale (1: Not appropriate at all, 5: Totally appropriate). Higher scores represent higher cognitive flexibility (Dennis & Vander Wal, 2010).

### 2.3. EEG Recording and Preprocessing

Experiments were performed in a soundproof and an electrically shielded room (a Faraday room), and participants ERPs were recorded during semantic memory FOK task. Presentation, recording, storage and analyses of the stimulus were conducted by using 64 Channel EEG NeuroScan system. EEG activity was recorded with 64 electrodes located in elastic Quick-caps (Neuromedical Supplies, Compumedics, Inc., Charlotte) depending on the international 10-20 system of electrode locations (Klem, Lüders, Jasper, & Elger, 1999). EOG activity was collected from two bipolar channels: two electrodes that were placed at the outer canthus of each eye, two electrodes that were placed below and above the left eye. Also, additional electrodes were placed at BP1/BP2 and on the left and right mastoids (M1/M2). All EEG electrodes were referenced on-line to Cz electrode at vertex and re-referenced off-line to connected mastoids. EEG/EOG signals were amplified and recorded at 1000 Hz sampling rate by using Synamp RT amplifier at AC mode (Neuroscan, Compumedics, Inc, Charlotte) with high-pass, low-pass and notch filter respectively; 0.15, 100 and 50 Hz. Additionally, EEG electrode impedance was kept below 5 kΩ. Curry 8 (Neuroscan, Compumedics, Inc. Charlotte) was performed in all data set of participants in EEG during pre-processing. Data was down-sampled to 250 Hz to reduce computational demands. Artifact rejection operated in three steps. In the first step, vertical and horizontal EEG/EOG channels that include activity passing over a threshold of ±100 μV were automatically detected and rejected. Secondly, trials with saccades identified over the horizontal EOG channel were manually removed. Thirdly, bad blocks were determined manually and removed from the continuous data. The segmentation was extracted with an interval of -200 ms preceding and 1000 ms following the onset. Because of the computation of ERPs, artifact-free segments were baseline corrected using 200 ms pre-stimulus period and then averaged for answers obtained from FOK judgments phase (know, do not know, FOK) and CJRs (high and low).

### 2.4. EEG Analysis

In the current study, mean analysis was used to evaluate ERPs, and mean amplitude (μV) values were detected for each participants at five time windows as follows; 0-100, 100-200, 200-300, 300-400 and 400-650 ms. Mean amplitude values were detected for both overall FOK, and levels of FOK (namely, know, do not know and FOK), and overall, high (4, 5, 6 responses on the scale), and (low 1, 2, 3 responses on the scale) recognition judgment phases separetly. Statistical analyses were conducted for four central electrodes: namely, Fz, Cz, Pz and Oz.

### 2.5. Procedure

Before the experiment, participants completed a questionnaire providing demographic information and were informed about the study. Participants were advised not to be hungry and not to use alcohol / caffeine, and to sleep well. Java programming language was used for presentation of the semantic FOK task. During the experiment, Windows 10 computer with a 29 inch monitor was used, and general knowledge questions and their answers were typed in white, Arial 24-point, lowercase letters on a black background. There was no time limit to answer the questions. For each phase, participants were given their answers with screen keyboard by using mouse and digitalized keyboard. Small breaks were given between phases of the task to prevent getting tired. Time of the experiment for each participant was approximately one and a half hour including setting up the EEG cap. At the end of the study, participants were received debriefing and were thanked for their participation.

# CHAPTER 3

# RESULTS

Before statistical analyses, main assumption of normality was evaluated except values of RTs, and violation of normality was not observed. However, linearity assumption was found violated as a main assumption of correlation analysis (Tabachnick & Fidell, 2007). Also, data was screened for outlier and missing values, and univariate and multivariate outlies were not determined. The results section was divided in two sections. First the behavioral results and then EEG/ERP results were presented, respectively.

## 3.1. Behavioral Results

The mean number of correctly recalled items was 37.4 (*SD* = 12.74; Min/ Max: 17/ 81), incorrectly recalled items was 21.08 (*SD* = 7.72; Min/ Max: 2/35) and unknown items was 34.51 (*SD* = 11.39; Min/ Max: 10/59). Also, mean value for correctly recognized items was 56.25 (*SD* = 10.27, Min/ Max: 39/92), and for incorrectly recognized items was 36.71 (*SD* = 10.27, Min/ Max: 1/54). In addition, percentage of correct recall was 34.41 and percentage of correct recognition was 52.08 among 93 questions for each phase. Average value for Gamma correlation was 0.49 (*SEM* = .05) and for calibration score was .46 (*SEM* = .01). Average response latency for FOK judgment phase was 3378.18 ms (*SD* = 1012.85), and RTs for only 'FOK' responses was 1134.25 ms (*SD* = 381.44). There was no significant correlation between ratings of 'know', 'FOK' and 'do not know' answers and total response time during FOK phase ($p > .05$). Also, there was no significant correlation between ratings of 'know' ($r(35) = .06$, $p = .72$), 'FOK' ($r(35) = -.01$, $p = .94$) and 'do not know' ($r(35) = -.08$, $p = .62$) during FOK phase and correct recall percentage.

To test the first hypothesis, correct answers during recall were divided as low (*M* = 29.57, *SD* =5.16) and high (*M* = 49.14, *SD* = 11.68), and same division was conducted for correct answers during recognition as low (*M* = 51.12, *SD* = 4.74) and high (*M* = 67.45, *SD* = 10.30). Participants' answers and RTs during FOK phase were compared according to high or low recall condition via one-way ANOVA. Results indicated that know ($F(1,34) = 13.27$, $p < .01$), do not know ($F(1,34) = 5.82$, $p < .05$) and FOK ($F(1,34) = 7.08$, $p <. 05$) answers during FOK judgment phase were significantly different with respect to high or low recall group (see Figure 3.1). Participants with high recall (*M* = 49.64, *SD* = 12.70) reported more 'know' answers compared to low recall (*M* = 34.38, *SD* = 11.75). For 'do not know' during FOK phase, answers from low recall participants (*M* = 20.85, *SD* = 8.54) was higher than high recall participants (*M* = 13.85, *SD* = 8.18). Participants with low recall (*M* = 37.76, *SD* = 8.08) gave more 'FOK' answers during FOK phase compared to participants with high recall (*M* = 29.50, *SD* = 10.31). On the other hand, RTs during FOK phase were not significantly different in terms of high or low recall ($p > .05$).

Also, performances during FOK judgment phase were retrospectively analyzed according to recognition performance (high vs. low recognition). 'Know' ($F$(1,34) = 14.98, $p$ < .01), 'do not know' ($F$(1,34) = 8.34, $p$ < .05) and 'FOK' ($F$(1,34) = 6.15, $p$ < .05) answers were significantly different with respect to participants' high and low recognition performance (Figure 3.2). 'Know' answers were higher for high recognition ($M$ = 52.00, $SD$ = 13.16) than low recognition ($M$ = 35.20, $SD$ = 11.34). 'Do not know' answers were higher for low recognition ($M$ = 20.75, $SD$ = 8.22) than high recognition ($M$ = 12.18, $SD$ = 7.96). And, 'FOK' answers were higher for low recognition ($M$ = 37.04, $SD$ = 8.23) than high recognition ($M$ = 28.81, $SD$ = 10.83) during FOK judgment phase.

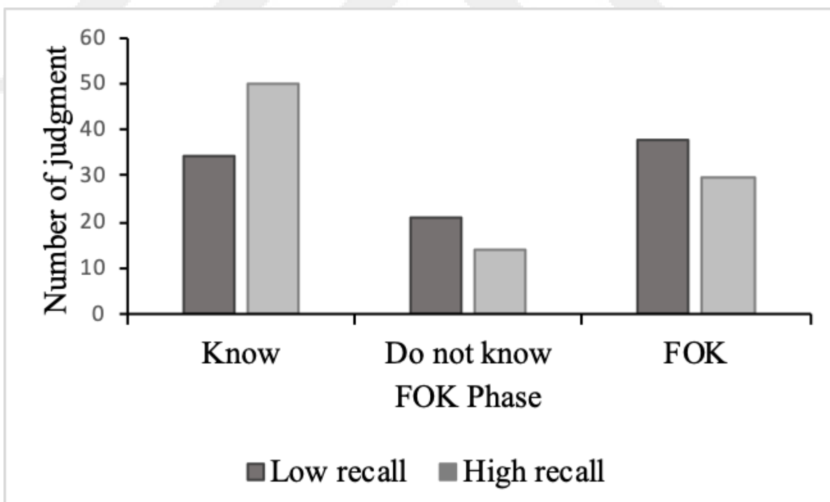


Figure 3.1. Frequency of judgments during FOK phase according to high and low recall

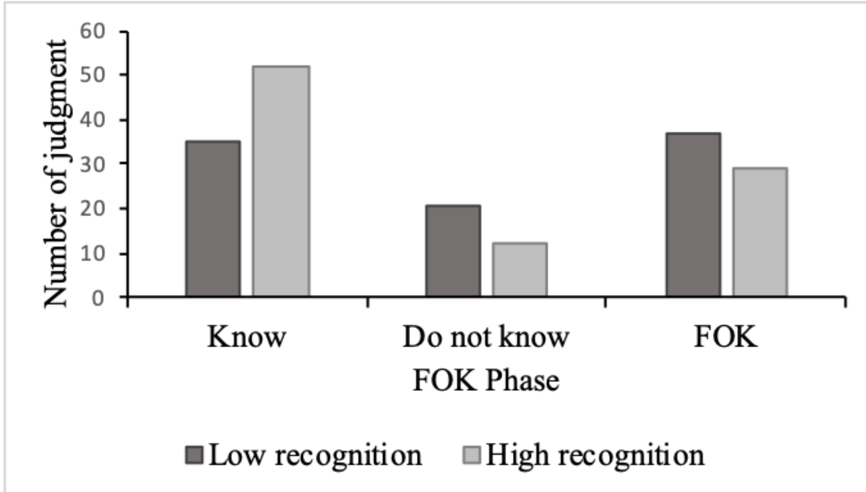


Figure 3.2. Frequency of judgments during FOK phase according to high and low recognition

To understand the relationship between set shifting, FOK and confidence judgments as stated in third hypothesis, Pearson correlation test was conducted. Results indicated that there were significant positive correlations between NLT and total response latency during FOK judgment phase ($r(34) = .34$, $p < .05$), number of ‘know’ answers during FOK phase and NLT ($r(34) = .41$, $p < .05$), RT for ‘FOK’ answers during FOK phase and NLT ($r(34) = .37$, $p < .05$), and number of ‘know’ answers during FOK phase and CST ($r(34) = .34$, $p < .05$). Also, there were significant negative correlations between ‘do not know’ answers during FOK phase and CST ($r(34) = -.36$, $p < .05$), and number of ‘FOK’ answers in FOK phase and NLT ($r(34) = -.48$, $p < .01$). Also, relationships between set shifting ability and CJRs with RTs were controlled. Results indicated that there were not significant relationships between set shifting ability and CJRs (see Table 3.1). Additionally, significant relationships were not observed in terms of cognitive flexibility with FOK judgments in FOK phase and CJRs ($p > .05$) (see Table 3.1).

Also, the relationship between values of FOK (number of know, do not know and FOK asnwers with their RTs) and recognition phases (number of correct, incorrect, high and low confidence with their RTs) were analyzed as stated in second hypothesis with Pearson correlation test. Results indicated that there were positive correlations between 'know' and number of correct recognition ($r(34) = .75$, $p < .01$), 'know' and high confidence ($r(34) = .51$, $p < .01$), 'do not know' and low confidence ($r(34) = .35$, $p < .05$), 'do not know' and number of incorrect recognition ($r(34) = .61$, $p < .01$), 'FOK' and number of incorrect recognition ($r(34) = .51$, $p < .01$), 'FOK' and low confidence ($r(34) = .42$, $p < .01$), 'FOK' and correct recognition RT ($r(34) = .53$, $p < .01$), 'FOK' and incorrect recognition RT ($r(34) = .38$, $p < .05$), 'know' RT and number of incorrect recognition ($r(34) = .52$, $p < .01$), 'know' RT and correct recognition RT ($r(34) = .33$, $p < .05$), 'know' RT and low confidence RT ($r(34) = .36$, $p < .05$), 'know' RT and high confidence RT ($r(34) = .29$, $p < .05$), 'know' RT and incorrect recognition RT ($r(34) = .33$, $p < .05$) (see Table 3.2).

Lastly, relationships between NLT shifting score with gamma ($r(35) = .01$, $p = .92$), and calibration scores ($r(35) = .07$, $p = .65$) were controlled via Pearson correlation analyses, however, significant relations were not found. The same analyses were conducted for relationship between CST shifting score with gamma ($r(35) = .08$, $p = .62$) and calibration scores ($r(35) = .09$, $p = .57$), and significant result was not found.

Table 3.1. Pearson correlation values between shifting and cognitive flexibility scores with FOK and CJRs

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.CST | 1 | | | | | | | | | | | | | |
| 2.NLT shifting | .28 | 1 | | | | | | | | | | | | |
| 3.CFI | .07 | .26 | 1 | | | | | | | | | | | |
| 4.Low confidence | -.08 | -.25 | -.24 | 1 | | | | | | | | | | |
| 5.High confidence | .08 | .26 | .24 | -1.0** | 1 | | | | | | | | | |
| 6.Low confidence RT | -.14 | .21 | -.05 | .018 | -.01 | 1 | | | | | | | | |
| 7.High confidence RT | .14 | .28 | .15 | -.027 | .02 | .21 | 1 | | | | | | | |
| 8.Know | .34* | .41* | .21 | -.51** | .51** | -.02 | .14 | 1 | | | | | | |
| 9.Do not know | -.36* | -.12 | -.27 | .35* | -.35* | -.04 | -.35* | -.73** | 1 | | | | | |
| 10.FOK | -.16 | -.48** | -.05 | .42* | -.42* | .08 | .11 | -.77** | .14 | 1 | | | | |
| 11.Know RT | -.06 | .20 | .05 | .25 | -.25 | .36* | .29 | -.39* | .39* | .21 | 1 | | | |
| 12.Do not know RT | .14 | .29 | .10 | -.13 | .13 | .21 | .58** | .12 | -.16 | -.02 | .58** | 1 | | |
| 13.FOK RT | .19 | .37* | .11 | -.02 | .02 | .15 | .59** | .14 | -.14 | -.08 | .58** | .74** | 1 | |
| 14.FOK phase total RT | .12 | .34* | .10 | .00 | -.00 | .26 | .58** | -.00 | -.01 | .01 | .79** | .92** | .89** | 1 |

*Note*. CST = concept shifting test, NLT = number letter task, CFI = cognitive flexibility inventory

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 3.2. Pearson correlations values between FOK and recognition phases

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Know | 1 | | | | | | | | | | | | | |
| 2.Do not know | -.73** | 1 | | | | | | | | | | | | |
| 3.FOK | -.77** | .14 | 1 | | | | | | | | | | | |
| 4.Know RT | -.40** | .39* | .22 | 1 | | | | | | | | | | |
| 5.Do not know RT | .12 | -.16 | -.02 | .58** | 1 | | | | | | | | | |
| 6.FOK RT | .148 | -.14 | -.08 | .58** | .74** | 1 | | | | | | | | |
| 7.Correct recognition | .75** | -.61** | -.51** | -.52** | -.01 | -.07 | 1 | | | | | | | |
| 8.Incorrect recognition | -.75** | .61** | .51** | .52** | .01 | .07 | -1.00** | 1 | | | | | | |
| 9.Low confidence | -.51** | .35* | .42** | .25 | -.12 | -.02 | -.40** | .40** | 1 | | | | | |
| 10.High confidence | .51** | -.35* | -.42** | -.25 | .12 | .02 | .40** | -.40** | -1.00** | 1 | | | | |
| 11.Correct recognition RT | -.37* | .00 | .53** | .33* | .31* | .44** | -.31* | .31* | .08 | -.08 | 1 | | | |
| 12.Incorrect recognition RT | -.16 | -.16 | .38* | .33* | .53** | .59** | -.10 | .10 | .00 | -.00 | .82** | 1 | | |
| 13.Low confidence RT | -.02 | -.04 | .08 | .36* | .21 | .15 | .02 | -.02 | .01 | -.01 | .15 | .09 | 1 | |
| 14.High confidence RT | .14 | -.35* | .11 | .29* | .58** | .59** | -.02 | .02 | -.02 | .02 | .37* | .50** | .21 | 1 |

** Correlation is significant at the 0.01 level (1-tailed).

* Correlation is significant at the 0.05 level (1-tailed).

## 3.2. ERP Results

### 3.2.1. Visual Analyses

In the current study, visual inspection analysis of grand average ERP waveforms was used to determine peaks of interest and their mean amplitude values. Grand average waveforms can be seen from Figure 3.3 and 3.4 for FOK (overall and FOK phase levels) and recognition confidence (overall, high and low) phases. Even though data was collected from 64 electrodes, 4 central electrodes were reported and analyzed. Since, it is known that FOK is mainly found as related with frontal, central and parietal regions, central electrodes from these regions were selected namely; Fz, Cz, Pz and Oz. However, general topography can be seen at Appendix 5 and 6.

Generally, it was seen from the Figure 3.3 that there is a negativity which peaks between 100-200 ms (N100) and it was followed by positive going wave around 200-300 ms (P200) for Cz electrode. Also, peak around 200 ms was especially clearly observed for Cz and Oz electrodes. There was also another observed negative going peak around 400 ms (N400) for each electrode. Lastly, it can be seen a slow wave as late positive component (LPC) between 400-500 ms for Fz and Cz electrodes. Additionally, there was a negativity late component around 800-100 ms for Pz and Oz electrodes especially for low confidence condition. Similarly, for Figure 3.4, there was positive going wave around 200 ms (P200), and it was followed by negative wave between 300-500 ms (N400), and LPC was observed especially for Fz and Cz electrode sides.

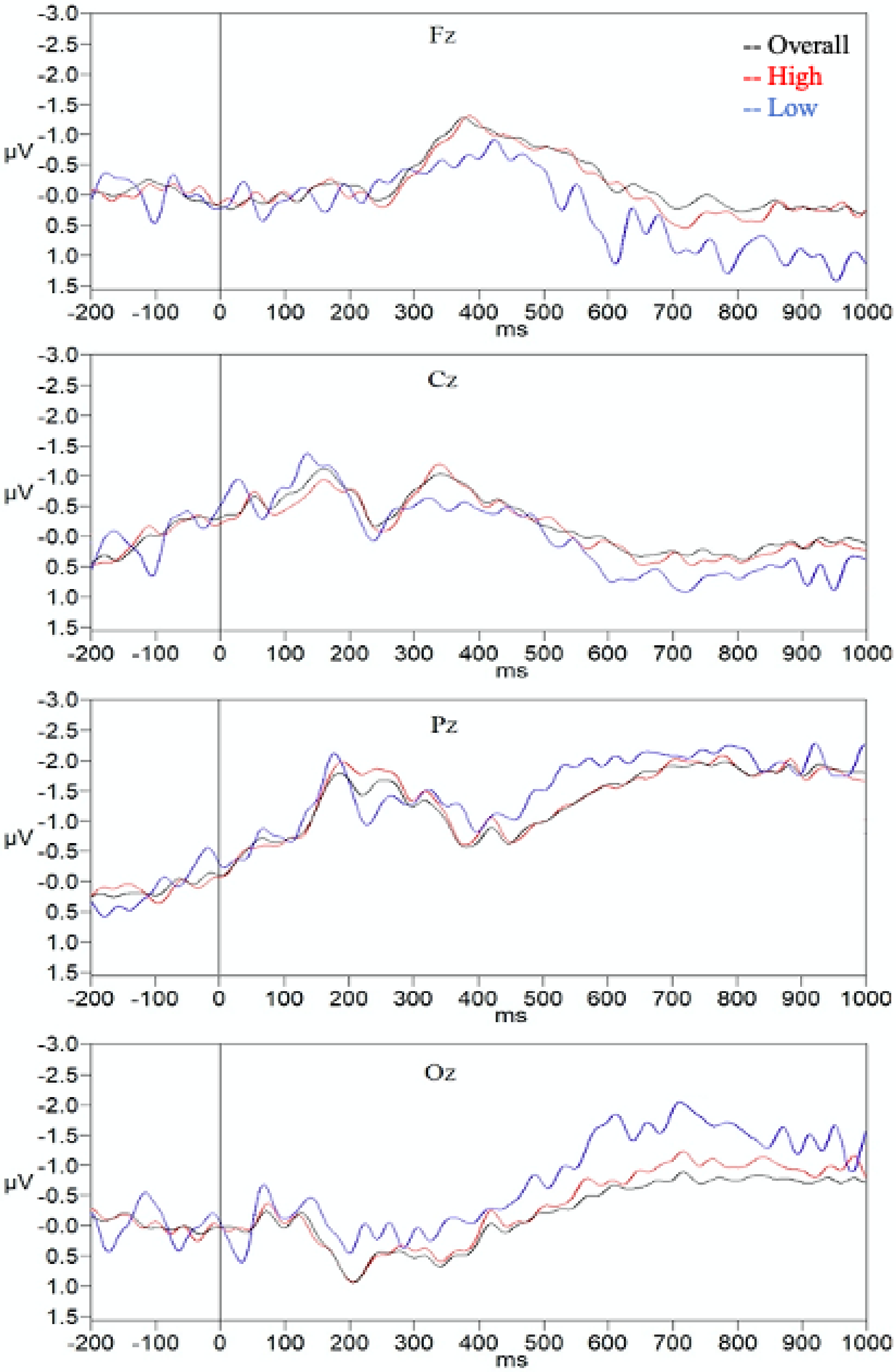


Figure 3.3. ERP grand average waveforms during confidence with overall, high and low at Fz, Cz, Pz and Oz electrodes

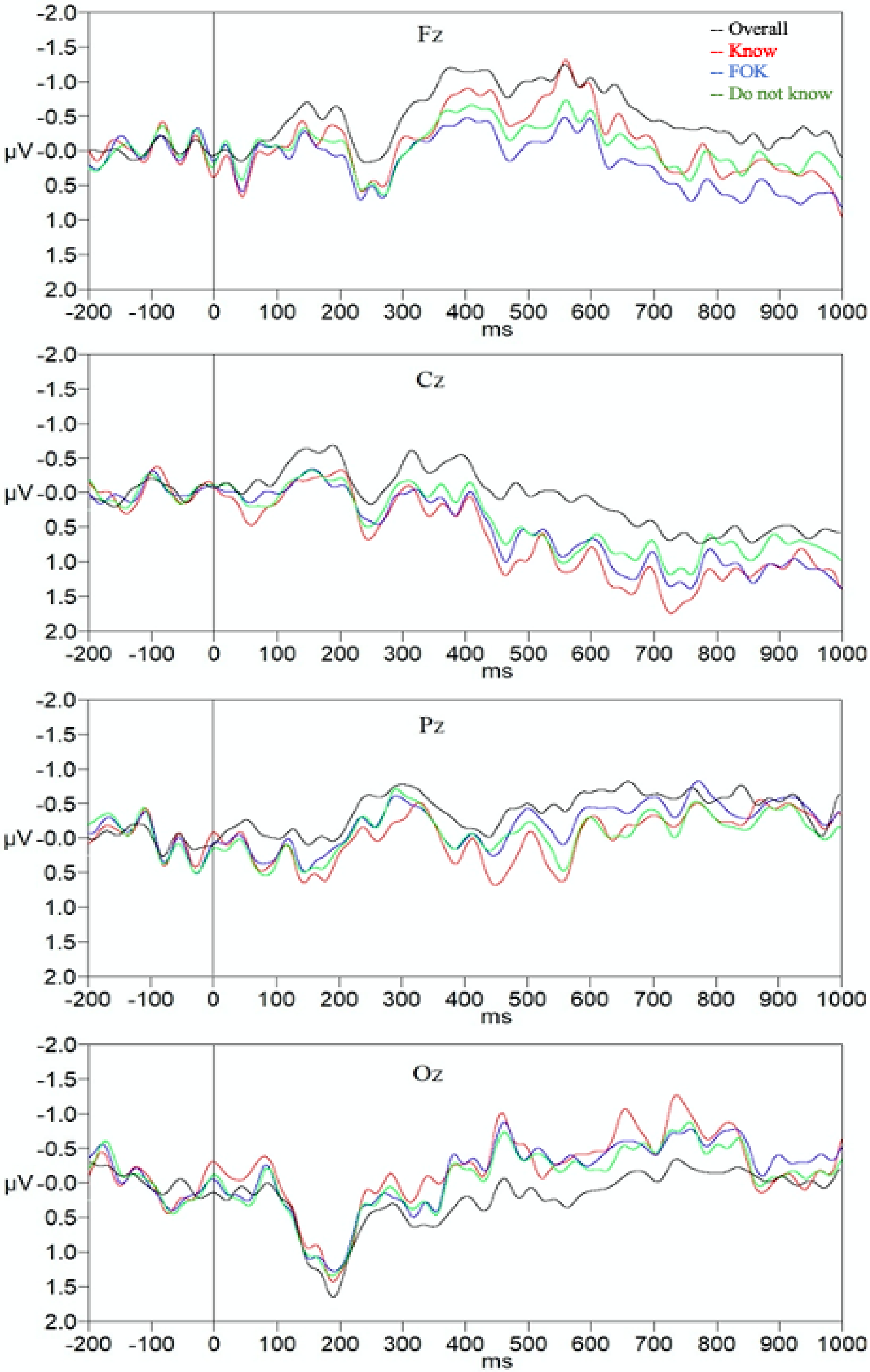


Figure 3.4. ERP grand average waveforms during FOK phase with overall and different levels of judgments at Fz, Cz, Pz and Oz electrodes

### 3.2.2. Statistical Results

Statistical analyses for ERP results were conducted in two steps to test the fourth hypothesis. In the first step, amplitude values during FOK (know, FOK, do not know) and CJRs (high and low) were analyzed for five time windows, namely 0-100, 100-200, 200-300, 300-400 and 400-650 ms. Accordingly, low confidence ratings (1, 2, 3) and high confidence ratings (4, 5, 6) were calculated as low and high ERP means. Analyses were conducted via within subject repeated measure ANOVA for FOK phase as 3 (FOK judgments: know, FOK, do not know) x 4 (electrode sides: Fz, Cz, Pz, Oz). Similarly, 2 (confidence judgments: high and low) x 4 (electrode sides: Fz, Cz, Pz, Oz) within subject repeated measure ANOVA was conducted for CJRs separately. All analyses were conducted for above mentioned five time windows separately. In the second step of the ERP analyses, overall amplitude values during FOK and CJRs were also analyzed without dividing their levels. For this purpose, within subject design repeated measure ANOVA was performed with overall amplitude values during FOK and CJRs phases for Fz, Cz, Pz and Oz electrode sides. Bonferroni confidence interval adjustment was applied for multiple comparisons, and Greenhouse – Geisser correction was applied when assumption of sphericity was violated. Also, paired sample t-test analyses were conducted for as post hoc between electrodes and conditions in previously mentioned time windows. Significant results were reported in the text only, however, all other results were summarized in tables with mean and standard error of mean values and that can be seen at Appendix 1, 2, 3 and 4.

#### 3.2.2.1. Comparisons between different FOK judgments (know, FOK, do not know) on ERPs

Results of the analyses indicated that there was no significant difference between amplitude values of know, FOK and do not know answers in 0-100, 100-200, 200-300, 300-400 and 400-650 ms time windows ($p > .05$) (see Appendix 1). However, when mean values were compared via visual graphics, it can be said that decision types were differentiated in FOK phase. During early time windows (200-300 ms), ‘FOK’ answers were more positive compared to other decisions in Fz, and the same pattern was observed for ‘know’ answers in Pz and Cz electrodes. Also, for all electrode sides, differentiation between decisions appeared in late time windows (after 400-500 ms). For Fz electrode, ‘FOK’ has more positive amplitude compared to ‘know’ and ‘do not know’ answers. Also, ‘know’ answer indicated more positive amplitude compared to ‘FOK’ and ‘do not know’ answers for Cz electrode. And, ‘FOK’ revealed more negative amplitude values than ‘know’ and ‘do not know’ answers especially between 500-800 ms for Pz electrode. For Oz electrode, the main differentiation from other decisions is for ‘know’ answers, and it indicated more negative going wave.

#### 3. 2. 2. 2. Comparisons between different CJRs (high and low) on ERPs

***3. 2. 2. 2. 1. 0-100 ms time window.*** The main effect of electrode on amplitude value during CJRs was significant ($\Lambda = .345$ $F(1.53, 30.67) = 4.847$, $p < .05$, $\eta^2 = .19$). Post hoc analyses revealed that Cz electrode ($M = -.55$, $SD = .13$) had higher amplitude than Fz electrode ($M = .13$, $SD = .15$), and Pz electrode ($M = -.61$, $SD = .18$) had higher amplitude value than Oz electrode ($M = -.02$, $SD = .17$). However, main effect of levels in CJRs and main interaction effect of electrode and levels in CJRs were not significant ($p$ > .05) (see Appendix 2).

***3. 2. 2. 2. 2. 100-200 ms time window.*** Main effect of electrode was significant on CJRs, $\Lambda$ = .377 $F$(1.85, 37.08) = 4.592, $p$ < .05, $\eta^2$ = .19. Cz electrode ($M$ = -.91, $SD$ = .24) was higher in amplitude than Fz electrode ($M$ = -.00, $SD$ = .29). Pz electrode ($M$ = -1.46, $SD$ = .31) was higher in amplitude than Oz electrode ($M$ = .09, $SD$ = .38). Other main and interaction effects were not significant ($p$ > .05) (see Appendix 2).

***3. 2. 2. 2. 3. 200-300 ms time window.*** Results indicated that there was a significant effect of electrode on amplitude values during CJRs, $\Lambda$ = .624 $F$(3, 60) = 3.919, $p$ < .05, $\eta^2$ = .16. Pz electrode ($M$ = -1.61, $SD$ = .48) had higher in amplitude than Oz electrode ($M$ = .37, $SD$ = .42). However, interaction effect of confidence judgments' levels and electrode, and effect of confidence judgments' levels were not significant ($p$ > .05) (see Appendix 2).

***3. 2. 2. 2. 4. 300-400 and 400-650 ms time windows.*** For time windows of 300-400 and 400-600 ms, significant effects of judgments' levels or electrode, and significant interaction effect were not found. However, even though all post hocs comparisons were non-significant, the main effect of electrode was significant. Therefore, paired sample t-test was used as post hoc comparisons in 300-400 ms. Results indicated that there were significant differences between Pz and Oz electrode for high confidence condition ($t$(20) = -3.120, $p$ < .05), and between Oz electrode for high confidence and Pz electrode for low confidence condition ($t$(20) = 2.966, $p$ < .05). Oz electrode for high confidence ($M$ = .44, $SD$ = .53) had lower amplitude value than both for Pz electrode during high confidence ($M$ = -1.17, $SD$ = .54), and Pz electrode for low confidence condition ($M$ = -1.38, $SD$ = .55) (see Figure 3.6).

### 3. 2. 2. 3. Comparisons for overall FOK judgments on ERPs

For time window of 100-200 ms, there was a significant main effect of electrode, $\Lambda = .573$ $F(2.00, 38.16) = 6.704$, $p < .05$, $\eta^2 = .26$. Oz electrode ($M$ = 1.00, $SD$ = 1.28) had higher amplitude than Fz ($M$ = -.52, $SD$ = 1.09) and Cz ($M$ = -.55, $SD$ = .85) electrode sides. However, no other significant relation was found for other time windows ($p > .05$) (see Appendix 3). On the other side, even though all post hoc comparisons were non-significant, the main effect of electrode was found significant. Thus, paired sample t-test was used as post hoc comparisons in 400-650 ms time window. Results indicated that there was a significant difference between Fz and Cz electrode sides in 400-650 ms time window ($t(19) = -4.294$, $p < .00$). Fz electrode ($M$ = -1.00, $SD$ = 1.72) had higher amplitude value than Cz electrode ($M$ = .02, $SD$ = 1.81) (see Figure 3.5).

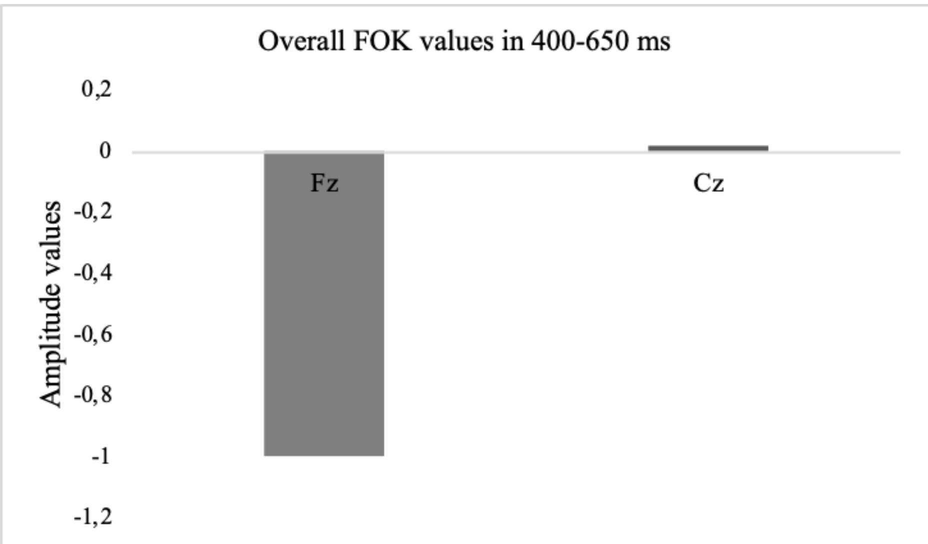


Figure 3.5. Overall FOK values at 400-600 ms time window

### 3. 2. 2. 4. Comparisons for overall CJRs on ERPs

***3. 2. 2. 4. 1. 0-100 ms time window.*** The main effect of electrode on amplitude values was found, $\Lambda = .435$ $F(1.65, 33.04) = 4.723$, $p < .05$, $\eta^2 = .19$. Cz electrode ($M = -.49$, $SD = .59$) had higher amplitude value than Fz electrode ($M = .15$, $SD = .76$), and Pz electrode ($M = -.61$, $SD = .85$) was higher in amplitude than Oz electrode ($M = -.00$, $SD = .76$).

***3. 2. 2. 4. 2. 100-200 ms time window.*** The main effect of electrode on amplitude values was significant, $\Lambda = .435$ $F(2.01, 40.20) = 5.137$, $p < .05$, $\eta^2 = .20$. Fz electrode ($M = .00$, $SD = 1.19$) had lower amplitude value than Cz electrode ($M = -.92$, $SD = .97$), and Oz electrode ($M = .23$, $SD = 1.70$) had lower amplitude value than Pz electrode ($M = -1.35$, $SD = 1.62$).

***3. 2. 2. 4. 3. 200-300 ms time window.*** The main effect of electrode was found for amplitude values, $\Lambda = .605$ $F(3, 60) = 4.473$, $p < .05$, $\eta^2 = .18$. Pz electrode ($M = -1.65$, $SD = 2.22$) had higher amplitude value than Oz electrode ($M = .59$, $SD = 2.11$).

***3. 2. 2. 4. 4. 300-400 and 400-650 ms time windows.*** Significant differences were not found between defined electrodes in time windows of 300-400 and 400-650 ms (see Appendix 4). Although the main effect of electrode was significant, all post hoc comparisons were not significant. Thus, paired sample t-test was conducted as post hoc comparison for 300-400 ms time window. Results showed that there was a significant difference between Oz and Pz electrode sides in 300-400 ms time window, $t(20) = -3.119$, $p < .01$. Pz electrode ($M = -1.08$, $SD = 2.37$) had higher amplitude value than Oz electrode ($M = .53$, $SD = 2.06$) (see Figure 3.6).

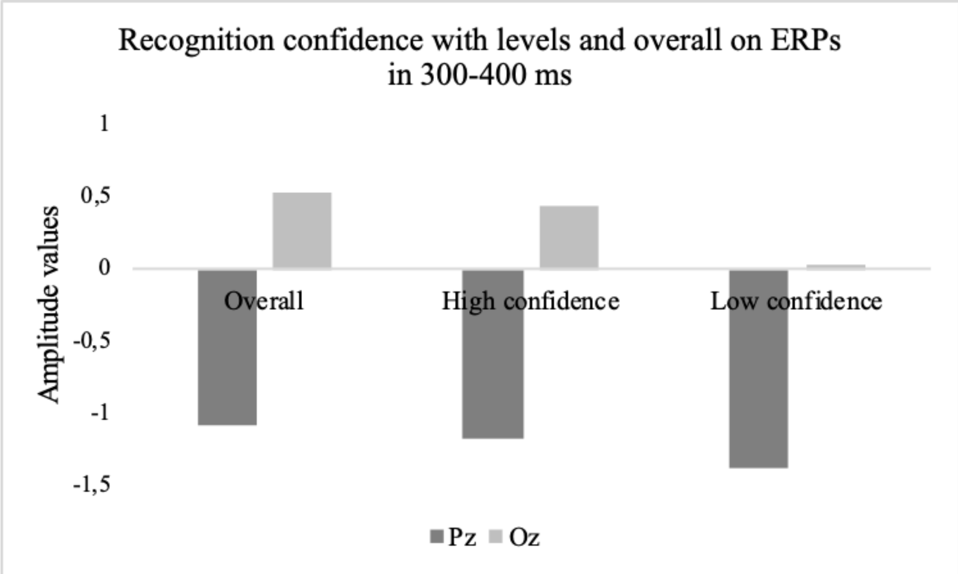


Figure 3.6. Recognition confidence with levels and overall on ERPs at 300-400 ms

### 3. 2. 3. Summary of ERP Results

Amplitude values were analyzed for both overall and different FOK and CJRs at five different time periods via four central electrode sides, namely Fz, Cz, Pz and Oz. For FOK judgment phase, significant result was only found in overall FOK values for Fz and Cz electrode in 400-650 ms time window, and Fz electrode showed higher amplitude value than Cz. However, amplitude values for overall and levels in CJRs indicated significant differences. Results generally showed that there was a following pattern for four electrodes in five time windows. To clarify, Cz electrode revealed higher amplitude value than Fz for early time windows, and same pattern is veridical for Oz and Pz electrode sides. Additionally, Pz electrode indicated not only higher amplitude value than Oz in early time windows, but also in 200-300 and 300-400 time windows.

# CHAPTER 4

# DISCUSSION

## 4.1. Overview

In the present study, FOK judgments and CJRs were analyzed by using EEG/ERPs in semantic memory task. For this purpose, Hart's (1965) RJR paradigm was used with 93 general knowledge questions. In that sense, occurrence of metacognitive judgments was evaluated with ERPs gathered from Fz, Cz, Pz and Oz which represents central electrodes in five different time periods namely; 0-100, 100-200, 200-300, 300-400, 400-650 ms. Additionally, participants' RTs and number of total correct, incorrect and missed answers were analyzed during recall, FOK and recognition phases. For the analyses of above mentioned behavioral variables, relationships between FOK and CJRs, set shifting ability and cognitive flexibility; in addition relationships between FOK judgments and CJRs were analyzed. Additionally, FOK judgments were evaluated according to recall and recognition phases both retrospectively and prospectively. General results indicated that there were both negative and positive significant relationships between FOK and set shifting ability, and FOK and CJRs. FOK answers were significantly differentiated according to recall and recognition performances that people with high recall and recognition reported more 'know' answers, and opposite pattern for 'FOK' answers.

ERP results of the study revealed that Cz had higher amplitude values than Fz electrode, and Pz had higher amplitude values than Oz electrode side for early time windows in overall and levels of confidence judgments. For overall FOK condition, only difference was observed between Fz and Cz electrodes in 400-650 ms time window. Fz electrode indicated higher amplitude value than Cz electrode. In the following section our results were discussed first for behavioral and secondly for ERP results.

### 4.2. Discussion for Behavioral Results

#### 4.2.1. Set shifting ability, cognitive flexibility and metacognitive judgments

Since the set shifting ability requires people to shift from one task to another, cognitive flexibility is necessary during set shifting. The concept of cognitive flexibility allows people to aim their attention on various tasks. Since they are quite interrelated cognitive processes, roles of these abilities were analyzed together while evaluating metacognitive judgments. It was assumed that when individuals make a judgment regarding a daily task, it is required to switch between thoughts or options and to focus their attention in order to properly direct their cognitive systems (Von Bastian & Druey, 2017). It is also generally accepted in the literature that individuals usually give faster responses to tasks when the trials include same stimuli repeated after each other compared to trials with mixed stimulus blocks. The difference in RTs or errors of individuals between these two conditions reflects switch or alternation cost (Von Bastian & Druey, 2017). In the current study, switch cost was measured for both NLT and CST when there is a necessity to switch between rules compared to no-switch condition.

Both behavioral and neuroimaging studies were conducted to understand mechanisms of set shifting ability in the literature, however, it could be hard to point out solid set shifting ability or its subdivisions due to intervening roles of external and internal stimulation such as various environmental stimuli and cognitive processes. In a recent study by Kim, Thesen and Woo (2017) investigated correlation between gray white matter volume in PFC and set shifting ability in healthy participants by using WCST and TMT. They found that correlation values were split between subregions of PFC, and TMT was found associated with grey white matter volume in Broca's area, right middle and superior frontal gyrus. However, WCST perseveration results were found positively associated with grey white matter in the left middle frontal gyrus. These findings indicate that shifting ability was not operated entirely by PFC, however, subregions of PFC also involve in these processes.

Behavioral results of the present study indicated both positive and negative correlations between set shifting ability and FOK judgments as they are both metacognitive processes associated with PFC. To specifiy, switching cost during NLT task was positively correlated with total RT of FOK phase, RT in only 'FOK' judgments, and number of 'know' answers. Also, it was negatively correlated with frequency of 'FOK' answers during FOK phase. Results for CST task in terms of FOK judgments revealed that it was positively correlated with number of 'know' answers, and negatively correlated with number of 'do not know' answers. These results supported the third hypothesis of the study in terms of FOK judgments. Perrotin and collegues (2008) did not observe a significant correlation between number of 'yes' FOK judgments and NLT, but found a significant positive correlation between NLT and gamma scores. Also, another study conducted by

Boduroglu et al. (2014) was not found significant relation between NLT shifting and metamemory measures, however, found significant C in episodic memory task. In the current study, significant correlation values were not found between NLT, gamma and calibration score, however, metacognitive measures which are ‘know’ answers, FOK total RT and ‘FOK’ answers’ RT were found positively correlated with NLT shifting score. Even though gamma values were not correlated, significant correlation between metacognitive measures revealed that shifting ability were directly related with cognitive functions in prefrontal lobe and executive functions which is consistent with the literature (Miyake et al., 2000). Moreover, observed inconsistency between these results revealed that there is a complex relationship between shifting ability and FOK as a metacognitive judgment. Differences between findings in the literature could also depend on variations in tasks, because FOK judgments were sensitive to task and perceptual stimuli (Miner & Reder, 1994). It was stated that alternation cost between trials was both associated to retrieval driven by the cue in response to particular rule, and to the executive processes operating between tasks (Rogers & Monsell, 1995). It can be speculated that significant positive correlations between ‘know’ answers with CST and NLT shifting scores could be more associated with cue-driven retrieval which was not observed before. Also, people could be rely on executive function processing demands while operating between rules as associated with correlation between shifting and RTs during FOK phase. In other words, these relations also include memory processes in addition to executive function processes such as retrieving some item from the memory to adjust a specific rule, and metacognitive judgments need similar involvement from both memory and executive functions.

Since shifting ability requires monitoring abilities, significant relations between CST, NLT and variables of FOK phase can be expected and same as for CJRs. However, relationship between confidence judgments and set shifting was not significant. Therefore, third hypothesis of the study was not supported by the findings in terms of CJRs. In the literature, it was stated that confidence and FOK judgments are differentiated from each other. Recognition accuracy is only regulated by memory strength, however, prospective confidence as FOK judgment is determined by more than one dimension which are both memory certainty and strength (Busey, Tunnicliff, Loftus, & Loftus, 2000). There is also another discussion regarding FOK and confidence judgments that FOK judgments are domain specific and depend on different cues in episodic and semantic memory, however, CJRs are domain general (Mazancieux, Dinze, Souchay, & Moulin, 2020). This suggestion may explain the non-significant relation between NLT, CST and confidence judgments compared to FOK phase. Because, when people evaluate their certainty about a memory pointer or try to reach a specific remembrance, they need to rely on monitoring and controlling processes as FOK judgment. On the other hand, this may change in CJRs while they are more confident about correctly recognized item. As supporting this, a significant difference was found between CJRs and FOK that individuals were significantly overconfident for CJRs compared to FOK judments (Mazancieux et al., 2020).

Another recent study by Von Bastian and Druey (2017) investigated subdomains of set shifting ability and how these different components have contribution to set shifting process. They found that it is hard to find a common shifting factor covering each underlying ability. In addition, authors stated that judgments regarding to both stimulus and its dimension, and response set shifting are both related and separable components of set shifting ability, however, stimulus set shifting like in TMT is the only factor found to be related to mapping shifting. Thus, it was concluded that even though stimulus response mapping was mentioned an only appropriate way of assessment in general set shifting ability, shifting between stimulus trials reflects shifts in visual attention as WM function rather than executive shifting process. In the current study, CST was applied as an updated version of TMT in paper pencil, and significant correlation was not found with other variables in FOK phase such as RTs. In that sense, this result can be confounded by detecting well-known material as visuo-spatial performance in WM.

Lastly, significant relations between CFI, FOK and confidence judgments were not found. Even though it was assumed in the current study that cognitive flexibility and shifting ability are so interrelated concepts, current results indicated that shifting ability is a quite complex operation with its subdivisions. It is stated as same that different types of cognitive flexibility such as shifting between dimensions, tasks or responses could be depending on different cognitive mechanisms (Kehagia et al., 2010 cited in Darby, Castro, Wasserman, & Sloutsky, 2018). Although the mechanism of cognitive flexibility is mostly linked to PFC, different neuroimaging studies showed that cognitive flexibility is also associated with hippocampus (Anacker & Hen, 2017). Therefore, eventhough its crucial role on set shifting ability is known, cognitive flexibility should be evaluated with tasks which are specific to its different mechanisms rather than paper pencil scales.

### 4.2.2. Discussion for Semantic Memory Task Variables

Percentage of correct recall was 34.41 and correct recognition was 52.08 for semantic memory task. Additionally, mean values of gamma (0.49) and calibration

(0.46) scores were calculated for participants. Gamma score was equivalent with FOK literature (Boduroglu et al., 2014; Luo, Kazuhisa, Ying, & Luo, 2004; Maril et al., 2003; Reggev et al., 2011; Souchay & Isingrini, 2012), however, it is a little small value when it is compared with episodic memory tasks. Such difference between values can be understood, because people's FOK accuracy may fall since they are evaluated with their previous knowledge about world instead of recently learned material. In either case, participants are quite accurate while predicting their future memory performance.

FOK judgment phase was evaluated according to participants' recall and recognition performances. Participants with high recall reported more 'know' answers compared to participants with low recall. Additionally, participants with low recall marked more 'do not know' and 'FOK' answers compared to those with high recall. The same pattern was also consistent for analyses of FOK phase according to recognition performances. People with high number of recognized item reported more 'know' answers compared to individuals with low recognition performance. Also, participants with low recognition performance marked more 'do not know' and 'FOK' answers when compared to individuals with high recognition performance. These findings are consistent in a sense that when individuals do not have enough experience or knowledge about a cue or an item, it is expected to report more 'do not know' answers, or vice versa.

However, different pattern was observed for 'FOK' answers in low recall and recognition conditions which is that participants marked more 'FOK' and 'do not know' answers. Also, when the correlations between FOK and recognition phase were evaluated rather than expected results (e.g. negative correlation between number of 'do not know' answers and correct recognitions), there were different findings. There was a significant negative correlation between number of 'FOK' answers and correct recognition, and, negative correlations were found between number of 'know' answers with 'FOK' and 'do not know' answers. Additionally, there were positive correlations between number of 'FOK' with incorrect recognition answers and number of low confidence. Therefore, it can be stated that first and second hypotheses of the study was supported by the current results. Tulving and Pearlstone (1966) stated that there is more available information than a person can access from memory, and sometimes people assume that they know something but actually not. In that sense, Koriat's (1994) accessibility theory is also related that people reach a piece of information about a memory pointer and make a judgment regarding that pointer, however, what they recall is not always necessarily successful. Therefore, when participants made a FOK judgment regarding their future memory performance, they may access a piece of information or a cue which is not enough to remember correct answer during the criterion test. Also, while participants made FOK judgments regarding a stimulus, they gave lower confidence to their answers. In that sense, CJRs and FOK are dissociated from each other (e.g. Mazancieux et al., 2020). From the results of the current study, it can be speculated that FOK judgments are domain specific as prospective judgment, however, CJRs are domain general as retrospective judgment. Schraw and Dennison (1994) stated about distinction between knowledge of cognition (a person's knowledge about his/her cognitive processes) and regulation of cognition (control aspects of learning such as planning, evaluation, information management etc.). Confidence judgments are evaluated as related to self monitoring part of metacognition even though it is quite related to other domains of metacognition (Kleitman, & Stankov, 2007). It was found that self-confidence is both a strong factor and not directly dependent on cognitive abilities (Kleitman, & Stankov, 2007).

Even though there are studies evaluated FOK judgments in three point Likert with fMRI studies (know, FOK, do not know) (Maril et al., 2001, 2003, 2005), there are not much evidence coming from behavioral results and ERP analysis. In that sense, decrease in variance while evaluating FOK judgment in three rather than six point Likert type may also cause to occur such findings, because there is a decrease in options for participants to choose.

### 4.3. Discussion for ERP Results

#### 4.3.1. ERP Results for Overall and Levels of FOK Phase

For overall FOK phase in early time windows, there was a significant difference between occipital and frontal regions in 100-200 ms. Oz electrode was higher in amplitude and more positive than Fz electrode side. Additionally, significant difference was observed between frontal and central regions for late time window (400-650 ms). Amplitude values for Fz electrode was higher and more negative than Cz electrode. On the other hand, significant results were not found in terms of levels of FOK judgments, however, differences in amplitude values were observed via visual analyses while participants make FOK judgments. It was detected that amplitude values were differentiated during FOK judgments, especially for late components. For Fz electrode, ‘FOK’ decisions were more positive than ‘know’ and ‘do not know’ answers. For central electrode, ‘know’ answers created more positive going wave compared to ‘do not know’ and ‘FOK’ answers. For parietal electrode, ‘FOK’ decisions created more negative wave compared to ‘know’ and ‘do not know’ judgments. Lastly, ‘know’ answers were more negative and clearly differentiated compared to other decisions in Oz electrode for late components. Reason behind the differentiation in occipital region could be speculated in a way that participants' neural reactions could be changed toward their already known items, and perception of these items could be different from others, since the current task requires reading general knowledge questions.

When the FOK judgments were evaluated, early frontal P200 and positive going peak around 300 ms (P3) is associated with familiarity of the item and it is gathered from central and frontal electrode sides (Paynter et al., 2009). Also, a fronto-central P200 and parietal N200 components were found while making FOK judgments in an episodic memory task (Irak et al., 2019). Different tasks were also used in ERP while measuring FOK judgments, and it was found that high FOK judgments created higher amplitude values than low FOK judgments for N100, P100, P200 and P300 components at frontal, central, parietal and occipital regions in face name recognition task (Irak, Soylu, & Turan, 2020). Additionally, it was known that negativity around 400-600 ms for frontal sides (FN400) has a pattern of increase for old items compared to new ones, and it has a midfrontal distribution which may extend to right and left sides of frontal lobe (Addante et al., 2012). However, recollection process was associated with positive going waves around 600-800 ms especially in parietal regions (Addante et al., 2012). And, such ERP component was also linked to autonoetic consciousness or explicit memory (Dunlosky & Bjork, 2013; Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997) which is mainly defined for one's conscious time travel experience through remembrances. Additionally, it was stated that LPC follows a person's cumulative exposure of the items when such memory signals related to decision and this situation was independent from whether such exposure recently happened or over the life time (Yang et al., 2019). Even though general knowledge about the world, known as semantic memory, was associated with noetic awareness, ERP findings indicated that both conscious and unconscious processes play roles in occurrence of such judgments and recollection. It was stated that such noetic feelings like FOK are based on inferential heuristics and they work implicitly, however, when these heuristics are activated and give rise to a consciouss feeling, they can then influence the controlled action (Koriat, 2000). Moreover, when frontal negativity during late time windows was considered, it was found that noetic awareness is linked to late negativity in fronto-central regions (600-1000 ms) (Düzel et al., 1997). From all these findings, it can also be assumed that processes of both familiarity and recollection have a strong and feeding role for each other in occurrence of such metacognitive judgments like it was hypothesized by Koriat and Levy-Sadot (2001). In that sense, even though significant results were not found especially for levels of FOK judgments unlike stated in the fourth hypothesis, visual graphics for especially frontal and parietal sides were supportive with the findings in the literature. In terms of FOK judgments, fourth hypothesis of the study was supported by the findings coming from the amplitude values at different electrode sides and time windows rather than levels of FOK judgments.

**4.3.2. ERP Results for Overall and Levels of Confidence Judgments**

Results coming from overall CJRs revealed that significant differences between amplitude values were mainly emerged before 400 ms compared to FOK judgments. For time windows of 0-100 and 100-200 ms, Cz electrode side had higher amplitude and more negative amplitude compared to Fz electrode. After 200 ms, differences between frontal and central regions were disappeared, and significant differences between occipital and parietal regions were emerged. Pz had higher in amplitude and more negative going wave than Oz for 200-300 and 300-400 ms time windows.

Similarly, when amplitude values of CJRs with levels (high and low) were evaluated, significant differences between all central electrodes were found similar to overall findings for early time windows (0-100 and 100-200 ms). Cz electrode side indicated higher amplitude and negativity than Fz, and same pattern was observed for between parietal and occipital regions. However, difference between frontal and central regions were not observed after early time windows, and significant differences were started to be observed between parietal and occipital regions between 200-400 ms. Oz electrode in high confidence indicated lower amplitude value than for both Pz in high confidence and Pz in low confidence conditions. Therefore, assumptions coming from the hypothesis of the study was partially supported that only amplitude values in early time windows were differentiated for CJRs rather than late time windows.

In the early emergence of negativity in parietal and central electrode sides, it was stated that parietal N200 was associated with filtering irrelevant information as a inhibition mechanism in terms of working memory (Nasr, Moeeny, & Esteky, 2008). In the concept of metacognitive judgments, it was found that there is negativity at parietal regions (N200) for general FOK judgments (Irak et al., 2019), and similar component was observed in the current study for confidence judgments both in levels and overall amplitude values. It was stated that low FOK judgments created larger parietal N200, and same pattern was observed in the present study for low confidence judgments in Pz electrode compared to Oz electrode side. It was concluded in a current study that negative component observed in parietal region in addition to fronto-central components may support the familiarity-based model (Irak et al., 2019). Additionally, such negative going waves were continue to emerge in 300-400 ms. Therefore, parietal contribution to such metacognitive judgments was also observed for confidence judgments, and observed negativity between 200-400 ms indicated that parietal contribution may take a long time than it was expected. Such cognitive process may have a feeding role for late processes, creating a connection from memory, or take a role in inhibition when distraction in memory is high due to task demands.

However, in the current analyses significant differences for late components (e.g. LPC) were not found unlike stated in the fourth hypothesis, eventhough there are findings regarding hit answers with high confidence (Addante et al., 2012). LPC was associated with a cognitive process that is responsible of preparing a response, which is preserved for a time after the initial representation of the stimulus (Gantman, Devraj-Kizuk, Mende-Siedlecki, Van Bavel, & Mathewson, 2020). Additionally, such component was linked to the integration of information from various processes and regions in the brain (Franklin, Strain, Snaider, McCall, & Faghihi, 2012). In that sense, differentiation between FOK and CJRs may be considered. When only confidence judgments were evaluated regardless of hit or miss condition, such metacognitive judgments may more rely on early cognitive processes (0-400 ms) or work as a threshold (Woodruff et al., 2006).

**4.4. Strengths and Limitations of the Present Study**

Current study has a value to contribute current FOK and CJRs literature, since there are scarce of evidence regarding ERP/EEG studies. Additionally, there are quite limited ERP studies evaluating FOK judgments with semantic memory. Even though four main central electrodes were analyzed for the purpose of the study, ERP data were collected from 64 channels. In the light of this, ERP data were accurate for both recollection and familiarity accounts that while people make judgments regarding their future recognition performance, they are quite accurate and this finding is apparent for both behavioral retrospective and prospective performances. In the sense of behavioral findings, present research had a research design to observe the role of set shifting ability on FOK and confidence judgments. Findings coming from this purpose are valuable, because such findings are rare and new. Therefore, understanding the role of such executive functions in occurrence of metacognitive judgments is important. Last but not the least, current study conducted a norming study in Turkish population with 154 questions from different question batteries which is quite important to accurately evaluate people's knowledge with a standardized measure. In that sense, frustrative effects of using outdating tools were eliminated from the study.

However, there are also limitations in the current study. In terms of behavioral measurement tools, CST task was conducted as paper pencil and specific time values were not collected due to application rules of the task. In that sense, sensitive values were not evaluated in the concept of task, so data and analyses may have overshadowed.

**4.5. Suggestions for Future Research**

Since general roles of executive functions on metacognitive judgments were known, specific contributions of these functions can be evaluated with different tasks. Such findings will be valuable to understand how metacognitive judgments occurs in the brain. Additionally, set shifting tasks can be computerized and rearranged to measure ERP to compare such findings with FOK judgments, so common ERP waveforms and time windows can be evaluated.

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**APPENDIX 1**

*Mean and SEM of amplitude values for FOK judgments' levels*

| Electrode | Time (ms) | Know | | FOK | | Do not know | |
|---|---|---|---|---|---|---|---|
| | | Mean | S.E.M | Mean | S.E.M | Mean | S.E.M |
| Fz | 0-100 | .20 | .21 | .12 | .19 | .01 | .22 |
| | 100-200 | -.28 | .26 | -.02 | .28 | -.20 | .28 |
| | 200-300 | .25 | .35 | .52 | .35 | .34 | .32 |
| | 300-400 | -.49 | .46 | -.21 | .46 | -.39 | .41 |
| | 400-650 | -.79 | .37 | -.16 | .38 | -.48 | .32 |
| Cz | 0-100 | .24 | .21 | .10 | .16 | .08 | .18 |
| | 100-200 | -.13 | .21 | -.16 | .22 | -.17 | .21 |
| | 200-300 | .27 | .37 | .13 | .35 | .18 | .32 |
| | 300-400 | .20 | .58 | .11 | .55 | .00 | .48 |
| | 400-650 | .93 | .63 | .69 | .56 | .64 | .54 |
| Pz | 0-100 | .14 | .25 | .16 | .16 | .24 | .21 |
| | 100-200 | .43 | .35 | .24 | .34 | .32 | .34 |
| | 200-300 | -.06 | .62 | -.41 | .61 | -.26 | .52 |
| | 300-400 | -.14 | .51 | -.20 | .54 | -.26 | .48 |
| | 400-650 | .20 | .53 | -.18 | .39 | -.00 | .39 |
| Oz | 0-100 | -.18 | .33 | .08 | .15 | .10 | .15 |
| | 100-200 | .88 | .34 | .88 | .34 | .98 | .34 |
| | 200-300 | .37 | .32 | .41 | .34 | .48 | .32 |
| | 300-400 | -.00 | .51 | .15 | .42 | .14 | .40 |
| | 400-650 | -.46 | .40 | -.40 | .36 | -.32 | .31 |

## APPENDIX 2

*Mean and SEM of amplitude values for recognition confidence judgments' levels*

| Electrode | Time (ms) | High confidence | | Low confidence | |
|---|---|---|---|---|---|
| | | Mean | S.E.M | Mean | S.E.M |
| Fz | 0-100 | .10 | .17 | .16 | .18 |
| | 100-200 | -.07 | .28 | .06 | .36 |
| | 200-300 | .03 | .39 | -.14 | .45 |
| | 300-400 | -.86 | .45 | -.46 | .45 |
| | 400-650 | -.56 | .41 | -.02 | .58 |
| Cz | 0-100 | -.45 | .12 | -.56 | .24 |
| | 100-200 | -.74 | .23 | -1.08 | .23 |
| | 200-300 | -.39 | .38 | -.29 | .36 |
| | 300-400 | -.94 | .29 | -.53 | .35 |
| | 400-650 | -.13 | .35 | .08 | .58 |
| Pz | 0-100 | -.56 | .24 | -.66 | .25 |
| | 100-200 | -1.40 | .38 | -1.52 | .30 |
| | 200-300 | -1.86 | .50 | -1.37 | .51 |
| | 300-400 | -1.17 | .54 | -1.38 | .55 |
| | 400-650 | -1.30 | .54 | -1.73 | .59 |
| Oz | 0-100 | -.05 | .20 | -.00 | .20 |
| | 100-200 | .27 | .41 | -.08 | .40 |
| | 200-300 | .57 | .47 | .18 | .41 |
| | 300-400 | .44 | .53 | .02 | .41 |
| | 400-650 | -.39 | .54 | -.94 | .47 |

## APPENDIX 3

*Mean and SEM of amplitude values for overall FOK phase*

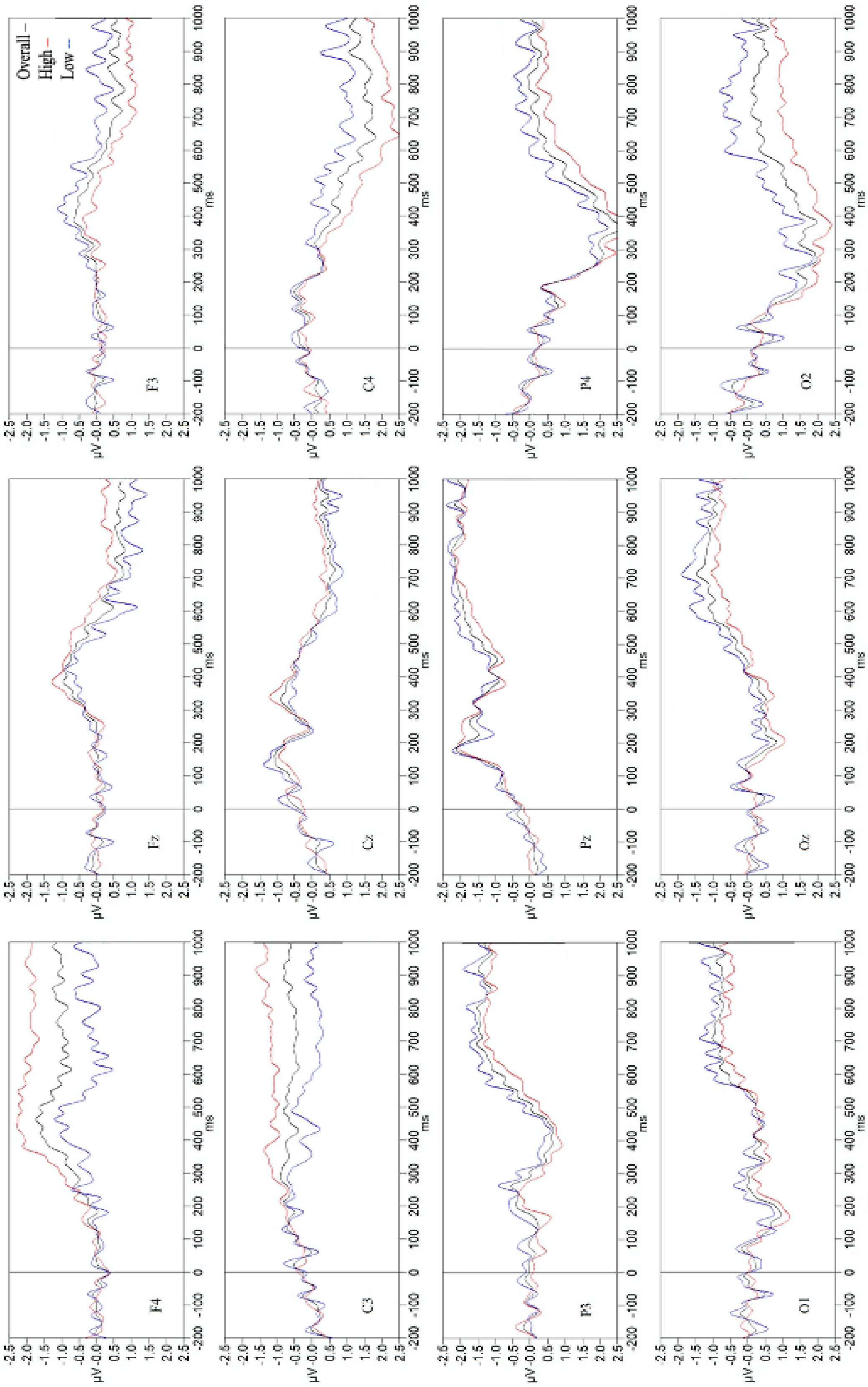
| Electrode | Time (ms) | FOK | |
|---|---|---|---|
| | | Mean | S.E.M |
| Fz | 0-100 | .00 | .15 |
| | 100-200 | -.52 | .19 |
| | 200-300 | -.07 | .34 |
| | 300-400 | -.90 | .41 |
| | 400-650 | -1.00 | .38 |
| Cz | 0-100 | -.09 | .11 |
| | 100-200 | -.55 | .19 |
| | 200-300 | -.09 | .35 |
| | 300-400 | -.45 | .44 |
| | 400-650 | .02 | .40 |
| Pz | 0-100 | -.10 | .12 |
| | 100-200 | -.00 | .29 |
| | 200-300 | -.53 | .41 |
| | 300-400 | -.50 | .37 |
| | 400-650 | -.43 | .22 |
| Oz | 0-100 | .14 | .12 |
| | 100-200 | 1.00 | .28 |
| | 200-300 | .63 | .30 |
| | 300-400 | .42 | .33 |
| | 400-650 | .19 | .29 |

## APPENDIX 4

*Mean and SEM of amplitude values for overall recognition confidence judgments*

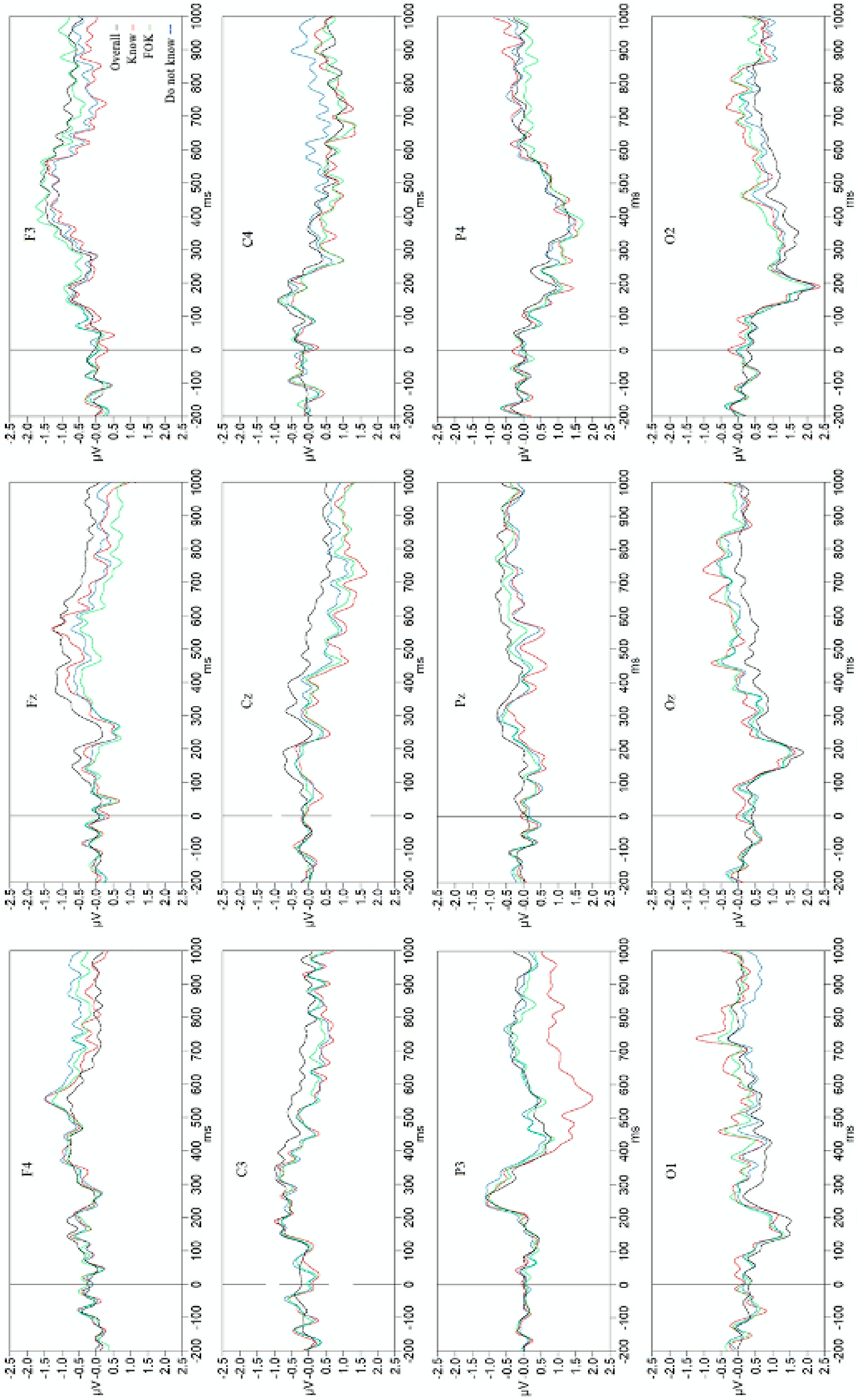
| Electrode | Time (ms) | Recognition confidence judgments | |
|---|---|---|---|
| | | Mean | S.E.M |
| Fz | 0-100 | .15 | .16 |
| | 100-200 | .00 | .26 |
| | 200-300 | -.06 | .37 |
| | 300-400 | -.93 | .47 |
| | 400-650 | -.60 | .40 |
| Cz | 0-100 | -.49 | .12 |
| | 100-200 | -.92 | .21 |
| | 200-300 | -.44 | .36 |
| | 300-400 | -.91 | .27 |
| | 400-650 | -.16 | .31 |
| Pz | 0-100 | -.61 | .18 |
| | 100-200 | -1.35 | .35 |
| | 200-300 | -1.65 | .48 |
| | 300-400 | -1.08 | .51 |
| | 400-650 | -1.29 | .53 |
| Oz | 0-100 | -.00 | .16 |
| | 100-200 | .23 | .37 |
| | 200-300 | .59 | .46 |
| | 300-400 | .53 | .45 |
| | 400-650 | -.26 | .37 |

## APPENDIX 5




Grand average ERP waveforms of confidence judgments with levels

## APPENDIX 6




Grand average ERP waveforms of FOK judgments with levels