Eastern Kentucky University

Encompass

Online Theses and Dissertations

Student Scholarship

2024

How Do Anxiety, Stress, Impulsiveness, And Sleep Quality Affect Memory

Hodavia Tshiya Kaseya
Eastern Kentucky University, odaviakaseya23@gmail.com

Follow this and additional works at: https://encompass.eku.edu/etd

Part of the Cognitive Neuroscience Commons, and the Cognitive Psychology Commons

Recommended Citation

Kaseya, Hodavia Tshiya, "How Do Anxiety, Stress, Impulsiveness, And Sleep Quality Affect Memory" (2024). *Online Theses and Dissertations*. 846.
https://encompass.eku.edu/etd/846

This Open Access Thesis is brought to you for free and open access by the Student Scholarship at Encompass. It has been accepted for inclusion in Online Theses and Dissertations by an authorized administrator of Encompass. For more information, please contact laura.edwards@eku.edu.

HOW DO ANXIETY, STRESS, IMPULSIVENESS, AND SLEEP QUALITY AFFECT MEMORY

BY

HODAVIA T. KASEYA

THESIS APPROVED:

Chair, Advisory Committee

Member, Advisory Committee

Member, Advisory Committee

Dean, Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master of Science degree at Eastern Kentucky University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this document are allowable without special permission, provided that accurate acknowledgements of the source are made. Permission for extensive quotation from or reproduction of this document may be granted by my major professor. In [his/her] absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this document for financial gain shall not be allowed without my written permission.

Signature:

X

Date: 10/9/2024

HOW DO ANXIETY, STRESS, IMPULSIVENESS, AND SLEEP QUALITY AFFECT MEMORY

BY

HODAVIA T. KASEYA

Submitted to the Faculty of the Graduate School of
Eastern Kentucky University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

2024

© Copyright by HODAVIA T. KASEYA 2024
All Rights Reserved.

DEDICATION

This thesis is dedicated to my mom and dad, whose unwavering love and guidance have shaped me into the person I am today. To my mom, Kamuanya, your strength and wisdom continue to inspire me. I am forever grateful for all you’ve done to help me reach this point, and I only wish you were here to share in this moment. This one is for you. Lastly, to my fiancé, Fidèle, my rock and greatest cheerleader, your belief in me has been a constant source of motivation. Thank you for always lifting me up and standing by my side. This accomplishment is as much yours as it is mine.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to my faculty mentor and professor, Dr. Lawson, whose guidance, encouragement, and insightful feedback have been invaluable throughout this entire journey. Your expertise and unfailing support helped me navigate challenges of this research, for that, I am truly grateful. Dr. Lawson, you are my inspiration, the mentor I aspire to become one day, and the person who made this all possible. I am also thankful to my committee members, Dr. Mitchell and Dr. Varakin, for their constructive suggestions and guidance, which helped me shape this thesis. Your advice has been instrumental in refining my ideas and strengthening my understanding of the topics discussed.

To my family, I owe everything. Your belief in me has kept me motivated. Finally, I am grateful to my friends and colleagues, whose cooperation and enthusiasm made this work possible. I would also like to acknowledge my cohort, Youmna. Thank you for being my support system throughout this journey. We've shared challenges, laughter, and growth, and I am grateful to have experienced this with you. Your encouragement and camaraderie made this process not only bearable but also unforgettable. This thesis is a culmination of the support, knowledge, and love I have received along the way. To everyone who has been a part of this journey, thank you.

ABSTRACT

Memory is a critical cognitive function that enables individuals to retain, recall, and apply knowledge across various contexts. Different memory systems, including working memory and long-term memory, collaborate to process and store information. Factors such as stress, sleep disturbances, anxiety, and impulsiveness can impact memory encoding and retrieval, especially in college students, whose academic success depends heavily on memory performance. This study examined the relationship between these everyday factors and memory performance by analyzing brain activity during memory encoding using Electroencephalography (EEG) and the Difference due to memory (DM) event-related potential (ERP) effect, to understand how stress, sleep, anxiety, and impulsiveness influence cognitive processing and recall. 51 college students recruited through Eastern Kentucky University's SONA system completed surveys assessing stress, anxiety, sleep disturbances, and impulsive behaviors, and participated in a memory task while EEG data was collected. The results highlight the complex relationship between these factors and memory processes, particularly emphasizing the role of anxiety in memory encoding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Memory is necessary for virtually all complex thoughts and actions. The ability to reuse knowledge or representations of previous and current events, as well as to remain consistent between the past and what is to come is a basic function of memory in life. All learning relies on memory since it enables you to retain and recall the knowledge you acquired. Additionally, the more comprehensive your framework of prior information is, the easier it is to connect new knowledge to that framework.

Human memory is not a unitary system, but rather a collection of systems (Baddeley, 1997). Research suggests that distinct types of memory function in humans to retain information both consciously and outside our awareness. It has been this contrast between conscious memory systems and more automatic systems that has been a recent focus for researchers.

Depending on the criterion used, there are many approaches to classifying different types of memory. One approach is to classify three distinct memory systems using duration as the criterion: attentional memory /sensory register, short-term /working memory, and long-term memory (Atkinson & Shiffrin, 1968; Matlin, 2003). Each of these systems includes both components of automatic and more conscious-controlled systems, although working memory is largely conscious in nature.

For instance, long-term memory (LTM) is often divided into procedural memory and semantic/declarative memory. Procedural memory is a more automatic form and reflects abilities that require practice and repetition to improve. One example of procedural memory is how practice and repetition will allow a person to learn to ride a bike, but consciously thinking about the steps of riding a bike will not suffice.

In accordance with Schwartz (2018), your "encyclopedia knowledge" or semantic memory is your organized understanding of the world. The perceptual, sensory, and motor systems serve as the basis for the unified memory system, which is disseminated in several brain areas (Yee et al., 2018). Semantic memory is vital for humans to identify things, comprehend and assign meaning to unfamiliar or abstract words, and engage with the outside world (Jones et al., 2015). It is also helpful for reading, figuring out where you are, and solving problems. For instance, you are aware that although wolves resemble dogs, they are wild animals, and you would be careless to want to pet one. Categories and concepts are the two primary forms of semantic information (Barsalou, 2009). Categories help us efficiently organize knowledge and make sense of the world by grouping similar things. With categories, conceptual relationships that belong together are represented. For instance, the knowledge that a wolf is a wild animal with four legs, that it is not a bird with wings or a beak. Concepts provide a more detailed and specific understanding of a category. They serve as mental representations of a category, such as the idea of a wolf and the understanding that it is related to other categories. These representations help us draw connections between related categories and enable us to apply past knowledge to new situations (Murphy, 2004).

Anderson's (1993) Adaptive Control of Thought (ACT) Theory is a comprehensive cognitive framework that aims to explain various cognitive processes, such as memory, learning, language, and problem-solving. ACT theory is based on the concept of a semantic memory network, which represents information as interconnected nodes or concepts connected by associative links. Practice and experience according to ACT can create or break links between concepts, which can affect learning and memory (Anderson, 2007). The theory suggests that adaptive control mechanisms play a crucial role in directing cognitive processes and enable individuals to adjust their behavior in response to changing tasks and environmental demands. The ACT theory provides a unified framework that connects different cognitive functions. It helps us understand how these mechanisms affect memory performance and directs our research toward examining the effects of stress, sleep disturbances, anxiety, and impulsiveness on cognitive control and memory.

CHAPTER II

LITERATURE REVIEW

Working, Sensory and Long-term Memory Systems

Working memory (WM) is a small-capacity form of short-term storage that utilizes information for conscious thought and is most active with difficult tasks such as learning, comprehension, and reasoning (Baddeley, 1992). Its performance is discrete from the vast storage capacity of long-term memory and is pivotal for ideal learning and development. Thus, working memory is a type of short-term memory but reflects the limited items we can process in our conscious stream of thought. A good way of understanding WM is that it serves as our conscious workbench where memories are combined with our current perceptual experiences to update and add to our long-term memory. It is essential for everyday life functioning; it allows us to investigate our current experience, as we move forward and to make sense of the world around us. Working memory is a cognitive system that allows us to temporarily store and manipulate information. In contrast, short-term memory is a subcomponent system that allows us to store information for a brief period. Working memory allows us to process, analyze, and think about information, whereas short-term memory is more limited in its use because the memories are not substantially altered.

Working memory is the cognitive function to stay concentrated on tasks and impede interferences. It aids with daily tasks such as writing essays, driving, studying, and is critical for encoding information into long-term memory (Baddeley, 2003). According to Baddeley (2010), the four components of working memory are the central executive, the visuospatial sketchpad, the episodic buffer, and the phonological loop. In processing data for memory, each component works independently of the others. Baddeley's working memory model begins with the phonological loop. This system element handles data gathered from both spoken and written language (Baddeley & Hitch, 1994). This component deals with matters like being taught information, having math problems, learning new words, or having addresses written down. Short-term memories are formed in this region during a discussion.

The second part of the phonological loop is the process of articulatory control. This is the internal voice that comprehends and uses the information from phonological storage. As a person speaks, the articulatory control process creates and generates the words. The visuospatial sketchpad processes visual and spatial information as opposed to the phonological loop, which processes spoken and written information (Baddeley & Hitch, 1994). Short-term memory serves as a storage space for this. The concept of spatial information refers to how people perceive their position in relation to other objects (Baddeley & Hitch, 1994).

The central executive component plays a crucial role in Baddeley's working memory paradigm. Because activities may need the utilization of many memories, the central executive manages memory and task switching, which is important for working memory (Baddeley, 2010). The central executive is also capable of preventing certain memories.

As working memory helps manage tasks and information, it also plays a key role in encoding. The first step in learning information is encoding. It is the most important stage in making a new memory. It is a technique for generating sensory information so that it may be evaluated and stored in the brain (McDermott & Roediger, 2018).

Information is processed and organized for storage and retrieval as well. Emotional events activate both conscious and unconscious neural pathways. The conscious pathways are responsible for the deliberate, hippocampus-based processing of sensory information, while unconscious pathways, driven by the amygdala, automatically increase attention and encoding, particularly for emotionally charged stimuli (Tyng et al., 2017). The conscious processes in the amygdala lead to the release of stress hormones such as adrenaline and cortisol, which enhance focus and strengthen memory encoding (McGaugh, 2004). As emotional intensity rises, synaptic plasticity improves, making remembering emotionally charged information easier later (McGaugh, 2004). As information is being encoded into memory, it is actively and deliberately modified.

Sensory memory (i.e., sensory registers) is a set of rapid and automated mechanisms that stores incoming information for a very short period, often a few seconds (Becker, 2023). Sensory memory is unique for each sense (i.e., sight, sound, touch, taste, smell). Unlike working memory, which can only keep a small amount of actively processed information, sensory memory has a very large capacity and is capable of storing an image of the sensory environment (Atkinson & Shiffrin, 1968). However, sensory memories are even more temporary than short-term memories. Unless they are transferred to working memory for additional processing and conscious consideration, they can fade fast, typically within seconds. This transfer of vital information from sensory memory to working memory enables us to acquire and retain significant details from our sensory experiences for subsequent cognitive processing and decision-making.

Long-term memory is the storage of long-lasting memories that can span several minutes or a lifetime depending on how well the information is encoded (Cowan, 2006). Procedural and declarative memory are the two types of long-term memory. Procedural memory is responsible for knowing how to do things and is largely unconscious. For example, learning how to ride a bike, play the piano, and how to make an omelet. Declarative memory is more consciously controlled and contains information about rules, events, and experiences that can be recalled when needed. Examples might include knowing the capital of a state, an important life event, or someone's birthday, as well as general information about the world. Memory encoding converts an event into a construct which is stored and then later recalled. Using mnemonic devices can help increase the ability to recall and retain information. According to Walker (2009), getting enough sleep improves memory retention and recall.

Encoding memories from WM to LTM

Consciously forming strong memories in long-term memory rely on a robust working memory (WM) activation. Working memory capacity (WMC) is the number of items a person can store in memory for a brief period (Vellage et al., 2019). The capacity of the WM is typically thought to be limited. Miller (1956) proposed the 'magical number seven,' suggesting that people can store around seven chunks of information in short-term memory. He referred to these pieces of information as "chunks," which are processed as groups. However, later research has refined this estimate, indicating that the number of chunks people can retain may be lower under specific experimental conditions. For example, Cowan (2001) suggested that the average WM capacity is closer to four chunks, particularly when distractions and rehearsal are minimized. Additionally, the number of chunks retained can vary based on how the chunks are classified and their characteristics (Service, 1998). For example, shorter words are retained for longer spans than longer words, with retention affected by phonological complexity and lexical status. Given the variability of these factors, measuring short-term or working memory capacity can be challenging.

Research shows that WMC generally allows individuals to store and manipulate around 3 to 5 items simultaneously, with an average capacity of 4. Those with lower WMC may struggle to maintain even this amount under certain conditions (Cowan, 2001). Kane et al. (2007) found that individuals with lower WMC tend to mind-wander more and have greater difficulty sustaining attention during tasks that require concentration and effort. This limitation can lead to challenges with tasks involving sustained attention, complex reasoning, and organization, as these tasks often require continuous cognitive engagement. However, WMC does not directly impact the ability to form or recall long-term memories, as working memory and long-term memory are distinct systems (Baddeley, 2000). On the other hand, those with higher WMC tend to perform better on tasks involving complex problem-solving, reasoning, and testing (Unsworth & Engle, 2007), as evidenced by the strong correlation between performance on working memory tasks and various measures of higher-order cognition.

There are several ways to measure working memory (Wang et al., 2015). Working memory load has been widely researched using the n-back task. Working memory tasks require the processing and temporary storage of items. The n-back task often involves updating working memory. In the n-back task, participants assess whether the current stimulus, which is commonly letters or numbers, matches the stimulus from prior trials. This specific task exemplifies updating working memory processes (changing old information with new ones) as well as generic working memory processes.

Considerable research has been conducted on college students' working memory, but it is still unclear how much everyday experiences affect working memory. The current study goal is to establish the extent of college students' working memory and how everyday life can influence their memory. Many factors affect college students' memory and how it is encoded, which influences what information you recall. Some key factors are stress, sleep disturbances, anxiety, and impulsiveness. For instance, a study by Alloway and Alloway (2010) found that working memory capacity significantly predicts academic performance in college students. Similarly, Unsworth et al. (2017) investigated the effect of sleep quality on working memory performance and concluded that sleep disturbances can impair working memory abilities. Additionally, Sari et al. (2016) explored the relationship between anxiety and working memory in college students and found that anxiety levels were associated with changes in WM processes. Furthermore, research conducted by Dougherty et al. (2004) has shown that impulsiveness in college students is associated with poor decision-making and engagement in risky behaviors. These studies highlight the need to understand how various factors, such as stress, sleep disturbances, anxiety, and impulsiveness can shape working memory in the college student population.

Working Memory in Older People

As humans age, there are a range of cognitive capacities, including a decline in working memory. Kontaxopoulou et al. (2017) found that older participants performed worse in incidental recall and recognition memory tasks when compared to younger participants. Older males performed significantly worse in intentional visuospatial free recall when compared to younger males, whereas older females performed similarly with the younger females in the same task.

Furthermore, older adults have increased difficulties in intentional memory compared to younger individuals while their incidental memory performance is intact. Intentional memory is a way an individual is told to memorize information. Incidental memory is a memory that is obtained without intention to remember. These results indicate that age influences incidental and intentional memory. This can be improved by practicing working memory skills and reducing multitasking. Bradlyn and Rollins (1980) found that subjects can attend to and name the color in which a word is printed. They are likely to process the word itself at least to a level of analysis that permits some retention. When subjects are instructed to read words and ignore print colors, their memory of the association between the word and print color is relatively less than when their primary task is to focus on naming the print color. These results show that if a participant tries to remember a color word in WM, it can impede the ability to identify the color, showing how divided attention impacts memory retention. It was also found that memory-monitoring (MEMO) can determine someone's memory storage (Hart

1967). MEMO allows participants to assess their knowledge, predicting whether they are likely to recognize or recall information. The results indicated that when someone feels that they know something, they are likely correct, and when they think they do not know it, they probably do not. However, it is important to note that MEMO reflects the accuracy of these judgments rather than directly determining memory storage.

Factors Affecting College Students' Working Memory

Working memory is critical to college student success because it allows students to read, pay attention during lectures, and recall information during exams. Working memory is a valuable skill for students to learn to strengthen so it can benefit them academically. It helps students hold on to information long enough to use it. For example, when working on a math equation you need to know which math formula is correct.

Stress reduces working memory performance. Stress affects information processing which in turn reduces students' ability to cognitively process information automatically. Being under stress can impede a person's capacity to encode memory and the ability to recall that information. Weerda et al. (2010) found only a weak effect of stress on behavioral measures in WM tasks. Their study suggested that psychological stress is associated with changes in neural activity in various parts of the hippocampus during encoding and retrieval. For instance, Robinson and Rollings (2011) found that participants who experienced the same internal mood state (either neutral or high stress/arousal) during both the learning and retrieval performed significantly better on recognition and recall tasks compared to those whose mood states were mismatched. This finding supports the concept of context-dependent memory, suggesting that consistent mood states can enhance memory performance, possibly by stabilizing neural activity in the hippocampus.

Various aspects of sleep such as duration, continuity, cycle, consistency, and environment all contribute to feeling rested and rejuvenated. Ensuring high-quality sleep each night is essential, as it plays a significant role in strengthening memories and enhancing cognitive function. You can process new information when you get a good night's sleep. When you learn something new, you can form a new memory. Not sleeping or getting enough sleep results in difficulty remembering new information learned. Other impacts include trouble focusing and learning. Previous research found that sleep disturbances affect working memory. For example, Xie et al. (2019) found that poor sleep quality and depressed mood can predict reduced WM capacity. Adolescents who obtain poor sleep on school nights (less than 8 hr./night) experience weak working memory performance when it comes to challenging tasks. Adolescents with poor sleep experienced daytime sleepiness, tiredness, and lack of motivation more than those with sufficient sleep. Adolescents who experienced sufficient sleep recalled more words in order. Therefore, if a person experienced a good amount of sleep, they performed better with recalling words (Gradisar et al., 2008; Frenda & Fenn 2016). Newbury et al. (2021) found that sleep deprivation has a deleterious impact rather than a facilitatory impact on memory. This indicates that sleep deprivation before learning decreases memory of what is learned. These previous studies, therefore, support the idea that sleep disturbances are negatively associated with memory.

Anxiety affects working memory by making it difficult to remember things like task instructions, conversations you previously had with someone, the information you just studied, etc. Prior studies have found that both state anxiety, which fluctuates depending on the situation, and trait anxiety, a more stable tendency to experience anxiety across different contexts (Endler & Kocovski, 2001) are correlated with or causally related to worse WM performance across task paradigms and contents. Anxiety was negatively correlated with both verbal and visuospatial WM performance along with the n-back task performance (Moran, 2016; Lukasik et al., 2019). Borkowski and Mann (1968) found that as proactive interference (PI) increased, STM declined. Although the PI developed, high anxiety resulted in a lower level of recall. Students demonstrated high levels of anxiety when put through to aversive visual stimulation and a reduction in their working memory and concentrated attention compared with the participants of the other groups without the same stimulation (Giron & Almeida, 2010). Figueira et al. (2017) found that the participants with the trait of high anxiety experienced a significant influence of the unpleasant emotional state on WM capacity, as indexed by contralateral delay activity (CDA). The asymptotic limit for the CDA amplitude was lower during the unpleasant emotional state than during the neutral one. Therefore, both the individuals who experienced more intrusive thoughts and those who were anxious were more susceptible to the influence of the emotional state.

Impulsivity, often defined as actions that are poorly conceived, prematurely expressed, unduly risky, or inappropriate to the situation and that often result in desirable outcomes (Mei et al., 2017), can have a significant impact on cognitive functioning and academic performance. One of the primary ways impulsivity affects working memory is by reducing the ability to sustain attention. College life is full of distractions, such as smartphones and social media, which can be particularly challenging for impulsive individuals to resist when they need to focus on academic tasks. This can lead to a constant diversion of their working memory resources from the task at hand, making it difficult to encode and retain information (Barkley, 1997). Moreover, impulsivity can make it harder to plan and organize effectively. College coursework often involves complicated assignments, long-term projects, and deadlines. Impulsive individuals may have difficulty creating and adhering to effective study schedules and time management, resulting in procrastination and last-minute cramming (Steel, 2007). Such habits can overload working memory, making it tougher to process and remember essential information. In addition, impulsivity may lead to poor decision-making in relation to sleep patterns and lifestyle choices. College students with high impulsivity may be more likely to stay up late, engage in excessive social activities, or neglect healthy sleep habits (Spinella, 2004). These behaviors can cause sleep disturbances, which, as previously stated, have a detrimental effect on working memory. Therefore, impulsivity indirectly affects working memory through its influence on sleep quality and patterns.

Factors Affecting Memory

Various factors affect encoding, which is converting sensory data into a format that can be retrieved later. Encoding is influenced by important factors such as attention, emotional relevance, and existing schemas or past knowledge. When people give their undivided attention to inputs, they can efficiently encode and recall them (Craik & Lockhart, 1972). Emotionally upsetting experiences are often stored and recalled more vividly than neutral ones due to the activation of the amygdala and the production of stress hormones (McGaugh, 2004). Additionally, people can more easily incorporate new information into their pre-existing conceptual frameworks, resulting in more effective encoding and retrieval (Anderson & Pichert, 1978). Personal factors like cognitive abilities and strategies can influence encoding efficiency. According to Unsworth and Engle (2007) individuals with high working memory capacities may encode and process information faster.

EEG & ERP

Electroencephalography (EEG) is a non-invasive way to measure brain electrical activity through scalp electrodes (Light et al., 2010). It can provide valuable insights into cognitive processes, brain functions, and neurological disorders (Michel & Koenig, 2018). With high temporal resolution, EEG is particularly useful for studying perception, attention, and memory (Luck, 2014). However, it has some limitations such as low spatial resolution, which can make it difficult to precisely locate brain activity, and sensitivity to noise and movements, which can affect accuracy (Nunez & Srinivasan, 2006). Despite these challenges, EEG remains a powerful tool for investigating brain function and understanding neurological disorders and cognitive processes. Ongoing research aims to refine EEG techniques and integrate them with other imaging modalities to gain insights into the human brain.

Event-related potentials (ERPs) are extremely small voltages generated in brain locations in response to certain events or stimuli. ERPs measure brain activity associated with both sensory and cognitive activities (Sur & Sinha, 2009). These are time-locked EEG changes in response to specific events, providing a noninvasive method for researching psychophysiological correlates of mental processes. Sur and

Sinha (2009), suggest that ERPs can be generated by various sensory, cognitive, or motor events.

ERP & Memory

Memory processes can be studied using event-related potentials (ERPs) which offer valuable insights into the neural mechanisms involved. Different stages of memory-encoding, consolidation, and retrieval-are associated with specific ERP components that shed light on these mechanisms. Memory performance improves when all information has been processed (Paller et al., 1987), with ERPs, triggered by specific stimuli like words, being valuable predictors of recall performance. By analyzing the amplitude, latency, and scalp distribution of the ERP waveform components, different cognitive processes can be identified (Luck, 2014). For instance, retrieval-vital for recalling information- activates memory-related neurons that work together to reconstruct memories (Tulving & Thomson, 1973).

One such component is the Difference due to memory (Dm) effect. The Dm component is an important focus that helps to differentiate between item memory (recognizing previously encountered stimuli) and source memory (recalling contextual details associated with stimuli (Paller et al., 1988)). To obtain the Dm effect, researchers compare ERP responses to correctly remembered items against those for incorrectly remembered items by subtracting the ERP waveform for non-recalled items from the waveform for recalled items (Friedman & Johnson, 2000). A positive Dm effect indicates greater neural response for items recalled correctly, suggesting enhanced processing related to memory retrieval. Conversely, a negative Dm effect implies reduced neural engagement for recalled items compared to non-recalled items, which might show difficulty in retrieval (Friedman & Johnson, 2000).

Moreover, ERPs play a significant role in understanding how encoding and retrieval processes interact. During the recall phase, memory-related neurons become active without external cues, and this neural activity can be detected through ERP analysis (Luck, 2014). Paller et al. (1988) findings revealed that words subsequently remembered elicited more positive ERPs within the 400-800 ms latency range following word onset, indicating that Dm is a reliable indicator of memory performance. Their research also emphasized the temporal dynamics of memory-related processes, showing that Dm may not solely reflect encoding processes but could also be influenced by post-acquisition factors like rehearsal and retrieval.

These findings highlight how ERPs offer a window into the neural processes that support memory. Not only do they aid in understanding memory encoding and retrieval, but they also provide insight into the broader cognitive processes of perception, attention, and decision-making (Luck, 2014). As demonstrated in research by Guo et al. (2006), understanding the neural mechanisms underlying item and source memory remains crucial, with ERPs continuing to play a pivotal role in cognitive neuroscience investigations.

Current Study and Hypotheses

The current study aims to examine the relationship between everyday factors and the encoding and subsequent recall of information. The study will focus on four main factors that commonly affect college students: stress, sleep disturbances, anxiety, and impulsiveness. These factors were selected due to their prevalence in students' lives, potentially influencing their cognitive functions and academic performance. There is a large body of research that has examined recognition and recall memory, and many studies have examined the individual impact of stress, sleep, anxiety, and impulsiveness on memory performance. Less research, however, has examined psychophysiological memory markers on these factors, and no known research has examined these four factors together in an EEG memory paradigm. It is important to understand how these factors interact during the encoding process, as captured by ERPs. This is crucial because it allows us to identify the neural processes that predict successful or unsuccessful recall at the time of encoding. Investigating the psychophysiological markers of encoding using EEG can provide a deeper understanding of the underlying neural mechanisms that contribute to memory performance, particularly under the influence of everyday challenges. This could offer valuable insights for designing interventions to improve encoding strategies in situations of heightened stress, poor sleep, anxiety, or impulsivity.

The Dm ERP effect is a sensitive psychophysiological marker of encoding and reflects a positive electrical waveform occurring 400 – 800 milliseconds. Our study will collect and analyze EEG data during the encoding phase to both capture brain differences in encoding between remembered and not remembered items, and then to examine relationships between this brain activation and the four factors that affect college students.

The memory task will involve presenting participants with a list of 30 words with EEG being recorded during this encoding phase. After a brief study period of five minutes, participants will be asked to recall as many words as possible. The goal of this task is to assess their working memory encoding into LTM, and its impact on subsequent retrieval. This study's significance lies in its ability to increase our understanding of brain and memory processes about everyday occurring factors. While previous research has focused on recognition memory or long-term memory retention, this study will shed light on the immediate impact of everyday stressors on recall memory. This research will also improve our understanding of what common factors are most important for memory in an academic setting. The findings can be useful for understanding memory function during critical periods of learning and academic performance.

Hypotheses:

1. A Dm ERP effect will differentiate recalled from not recalled words.
2. Participants who experience higher levels of stress will exhibit lower recall memory performance compared to those with lower stress levels.
3. Sleep disturbances will be negatively correlated with participants' ability to recall information.
4. Higher levels of anxiety will be negatively associated with recall memory performance.
5. Impulsiveness will negatively predict recall memory performance.
6. The Dm ERP effect will be related to factors that affect college students (i.e., stress, sleep disturbances, anxiety, impulsiveness).

CHAPTER III

METHOD

Participants

51 college students enrolled at Eastern Kentucky University were recruited through the SONA online sign-up and participation system (Sona System Ltd.). The students were 18 years of age or older and currently in Psychology courses PSY 200 (Introduction to Psychology), 240 (Scientific Literacy in Psychology), 340W (Research Literacy in Psychology), and 440 (Applied Scientific Literacy in Psychology). A recruitment statement was posted on SONA that allowed those who were interested in the study to participate. Participants received 2 outside credits through SONA which was applied towards a course completion credit or extra credit for a course. All participants provided informed consent before participating in the study, and IRB approval was gained.

The determination that the optimal sample size was 40 was determined using the G*Power computer program (Faul, Erdfelder, Buchner, & Lang, 2009) for multiple regression, logistical regression, and ANOVA tests. This program allowed us to make informed decisions regarding the number of participants needed for meaningful results. In our calculations, we considered the following key parameters:

- Effect Size (F^2): We selected an effect size of 0.35 for our analysis based on a medium effect size recommendation for ERP research, as proposed by Clayson, Carbine, Baldwin, and Larson (2019). Their study findings indicated that an effect size of 0.35 represents a conservative estimate for medium effects in the context of ERP research.

- Alpha Level (α): We established a significance level (α) of 0.05, corresponding to a 5% probability of making a Type I error.

- Power (1-β Error Probability): Our desired power level (1-β) was set at 0.80, signifying an 80% probability of detecting an effect if it indeed exists.

- Number of Predictors: Our analysis encompassed four predictor variables: stress, anxiety, sleep disturbances, and impulsiveness.

It is important to note that in Clayson, Carbine, Baldwin, and Larson's (2019) ERP research study, the average sample size per group was 21. Statistical power ranged from 0.72 to 0.98 for large effects, 0.35 to 0.73 for medium effects, and 0.10 to 0.18 for small effects. These findings highlighted the critical importance of adequately powered studies in ERP research and helped us decide on the effect size for this study.

Measures/Materials

Participants completed a demographic form (gender, age, ethnicity, education) and four surveys that assessed participants' stress levels, anxiety, sleep quality, and factors that could lead to impulsive behaviors. Participants were also asked to participate in a memorization task during which ERPs were recorded.

Perceived Stress Scale. A 10-item questionnaire was used from Cohen and Williamson (1988) to measure the participants' stress (see Appendix S). Stress levels reflected on their thoughts and feelings during the past month. Participants answered the questions using a 5-point Likert scale (0 = *never*, 1 = *almost never*, 2 = *sometimes*, 3 = *fairly often*, and 4 = *very often*).

State-Trait Anxiety Inventory. A 20-item questionnaire was used from Spielberg (1977) to measure the participants' anxiety by asking the participants about how they were feeling at the moment (see Appendix S). Participants answered the questions using a 4-point Likert scale (1 = *not at all*, 2 = *somewhat*, 3 = *moderately so* and 4 = *very much so*).

The Pittsburgh Sleep Quality Index (PSQI). A 9-item questionnaire was used from Buysse et al. (1989) to measure the participants' sleep disturbances in the past month (see Appendix S). Participants answered the questions using a 4-point Likert scale (0= *not during this month*, 1= *less than once a week*, 2= *once or twice a week*, 3= *three or more times a week*).

UPPS-P. A 59-item questionnaire was used from Cyders et al. (2007) to measure the participants' factors that could lead to impulsive behaviors (see Appendix S). Participants answered the questions using a 4-point Likert scale (1 = *agree strongly,* 2 = *agree some,* 3 = *disagree some* and 4 = *disagree strongly*).

Memorization Task. A memorization task was used to measure the participants' encoding and retrieval memory processes (Lawson et al., 2000). Participants were asked to recall as many words as they can from the word list and write them on paper. The task included a list of 30 words that were carefully selected to incorporate a diverse vocabulary, including both concrete and abstract words. This diversity allowed us to investigate memory processes under varying cognitive demands.

Each word in the list was selected with accuracy according to specific criteria. All words in the list consisted of precisely 5 letters, and the syllable count of the words was constant, with each word containing either 1 or 2 syllables. We used Google Ngram to assess the relative frequency of occurrence for each word in the list to confirm the suitability of the word stimuli. This ensured that the selected words were of an appropriate level of familiarity to the participants.

Participants were given a list of 30 words to memorize in 5 minutes. During this study phase, each word was presented for 3 seconds with an inter-stimulus interval of 1 second. Each word was presented twice in random order. After being given time to study the words, participants engaged in basic math problems, such as addition and subtraction. This additional cognitive activity served as a distractor task to prevent immediate recall and to allow for a more thorough evaluation of memory retention.

During the 5-minute study phase, EEG data will be collected. This involved placing electrodes on the scalp with an elastic EEG cap to measure electrical activity in the brain. By recording EEG data during the study phase, we aimed to investigate how neural activity relates to memory formation and how everyday factors can impact these processes.

After the distractor task, participants had 5 minutes to recall and write down as many words as they could remember from the initial study phase. This recall process was conducted in a free-recall manner, with participants not required to remember the words in any specific order.

Procedure

Participants were recruited and asked to sign up for the study through the SONA system (see Appendix B). A consent form was given to the participants before the study began (see Appendix C). They then completed a demographic survey and the four different surveys measuring their stress, anxiety, sleep disturbances, and impulsive behaviors (see Appendix D). The surveys were in paper format, with instructions at the top of the surveys; however, participants could ask questions if needed. The surveys took about 15 minutes to complete, but participants worked at their own pace. After completing the surveys, participants were hooked up to the EEG system. This involved placing an electrode cap on their head, filling electrodes with conductive gel, and checking for good electrical impedance. This process took about 5 to10 minutes. After the EEG cap placement, participants completed the memorization task. This task was timed and took approximately 30 minutes to complete. Instructions for the task were provided on the computer screen, and participants were informed to ask questions as needed. After completing the memorization task, they received a debriefing form and were thanked for their participation (see Appendix E).

Behavioral and Survey Scoring

A sum score was obtained for the words recalled by each participant from the memory task (1 point for each word recalled correctly). For the Stress survey, items 4,5,7, and 8 were reverse scored. Scores were summed across all scale items and kept as a continuous measure. For the Anxiety survey, all items were reverse scored. Scores were summed across all scale items and kept as a continuous measure. The Sleep Disturbances survey was a multiple-item measure. Scores were averaged and kept as a continuous measure. For the Impulsiveness survey, scores were averaged and kept as a continuous measure.

EEG Data Collection

The electrode sites PZ, FZ, T3, T4, FP1, FP2, F7, and F8 were used, and CZ as the reference. EEG data was collected while the participants studied the list of 30 words but not during the distractor task and recall. The placement of the electrode followed the 10-20 system (see Figure 16 for a schematic of electrode placement). Once the participants finished, the electrode cap was removed. They were given a debriefing form and allowed to leave.

Statistical Data Analyses

EEG data analysis was conducted using EEGlab software within MATLAB. Initially, the raw EEG data were preprocessed, which involves removing artifacts, filtering, and referencing. After the preprocessing, the grand event-related potentials (ERPs) were computed and visually examined. The results of the visual inspection aided in determining the amplitude windows for the Dm ERP components, which are critical indicators of cognitive processing. These determined amplitude windows served as the basis for quantifying the amplitude strength for the brainwaves. This amplitude strength data was used in subsequent statistical analyses.

Behavioral data were collected from participants, including four distinct measures: stress levels, anxiety, sleep disturbances, and impulsive behaviors. Additionally, data reflecting item recall and false recall were gathered. These data were analyzed using Jamovi, where multiple regression analyses to assess whether the four measured variables (stress, anxiety, sleep disturbances, and impulsive behaviors) collectively predicted the dependent variables of memory recall and false recall. Linear regression analyses were also used to examine whether these same predictor variables can predict amplitude strength for the Dm waves in the EEG data.

CHAPTER IV

RESULTS

Behavioral Results

Participants on average correctly recalled 10.3 words during the memory task. The average number of false recalls was 1.67, suggesting that while participants generally recalled words accurately, there were occasional errors. Figures 1 – 8 illustrate the correlation between the variables. A Pearson correlation analysis examined the relationships between stress, sleep disturbances, anxiety, impulsiveness, recall memory, and false recall (see Table 1). The analysis showed several significant correlations. Anxiety showed a significant positive correlation with stress, $r(49) = 0.728$, $p < .001$, indicating that as anxiety levels increase, stress levels tend to increase among participants. Additionally, there was a significant positive correlation between stress and sleep disturbances, $r(49) = 0.375$, $p = 0.007$. There was also a significant negative correlation between false recall and recall, $r(49) = -0.408$, $p = 0.003$.

Table 1. *Pearson correlation and P-values, Stress, Sleep Disturbances, Anxiety, Impulsiveness, Recall, and False Recall*

Variable		1	2	3	4	5
1. Stress	Pearson's r p-value					
2. Sleep Disturbances	Pearson's r p-value	0.375 0.007*				
3. Anxiety	Pearson's r p-value	0.728 <.001***	0.275 0.051			
4. Impulsiveness	Pearson's r p-value	0.252 0.075	-0.018 0.898	0.255 0.071		
5. Recall	Pearson's r p-value	-0.178 0.211	0.014 0.923	-0.251 0.075	-0.266 0.059	
6. False Recall	Pearson's r p-value	0.045 0.756	-0.121 0.397	-0.031 0.830	0.197 0.166	-0.408 0.003**

Note. * indicates p < .05, ** indicates p < .01, *** indicates p < .001

Contrary to Hypothesis 1, stress was not correlated with recall memory, r (49) = -0.178, p = 0.211. Furthermore, the hypothesis that sleep disturbances would negatively correlate with participants' ability to recall was not supported, r (49) = 0.014, p = 0.923. Similarly, the hypothesis that higher levels of anxiety would be negatively associated with recall memory was not supported, r (49) = -0.251, p = 0.075 (marginal effect). The hypothesis that impulsiveness would negatively predict recall memory performance was not supported, r (49) = -0.266, p = 0.059 (marginal effect).

Interestingly, there was a marginal effect between sleep disturbances and anxiety, r (49) = 0.275, p = 0.051. There was also a marginal effect between impulsiveness and anxiety, r (49), =0.255, p = 0.071, as well as between impulsiveness and stress, r (49) = 0.252, p = 0.075.

ERP Results

Figures 9 – 14 provide ERP grand average waves for each electrode site. The differences due to memory (Dm) effects were determined using repeated measures ANOVA for each electrode. The results are shown in Table 2. Electrode FP1 showed a significant Dm effect (p = 0.044), and electrode F7 showed a marginal Dm effect (p = 0.055). In contrast electrodes FZ, FP2, F8, and T3 did not show significant Dm effects (see Table 2).

Table 2. *Repeated Measures ANOVA Results for Dm Effect Across Different Electrodes*

Electrode	Sum of Squares	df	Mean Square	F	p	Significant Effect ($p < 0.05$)
FZ	6.35e-4	1	6.35e-4	0.778	0.382	No
FP1	0.0403	1	0.04032	4.25	0.044	Yes
FP2	0.0205	1	0.02048	2.16	0.148	No
F7	0.0284	1	0.02837	3.85	0.055	No
F8	0.00962	1	0.00962	1.74	0.194	No
T3	0.0178	1	0.1776	2.59	0.114	No

Linear regression analyses were conducted to determine the relationship between the Dm ERP effect and factors affecting college students (stress, sleep disturbances, anxiety, and impulsiveness) at electrodes FP1 and F7. Electrode F7 showed a significant relationship between anxiety and the Dm ERP effect ($p = 0.003$). Additionally, stress showed a marginal effect ($p = 0.094$), and sleep disturbances also showed a marginal effect ($p = 0.057$). However, impulsiveness was not significantly correlated with the Dm ERP effect ($p = 0.830$). At electrode FP1, none of the factors significantly correlated with the Dm ERP effect (see Table 3).

Table 3. *Linear Regression for Dm Predictors at Electrodes FP1 and F7*

Predictor	Estimate (FP1)	p-value (FP1)	Estimate (F7)	p-value (F7)
Intercept	0.04784	0.806	-0.12837	0.265
Stress	0.00177	0.775	-0.00616	0.094
Sleep Disturbances	0.00173	0.772	-0.00679	0.057
Anxiety	-0.00592	0.142	0.00743	0.003**
Impulsiveness	0.08533	0.300	-0.01032	0.830

Note. * indicates p < .05, ** indicates p < .01, *** indicates p < .001

CHAPTER V

DISCUSSION

The current thesis examined the impact of stress, sleep disturbances, anxiety, and impulsiveness on memory recall and the Dm ERP effect. Behavioral results found that only anxiety and impulsivity marginally correlated with recall. For the ERP data, the Dm effect was found frontally, and increased anxiety was related to a more pronounced Dm effect. These results show that anxiety and likely impulsivity affect encoding recall, and that frontal brain processes are most implicated in encoding differences that lead to recall.

Behavioral Findings

The hypotheses proposed that higher levels of stress, sleep disturbances, and anxiety would be negatively correlated with recall memory performance, and that impulsiveness would also negatively relate to recall memory performance. The results only partially supported our behavioral hypotheses, as stress and sleep disturbances were not significantly correlated with recall memory performance. Anxiety (p = .075) and impulsiveness (p. = .059) showed a marginally negative relationship with recall. This contrasts with Craik and Lockhart's (1972) findings which emphasize that deeper levels of processing, such as focusing on meaning, enhance recall. In our study, anxiety and impulsiveness appeared to hinder, rather than facilitated deep encoding and retrieval of information. Similarly, McGaugh (2004) found that emotional arousal, mediated by stress hormones and amygdala activation, enhances memory consolidation, whereas our results suggest that anxiety may interfere with memory performance under certain conditions. Additionally, Unsworth and Engle (2007) demonstrated that individuals with higher working memory capacity are able to maintain task goals and retrieve relevant information, leading to improved recall. However, our finding indicates that impulsiveness was marginally negatively related to recall, suggesting that poor attention control may have hindered participants' ability to encode and retrieve information effectively.

Dm ERP Findings

In addition, the study examined the impact of Dm ERP on memory recall and its connection with stress, sleep disturbances, anxiety, and impulsiveness factors affecting college students. It was hypothesized that the Dm ERP effect would differentiate recalled from not recalled words and relate to factors such as stress, sleep disturbances, anxiety, and impulsiveness.

The Dm effect is known to reflect brain activity during the study phase, and the recall phase is used to sort words into subsequently recalled and subsequently forgotten items. The hypothesis that the ERPs during the study phase could differentiate between recalled and not-recalled words was supported, but at only electrode FP1 ($p = 0.044$) and marginally at F7 ($p = .055$). This finding supports previous research by Paller et al. (1988), who found the Dm effect to be a reliable indicator of memory performance. In contrast to prior research, however, the Dm effect is often found in posterior electrodes. For our results, FZ, FP2, F8, and T3 did not show significant Dm effects and warrant further investigation (see Table 2).

Previous research has typically found the Dm effect occurring between 400-800 ms post-stimulus, predominantly at centro-parietal sites, which are often associated with deeper memory encoding processes (Paller et al., 1988). However, the Dm effect observed in this study at frontal electrodes such as FP1 and F7 presents an interesting distinction. While frontal differences in the Dm effect have been reported under specific task conditions that require cognitive control or attentional resources (Mangels et al., 2001), they are less commonly observed compared to centro-parietal sites. This frontal Dm effect observed in the current study could indicate the involvement of brain regions associated with cognitive control and attention during encoding, which may differ from the classic Dm effect seen at parietal sites that typically reflects more automatic memory processes.

A frontal Dm effect at FP1 and marginally at F7 in this study could point to a different set of brain processes influencing memory encoding, particularly those related to the emotional or attentional modulation of the task. The absence of significant effects at typical centro-parietal electrodes like FZ and FP2 further distinguishes these findings from traditional Dm studies (Paller et al.,1987). This variation from prior research suggests that future studies should investigate the role of frontal regions in modulating the Dm effect, particularly under conditions that engage emotional or attentional processes, as seen in this study involving anxiety.

The second hypothesis proposed that the Dm ERP effect would be related to stress, sleep disturbances, anxiety, and impulsiveness. The results of the linear regression analyses offered mixed support for this hypothesis. At electrode F7, there was a significant relationship between anxiety and the Dm ERP effect ($p = 0.003$). This indicates that higher levels of anxiety are correlated to a more pronounced Dm ERP effect. This finding suggests that anxiety may intensify the neural differentiation between recalled and not recalled words, possibly due to increased cognitive or emotional engagement. This finding supports the notion that emotionally significant experiences, such as those involving anxiety, can improve memory retention (McGaugh, 2004). Stress ($p = 0.094$) and sleep disturbances ($p = 0.057$) exhibited marginal effects at electrode F7. These marginal effects indicate that both stress and sleep disturbances might have some influence on the Dm ERP effect, although the relationships are not strong. Impulsiveness was not significantly associated with the Dm ERP effect at electrode F7 ($p = 0.830$), suggesting that impulsiveness has a weak impact on the neural processes involved in memory recall.

At electrode FP1, none of the factors (stress, sleep disturbances, anxiety, impulsiveness) significantly correlated with the Dm ERP effect (see Table 3). This suggests that the neural mechanisms associated with electrode FP1 are not as sensitive to these factors as those captured by electrode F7. The significant Dm effect at electrode F7 highlights the importance of using ERPs to study memory processes. This finding reinforces the use of EEG and ERP techniques in cognitive neuroscience for identifying neural factors related to memory performance (Luck, 2014). The significant correlation between anxiety and the Dm ERP effect at electrode F7 emphasizes the impact of emotional states on shaping neural activity associated with memory. This finding indicates that anxiety might improve the distinction between remembered and forgotten words, possibly by increasing cognitive or emotional involvement during memory-related activities.

The marginal effects of stress and sleep disturbances on the Dm ERP effect at electrode F7 suggest that these factors may influence memory-related neural processes, although these effects did not reach statistical significance. These trends indicate areas for further investigation into how stress and sleep disturbances impact memory at both neural and behavioral levels. Notably, the behavioral results showed significant correlations among several variables, shedding light on their influence on memory performance.

Previous research has shown that frontal electrodes, such as F7, are particularly sensitive to differences in cognitive processes, such as shallow versus deeply encoded words, as demonstrated by Jaeger et al. (2008). This emphasizes the role of frontal regions, particularly in the left hemisphere, in modulating the depth of encoding, which is crucial for memory retrieval processes. Anxiety, as an emotional state, may enhance left hemisphere activation during memory tasks by increasing cognitive effort and engagement with emotionally charged material.

Furthermore, the significant correlation between anxiety and the Dm ERP effect at electrode F7 highlights the impact of emotional states on neural activity associated with memory. Given the frontal and left hemisphere involvement in memory retrieval, the increased activation observed in anxious individuals could facilitate the neural differentiation between remembered and forgotten words, potentially due to heightened cognitive or emotional involvement during memory-related tasks. Anxiety may modulate memory retrieval by amplifying the attentional resources allocated to the task, thus affecting neural activation in frontal regions.

Although the effects of stress and sleep disturbances on the Dm ERP effect at F7 were only marginal, their potential influence on memory-related neural processes cannot be overlooked. Further exploration into how these factors impact both neural and behavioral outcomes is necessary, as the behavioral results revealed significant relations among variables. For example, stress and sleep disturbances were positively correlated, r (49) = 0.375, p = 0.007, indicating that higher stress is associated with more sleep disturbances. Anxiety was negatively correlated with stress, r (49) = -0.728, p < 0.001, suggesting that higher anxiety levels correspond with lower stress levels among participants. Additionally, there was a negative correlation between false recall and memory recall, r (49) = -0.408, p = 0.003, indicating that an increase in false memory recall is associated with a decrease in accurate recall.

Marginal effects provided additional insights into the data. There was a marginal effect between sleep disturbances and anxiety, r (49) = 0.275, p = 0.051, and between impulsiveness and anxiety, r (49) = 0.255, p = 0.071. Additionally, a marginal effect was observed between impulsiveness and stress r (49) = 0.252, p = 0.075, as well as between impulsiveness and recall, r (49) = -0.266, p = 0.059, and between anxiety and recall, r (49) = -0.251, p = 0.075.

The hypothesis predicting that higher levels of stress will exhibit lower recall memory was not significant, *r* (49) = -0.178, p = 0.211. Similarly, the predicted negative correlation between sleep disturbances and recall memory, was not supported, r (49) = 0.014, p = 0.923. Hypotheses predicting that anxiety and impulsiveness would be negatively associated with recall memory, were not supported. These results contrast with the findings of both Gradisar et al. (2008) and Frenda and Fenn (2016), who discovered that students' working memory performance declines when they get less sleep on school nights. Previous research has also shown that high levels of anxiety can reduce working memory and attention (Borkowski & Mann, 1968; Giron & Almeida, 2010). Additionally, the results of Robinson and Rollings (2010) indicate that stress can affect mood, which in turn impacts participants' ability to remember and recognize visual cues. Other studies have found that impulsivity impairs working memory by reducing sustained attention and increasing susceptibility to distractions (Barkley, 1997). Moreover, impulsivity affects planning and organization, leading to poorer memory performance (Steele, 2007).

Implications

Our study used a free recall paradigm where participants wrote out words, which may provide a different level of sensitivity in encoding compared to prior studies using Dm ERP analysis. Fernandez et al. (1999) employed a similar free recall paradigm and found distinct Dm effects during encoding, focusing on how memory-related neural processes are engaged during free recall tasks. Similarly, Fabiani et al. (1986) also observed Dm effects during free recall tasks, particularly at parietal sites, suggesting that free recall can elicit specific neural signatures during encoding.

While prior studies have shown Dm effects in free recall paradigms, our findings indicate a more frontally oriented Dm effect, particularly at FP1 and F7, which is less commonly observed in these paradigms. This difference may reflect a different set of cognitive processes involved in free recall, perhaps more related to cognitive control or attentional modulation during memory encoding. Thus, our study’s frontal Dm effects may suggest a new approach to understanding how free recall engages the brain’s memory systems differently from previous studies, warranting further research into the role of frontal regions in free recall memory tasks.

The results of this study improve our understanding of how different factors interact to influence memory performance. Even though the relationships between stress, sleep disturbances, anxiety, impulsiveness, and memory recall did not align with the initial hypotheses, these differences suggest that the interactions may be more complex than expected. The significant positive correlation between stress and sleep disturbances supports existing literature, indicating that stress can disrupt sleep. The interesting negative correlation between anxiety and stress might suggest a potential coping mechanism where higher anxiety could decrease perceived stress, or vice versa. Furthermore, the negative correlation between false recall and memory recall emphasizes the impact of memory distortions, as an increase in false memories corresponds with decreased accurate recall.

These results emphasize the importance of considering psychological states in memory retrieval. Since anxiety significantly impacts memory, interventions such as mindfulness, stress management, and counseling may benefit individuals with high anxiety levels. Educators and practitioners should account for psychological differences when designing learning and assessment methods, as personalized approaches that acknowledge students' mental and emotional states could lead to improved educational outcomes. Further exploration of the Dm ERP effect across a broader range of electrodes and brain regions may provide a more comprehensive understanding of the neural mechanisms involved in memory retrieval.

Limitations and Future Research

There are a few limitations to the study that should be addressed. Firstly, the sample size was relatively small (N=51), which may limit the generalizability of the findings. Previous studies had larger sample sizes, ranging from 100 to 350 participants (Xie et al., 2019; Giron & Almeida, 2010). The results of this study show that the impact of factors on memory encoding was generally smaller than the medium effect size of 0.35 recommended by Clayson et al. (2019). Although some relationships came close to the medium effect size, many of the correlations were lower. This suggests that stress, sleep disturbances, anxiety, and impulsiveness may not have as strong an influence on memory encoding as previously thought. These factors may affect memory performance in more subtle ways or require different conditions to have a stronger impact. The small effect sizes indicate the need for further research to examine these factors under different conditions and use potentially different methods to better understand their role in memory encoding. Additionally, the measures of stress, sleep disturbances, anxiety, and impulsiveness relied heavily on self-reported data. This could introduce biases and impact the accuracy of the information, as participants were not asked to significantly alter their behaviors, such as going without sleep for extended periods. Thus, their ability to encode information was aligned with their current habits, which might not reflect the effects of extreme variations in these factors.

Future research should aim to replicate these findings using larger and more diverse samples for better generalizability. It would also be helpful to use objective measures of stress and sleep disturbances, such as physiological indicators or sleep-tracking devices, to obtain more accurate data and improve the reliability of the results. Additionally, conducting experimental studies that manipulate stress, anxiety, and sleep disturbances could help establish causal relationships between these variables and memory performance. By addressing these limitations and exploring these avenues, future research can contribute to a more comprehensive understanding of how psychological factors impact memory encoding and retrieval.

Conclusion

This study examined how stress, sleep disturbances, anxiety, and impulsiveness impact memory performance. We used both behavioral measures and EEG-derived event-related potentials (ERPs). The original hypotheses suggested that these factors would negatively affect recall memory performance, but the results did not fully support this. Stress, sleep disturbances, and impulsiveness did not show significant correlations with memory recall. Although anxiety had a significant relationship with the Dm ERP effect at one electrode, it did not consistently predict memory performance across all electrodes.

The findings emphasize the complex influence of psychological factors on memory encoding and retrieval. The strong positive correlation between stress and sleep disturbances highlights the impact of stress on sleep quality, which is consistent with existing literature. The negative correlation between false recall and accurate recall emphasizes the role of memory distortions in memory performance.

These results suggest that while certain psychological states like anxiety may affect memory processes, the effects of stress, sleep disturbances, and impulsiveness may be less precise than expected. This emphasizes the need to consider individual differences and contextual factors when interpreting the impact of psychological variables on memory.

Future research should replicate these findings with larger and more diverse samples and utilize objective measures to improve data accuracy. Additionally, experimental manipulations of stress, anxiety, and sleep disturbances could provide further insights into their causal effects on memory. Overall, this study enhances our understanding of the complex relationships between psychological factors and memory, highlighting the need for personalized approaches to address these variables effectively in educational and clinical settings.

REFERENCES

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology*, *106*(1), 20–29. https://doi.org./10.1016/j.jecp.2009.11.003

Anderson, J.R. (1993). Rules of the mind (1st ed.). Psychology Press. https://doi.org/10.4324/9781315806938

Anderson, J. R. (2007). *How can the human mind occur in the physical universe?* Oxford University Press. https://doi.org./10.1093/acprof:oso/9780195324259.001.0001

Anderson, R. C., & Pichert, J. W. (1978). Recall of previously unrecallable information following a shift in perspective. *Journal of Verbal Learning & Verbal Behavior*, *17*(1), 1–12. https://doi.org./10.1016/S0022-5371(78)90485-1

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2, pp. 89–105). Academic Press. https://doi.org/10.1016/S0079-7421(08)60422-3

Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of Learning and Motivation*, 47–89. https://doi.org/10.1016/s0079-7421(08)60452-1

Baddeley, A. D., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology, 8*(4), 485–493. https://doi.org/10.1037//0894-4105.8.4.485

Baddeley, A. D. (1997). *Human memory: Theory and practice*. Psychology Press.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417–423. https://doi.org/10.1016/s1364-6613(00)01538-2

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews Neuroscience, 4*(10), 829–839. https://doi.org/10.1038/nrn1201

Baddeley, A. (2010). Working memory. *Current Biology, 20*(4), R136–R140. https://doi.org/10.1016/j.cub.2009.12.014

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121*(1), 65–94. https://doi.org/10.1037//0033-2909.121.1.65

Barsalou, L. W. (2009). Simulation, situated conceptualization, and prediction. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1521), 1281–1289. https://doi.org/10.1098/rstb.2008.0319

Becker, B. (2023, August). How memories are made: Stages of memory formation. How Memories Are Made: Stages of Memory Formation | *Lesley University*. https://lesley.edu/article/stages-of-memory#:~:text=In%20the%20sensory%20register%20process,%E2%80%9D%20and%20%E2%80%9Cechoic%E2%80%9D%20memory.

Borkowski, J. G., & Mann, T. (1968). Effects of anxiety and interference on short-term memory. *Journal of Experimental Psychology*, *78*(2, Pt.1), 352–354. https://doi.org/10.1037/h0026307

Bradlyn, A. S., & Rollins, H. A. (1980). Incidental memory for the color-word association in the Stroop color-word test. *Bulletin of the Psychonomic Society, 16*(4), 269–272. https://doi.org/10.3758/bf03329540

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research, 28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4

Clayson, P. E., Carbine, K. A., Baldwin, S. A., & Larson, M. J. (2019). Methodological reporting behavior, sample sizes, and statistical power in studies of event-related potentials: Barriers to reproducibility and replicability. *Psychophysiology, 56*(11), e13437. https://doi.org/10.1111/psyp.13437

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior, 24*(4), 386–396. https://doi.org/10.2307/2136404

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24*(1), 87–114. https://doi.org/10.1017/s0140525x01003922

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? In *Essence of Memory, 169*, 323–338. https://doi.org/10.1016/s0079-6123(07)00020-9

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*(6), 671–684. https://doi.org/10.1016/s0022-5371(72)80001-x

Cyders, M. A., Smith, G. T., Spillane, N. S., Fischer, S., Annus, A. M., & Peterson, C. (2007). Integration of impulsivity and positive mood to predict risky behavior: Development and validation of a measure of positive urgency. *Psychological Assessment, 19*(1), 107–118. https://doi.org/10.1037/1040-3590.19.1.107

Dougherty, D. M., Mathias, C. W., Marsh, D. M., Papageorgiou, T. D., Swann, A. C., & Moeller, F. G. (2004). Laboratory Measured Behavioral Impulsivity Relates to Suicide Attempt History. *Suicide and Life-Threatening Behavior, 34*(4), 374–385. Portico. https://doi.org/10.1521/suli.34.4.374.53738

Endler, N. S., & Kocovski, N. L. (2001). State and trait anxiety revisited. *Journal of Anxiety Disorders*, *15*(3), 231–245. https://doi.org/10.1016/S0887-6185(01)00060-3

Fabiani, M., Karis, D., & Donchin, E. (1986). P300 and recall in an incidental memory paradigm. *Psychophysiology*, *23*(3), 298–308. https://doi.org/10.1111/j.1469-8986.1986.tb00636.x

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149–1160. https://doi.org/10.3758/brm.41.4.1149

Fernández, G., Effern, A., Grunwald, T., Pezer, N., Lehnertz, K., Dümplemann, M., Roost, D. V., & Elger, C. E. (1999). Real-time tracking of memory formation in the human rhinal cortex and hippocampus. *Science*, *285*(5433), 1582–1585. https://doi.org/10.1126/science.285.5433.1582

Figueira, J. S. B., Oliveira, L., Pereira, M. G., Pacheco, L. B., Lobo, I., Motta-Ribeiro, G. C., & David, I. A. (2017). An unpleasant emotional state reduces working memory capacity: Electrophysiological evidence. *Social Cognitive and Affective Neuroscience*, *12*(6), 984–992. https://doi.org/10.1093/scan/nsx030

Frenda, S. J., & Fenn, K. M. (2016). Sleep less, think worse: The effect of sleep deprivation on working memory. *Journal of Applied Research in Memory and Cognition*, *5*(4), 463–469. https://doi.org/10.1016/j.jarmac.2016.10.001

Giron, P. R., & de Almeida, R. M. M. (2010). Influence of aversive visual stimulation on attention, working memory, and anxiety in university students. *Psychology & Neuroscience*, *3*(1), 109–115. https://doi.org/10.3922/j.psns.2010.1.014

Gradisar, M., Terrill, G., Johnston, A., & Douglas, P. (2008). Adolescent sleep and working memory performance. *Sleep and Biological Rhythms, 6*(3), 146–154. https://doi.org/10.1111/j.1479-8425.2008.00353.x

Guo, C., Duan, L., Li, W., & Paller, K. A. (2006). Distinguishing source memory and item memory: Brain potentials at encoding and retrieval. *Brain Research, 1118*(1), 142–154. https://doi.org/10.1016/j.brainres.2006.08.034

Hart, J. T. (1967). Second-try recall, recognition, and the memory-monitoring process. *Journal of Educational Psychology, 58*(4), 193–197. https://doi.org/10.1037/h0024908

Hulme, C., Roodenrys, S., Brown, G., & Mercer, R. (1995). The role of long-term memory mechanisms in memory span. *British Journal of Psychology, 86*(4), 527–536. Portico. https://doi.org/10.1111/j.2044-8295.1995.tb02570.x

Jaeger, A., & Parente, M. A. de M. P. (2008). Event-related potentials and the study of memory retrieval: A critical review. *Dementia & Neuropsychologia*, *2*(4), 248–255. https://doi.org/10.1590/S1980-57642009DN20400003

Jones, M. N., Willits, J., & Dennis, S. (2015). Models of semantic memory. In J. R. Busemeyer, Z. Wang, J. T. Townsend, & A. Eidels (Eds.), *The Oxford handbook of computational and mathematical psychology*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199957996.013.11

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science*, *18*(7), 614–621. https://doi.org/10.1111/j.1467-9280.2007.01948.x

Klein, S. B. (2014). What memory is. *Wiley Interdisciplinary Reviews Cognitive Science, 6*(1), 1–38. https://doi.org/10.1002/wcs.1333

Kontaxopoulou, D., Beratis, I. N., Fragkiadaki, S., Pavlou, D., Yannis, G., Economou, A., Papanicolaou, A. C., & Papageorgiou, S. G. (2017). Incidental and Intentional Memory: Their relation with attention and executive functions. *Archives of Clinical Neuropsychology, 32*(5), 519–532. https://doi.org/10.1093/arclin/acx027

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology, 62*(1), 621–647. https://doi.org/10.1146/annurev.psych.093008.131123

Lawson, A. L., Pratarelli, M. E., & Sprowls, D. A. (2000). Visual bimodal encoding and concreteness effects on free recall. *North American Journal of Psychology*, *2*(2), 219–232.

Light, G. A., Williams, L. E., Minow, F., Sprock, J., Rissling, A., Sharp, R., Swerdlow, N. R., & Braff, D. L. (2010). Electroencephalography (EEG) and event-related potentials (ERPs) with human participants. *Current Protocols in Neuroscience, 52*(1). Portico. https://doi.org/10.1002/0471142301.ns0625s52

Luck, S. J. (2014). *An Introduction to the Event-Related Potential Technique (2nd ed.)*. Cambridge, MA: MIT Press.

Lukasik, K. M., Waris, O., Soveri, A., Lehtonen, M., & Laine, M. (2019). The relationship of anxiety and stress with working memory performance in a large non-depressed sample. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.00004

Mangels, J. A., Picton, T. W., & Craik, F. I. M. (2001). Attention and successful episodic encoding: An event-related potential study. *Cognitive Brain Research*, *11*(1), 77–95. https://doi.org/10.1016/S0926-6410(00)00066-5

Matlin, M. W. (2003). *Cognition*. Rosewood Drive, Danvers, MA.

McDermott, K. B., & Roediger, H. L. (2018). Memory (encoding, storage, retrieval). *General Psychology FA2018. Noba Project: Milwaukie, OR*, 117-153.

McGaugh, J. L. (2004). The amygdala modulates the consolidation of memories of emotionally arousing experiences. *Annual Review of Neuroscience, 27*, 1–28. https://doi.org/10.1146/annurev.neuro.27.070203.144157

Mei, X., Tian, L., Xue, Z., & Li, X. (2017). A working memory task reveals different patterns of impulsivity in male and female college students. *Behavioural Processes*, *138*, 127–133. https://doi.org/10.1016/j.beproc.2017.02.023

Michel, C. M., & Koenig, T. (2018). EEG microstates as a tool for studying the temporal dynamics of whole-brain neuronal networks: A review. *NeuroImage, 180*, 577–593. https://doi.org/10.1016/j.neuroimage.2017.11.062

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*(2), 81–97. https://doi.org/10.1037/h0043158

Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin, 142*(8), 831–864. https://doi.org/10.1037/bul0000051

Murphy, G. L. (2004). *The big book of concepts*. MIT Press.

Newbury, C. R., Crowley, R., Rastle, K., & Tamminen, J. (2021). Sleep deprivation and memory: Meta-analytic reviews of studies on sleep deprivation before and after learning. *Psychological Bulletin*, *147*(11), 1215–1240. https://doi.org/10.1037/bul0000348

Nunez, P. L., & Srinivasan, R. (2006). High-resolution EEG. *Electric Fields of the Brain: The neurophysics of EEG* (2nd ed., pp. 313–352). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195050387.003.0008

Paller, K. A., Kutas, M., & Mayes, A. R. (1987). Neural correlates of encoding in an incidental learning paradigm. *Electroencephalography and Clinical Neurophysiology, 67*(4), 360–371. https://doi.org/10.1016/0013-4694(87)90124-6

Paller, K. A., McCarthy, G., & Wood, C. C. (1988). ERPs predictive of subsequent recall and recognition performance. *Biological Psychology, 26*(1–3), 269–276. https://doi.org/10.1016/0301-0511(88)90023-3

Robinson, S. J., & Rollings, L. J. L. (2011). The effect of mood-context on visual recognition and recall memory. *Journal of General Psychology*, *138*(1), 66–79. https://doi.org/10.1080/00221309.2010.534405

Sari, B. A., Koster, E. H. W., Pourtois, G., & Derakshan, N. (2016). Training working memory to improve attentional control in anxiety: A proof-of-principle study using behavioral and electrophysiological measures. Biological Psychology, 121, 203–212. https://doi.org/10.1016/j.biopsycho.2015.09.008

Schwartz, B. L. (2018). *Memory: Foundations and applications* (3rd ed.). SAGE Publications.

Service, E. (1998). The effect of word length on immediate serial recall depends on phonological complexity, not articulatory duration. *The Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 51A*(2), 283–304. https://doi.org/10.1080/713755759

Spielberger, C. D. (1983). *State-trait anxiety inventory for adults*. Mind Garden. https://doi.org/10.1037/t06496-000

Spinella, M. (2004). Neurobehavioral correlates of impulsivity: Evidence of prefrontal involvement. *International Journal of Neuroscience*, *114*(1), 95–104. https://doi.org/10.1080/00207450490249347

Steel, P. (2007). The nature of procrastination: A meta-analytic and theoretical review of quintessential self-regulatory failure. *Psychological Bulletin*, *133*(1), 65–94. https://doi.org/10.1037/0033-2909.133.1.65

Sur, S., & Sinha, V. (2009). Event-related potential: An overview. *Industrial Psychiatry Journal, 18*(1), 70. https://doi.org/10.4103/0972-6748.57865

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, *80*(5), 352–373. https://doi.org/10.1037/h0020071

Tyng, C. M., Amin, H. U., Saad, M. N. M., & Malik, A. S. (2017). The influences of emotion on learning and memory. *Frontiers in Psychology, 8*. https://doi.org/10.3389/fpsyg.2017.01454

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review*, *114*(1), 104–132. https://doi.org/10.1037/0033-295X.114.1.104

Unsworth, N., & Engle, R. W. (2007). Individual differences in working memory capacity and retrieval: A cue-dependent search approach. In J. S. Nairne (Ed.), *The foundations of remembering: Essays in honor of Henry L. Roediger, III.* (pp. 241–258). Psychology Press.

Unsworth, N., Spillers, G. J., & Brewer, G. A. (2012). Working memory capacity and retrieval limitations from long-term memory: An examination of differences in accessibility. *The Quarterly Journal of Experimental Psychology*, *65*(12), 2397–2410. https://doi.org/10.1080/17470218.2012.690438

Vellage, A. K., Müller, P., Schmicker, M., Hopf, J. M., & Müller, N. G. (2019). High working memory capacity at the cost of precision? *Brain sciences*, *9*(9), 210. https://doi.org/10.3390/brainsci9090210

Walker, M. P. (2009). The role of slow wave sleep in memory processing. *Journal of Clinical Sleep Medicine, 5*(2 suppl). https://doi.org/10.5664/jcsm.5.2s.s20

Wang, S., Gwizdka, J., & Chaovalitwongse, W. A. (2015). Using wireless EEG signals to assess memory workload in the n-back task. *IEEE Transactions on Human-Machine Systems*, *46*(3), 424-435.

Weerda, R., Muehlhan, M., Wolf, O. T., & Thiel, C. M. (2010). Effects of acute psychosocial stress on working memory related brain activity in men. *Human Brain Mapping*, *31*(9), 1418–1429. https://doi.org/10.1002/hbm.20945

Xie, W., Berry, A., Lustig, C., Deldin, P., & Zhang, W. (2019). Poor sleep quality and compromised visual working memory capacity. *Journal of the International Neuropsychological Society*, *25*(6), 583–594. https://doi.org/10.1017/S1355617719000183

Yee, E., Jones, M. N., & McRae, K. (2018). Semantic memory. In *Stevens' handbook of experimental psychology and cognitive neuroscience* (Vol. 3). https://doi.org/10.1002/9781119170174.epcn309

APPENDICES

Appendix A:

Figures

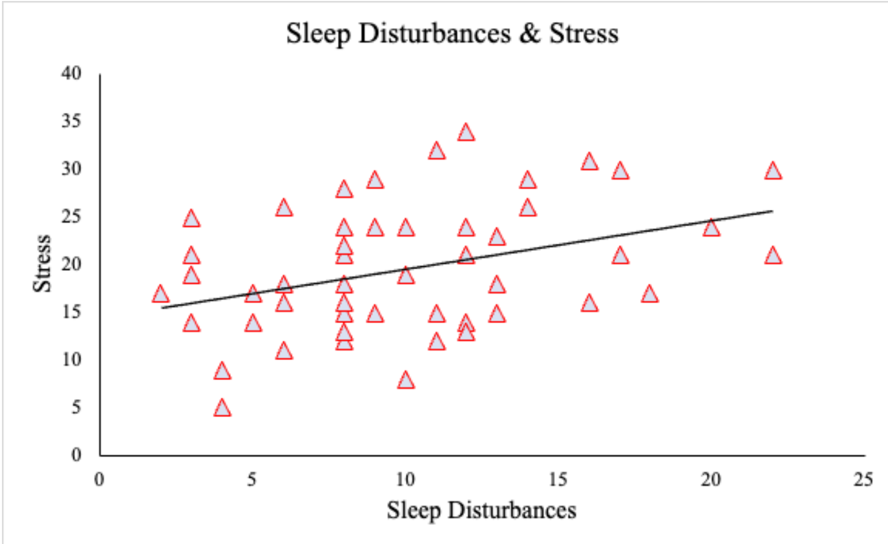

Figure 1. Correlation between Sleep Disturbances and Stress.

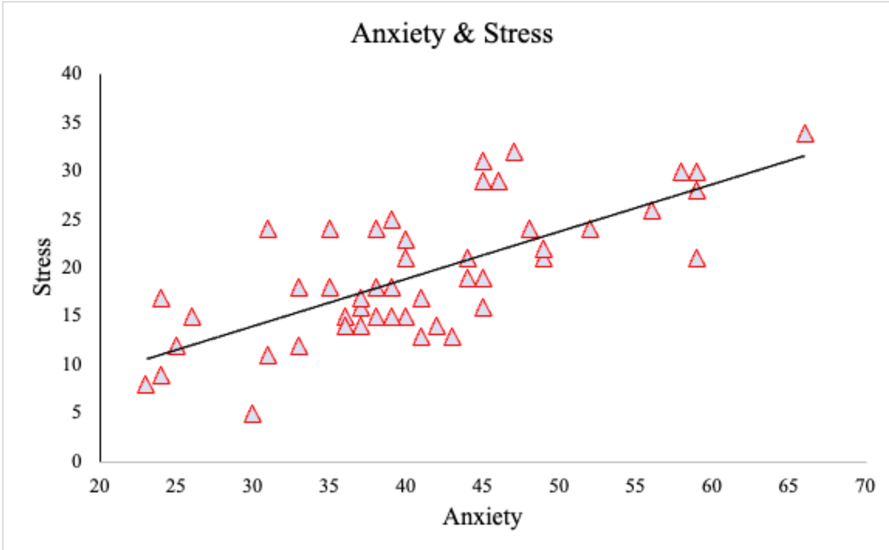

Figure 2. Correlation between Anxiety and Stress.

Figure 3. Correlation between Sleep Disturbances and Anxiety.

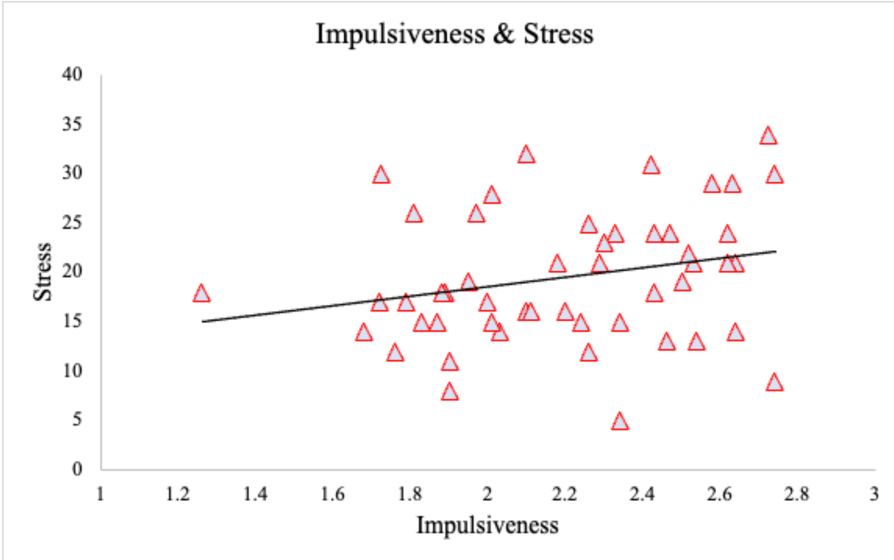

Figure 4. Correlation between Impulsiveness and Stress.

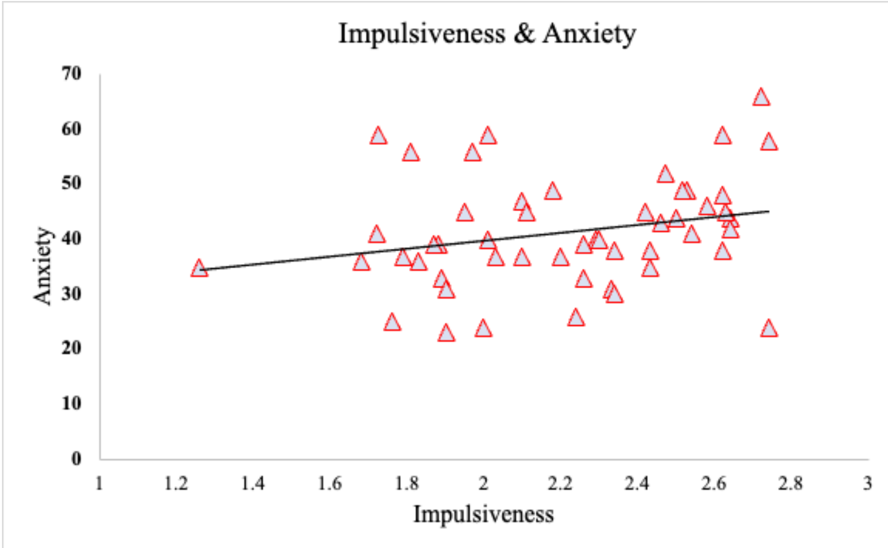

Figure 5. Correlation between Impulsiveness and Anxiety.

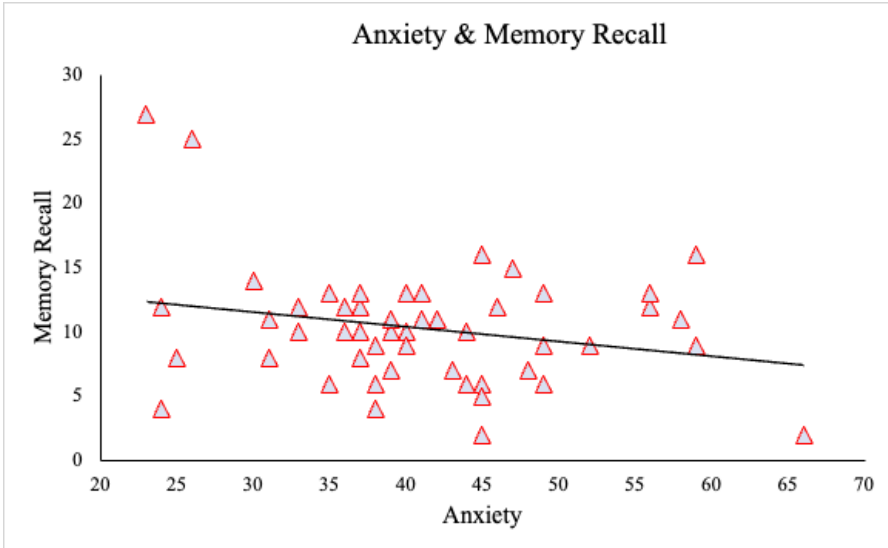

Figure 6. Correlation between Anxiety and Memory Recall.

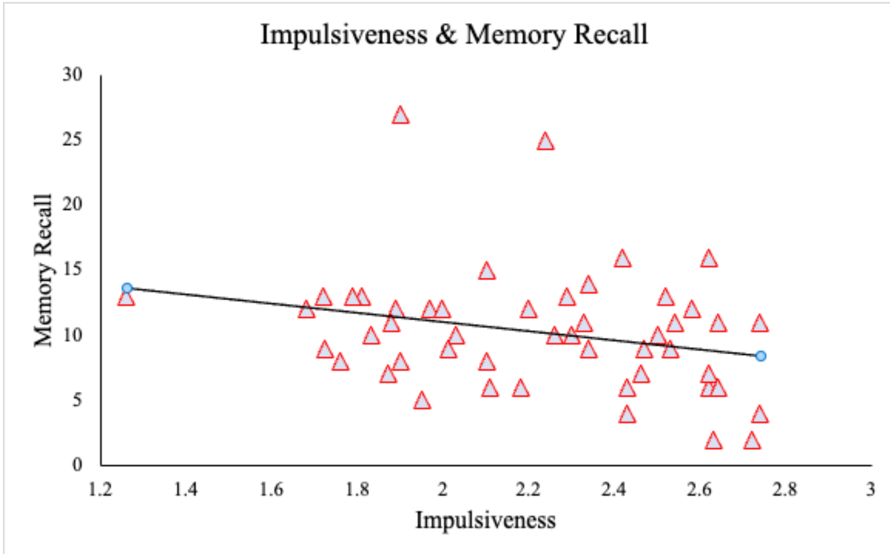

Figure 7. Correlation between Impulsiveness and Memory Recall.

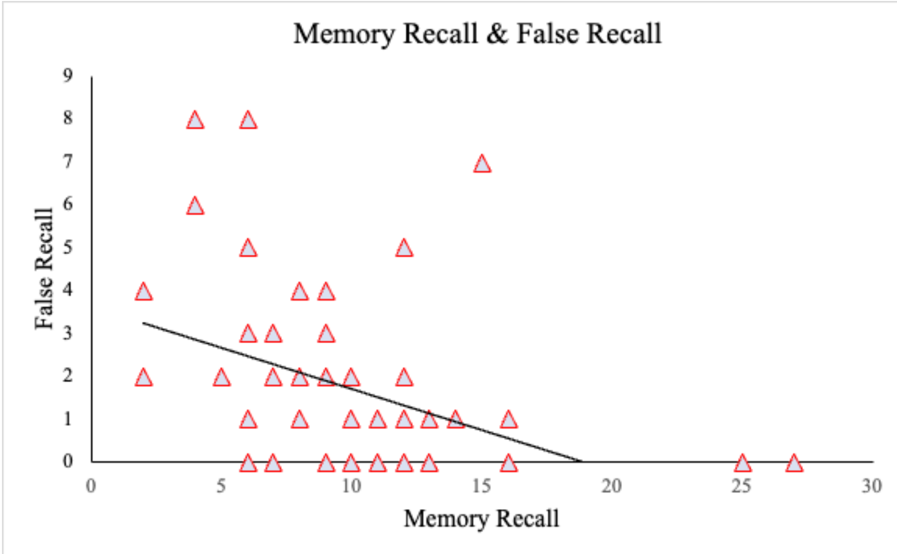

Figure 8. Correlation between Memory Recall and False Recall.

Figure 9: Dm Effect for Electrode Fp1.

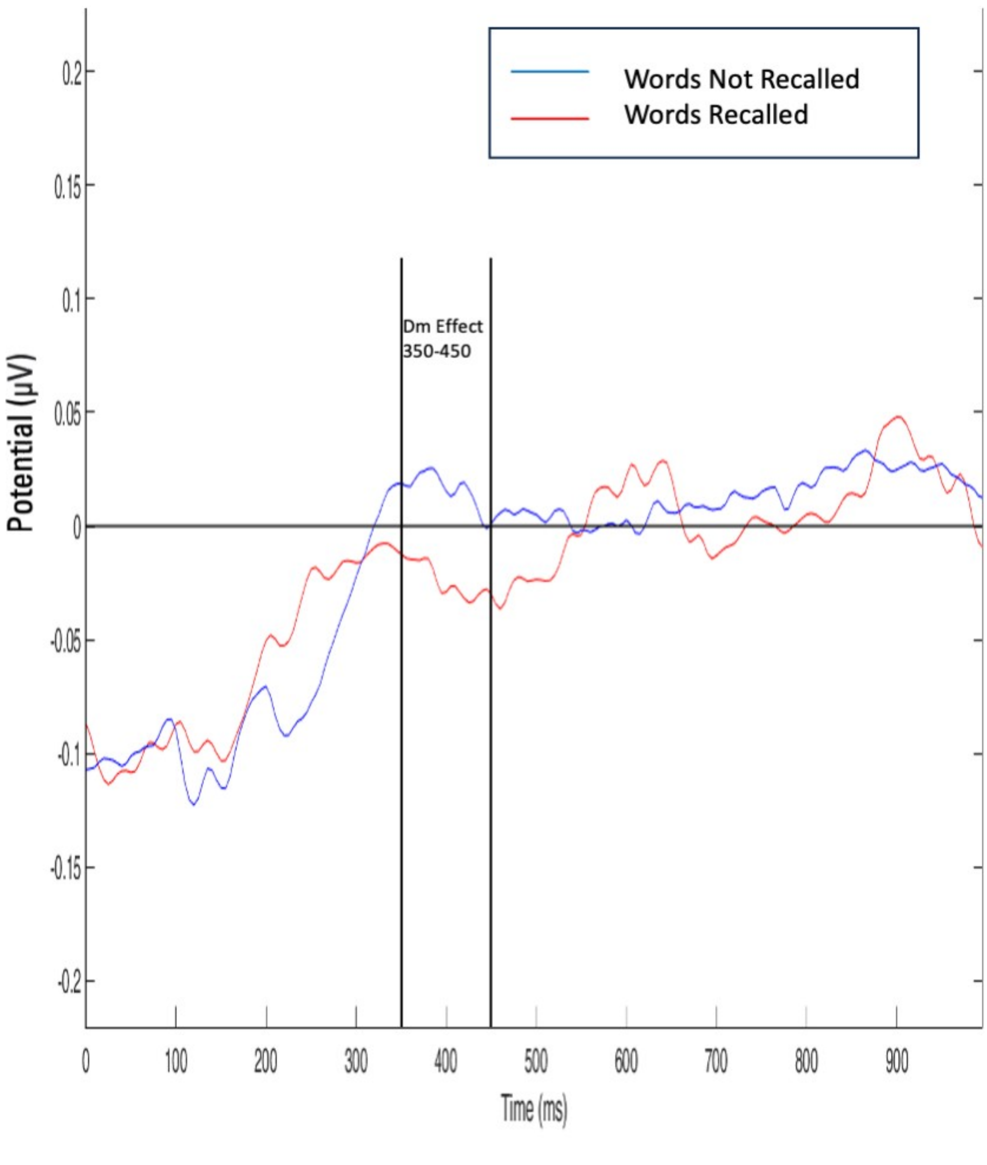

Figure 9. Dm Effect for Electrode Fp1**.**

Figure 10: Dm Effect for Electrode Fp2.

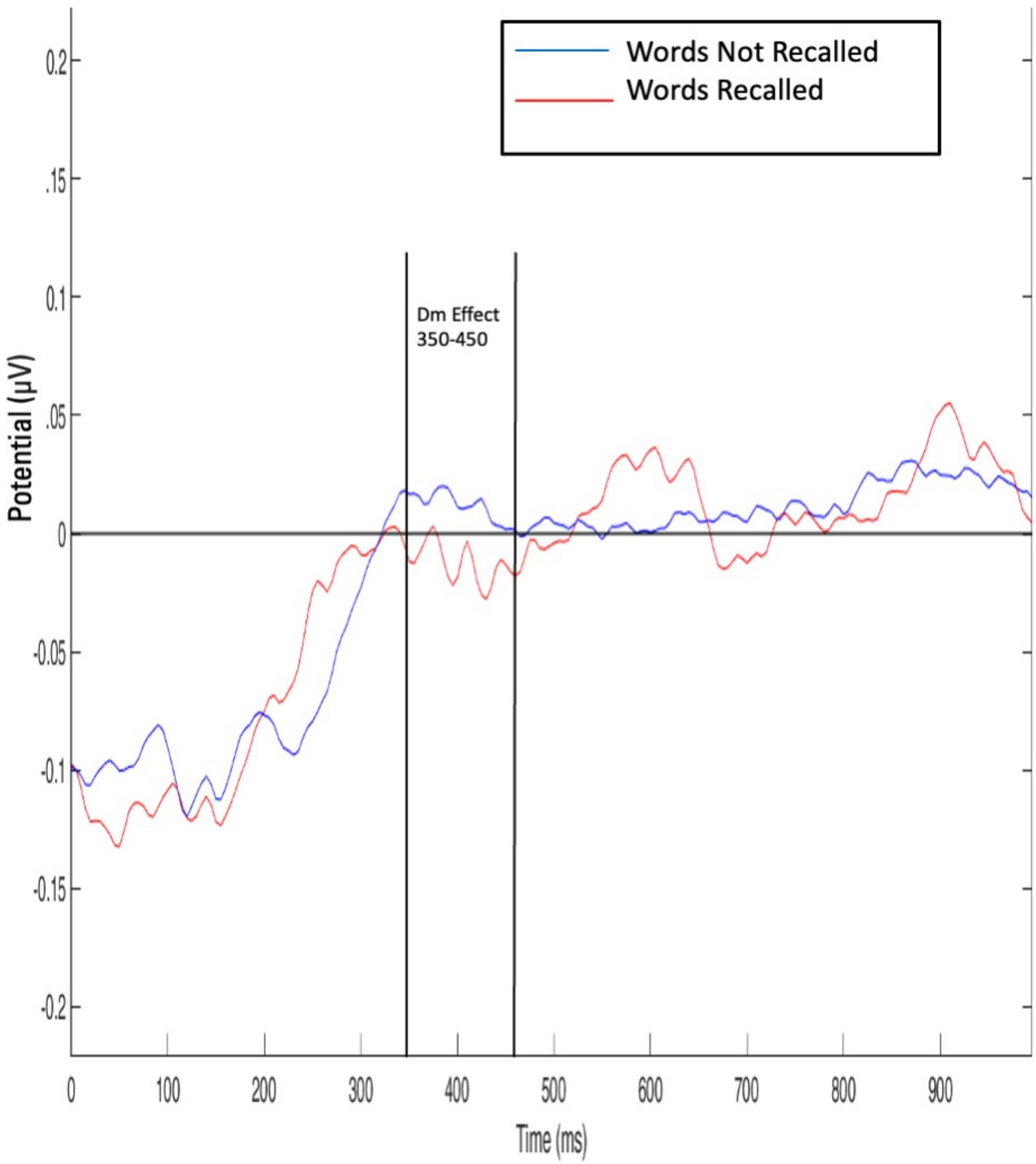

Figure 10. Dm Effect for Electrode Fp2.

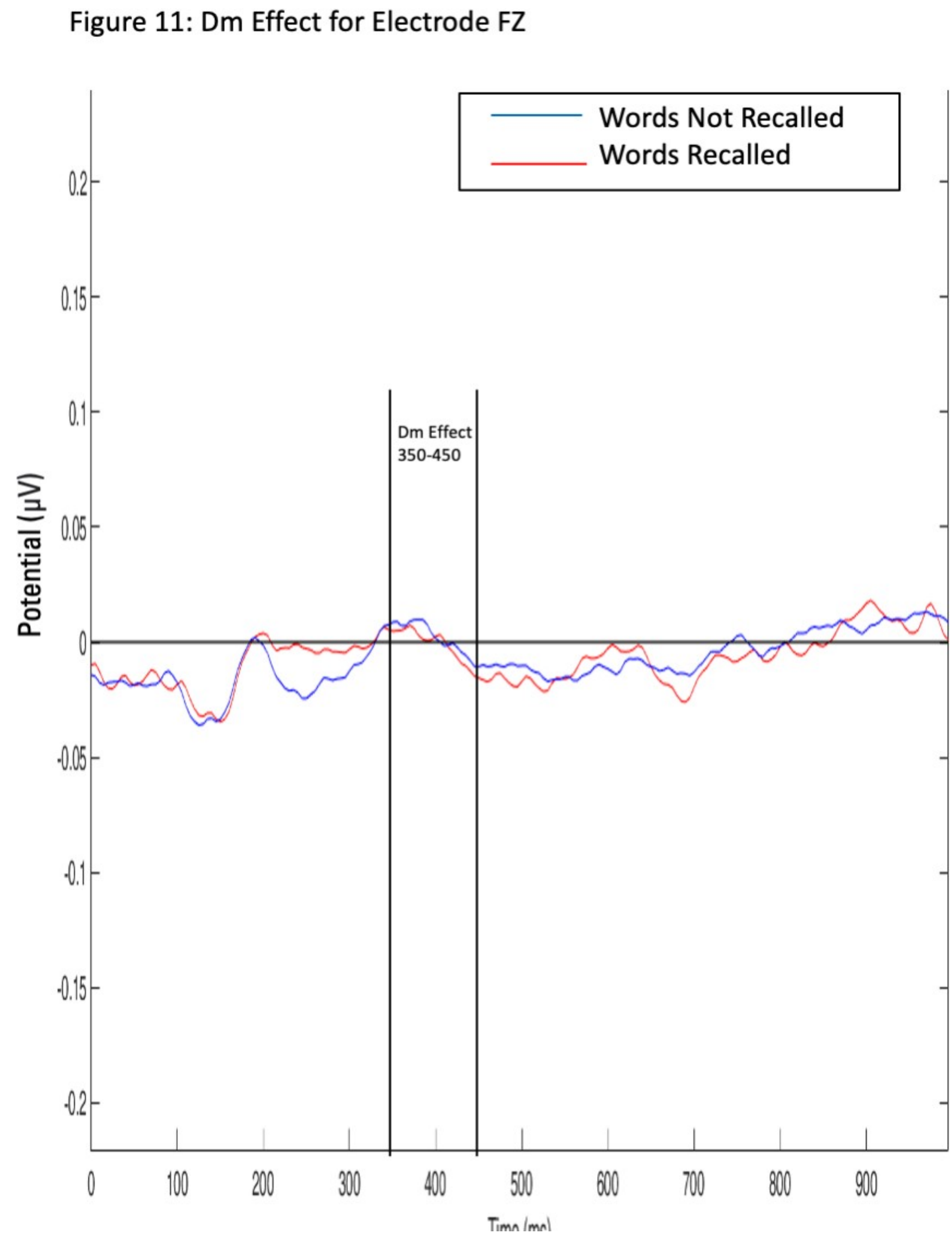

Figure 11. Dm Effect for Electrode FZ**.**

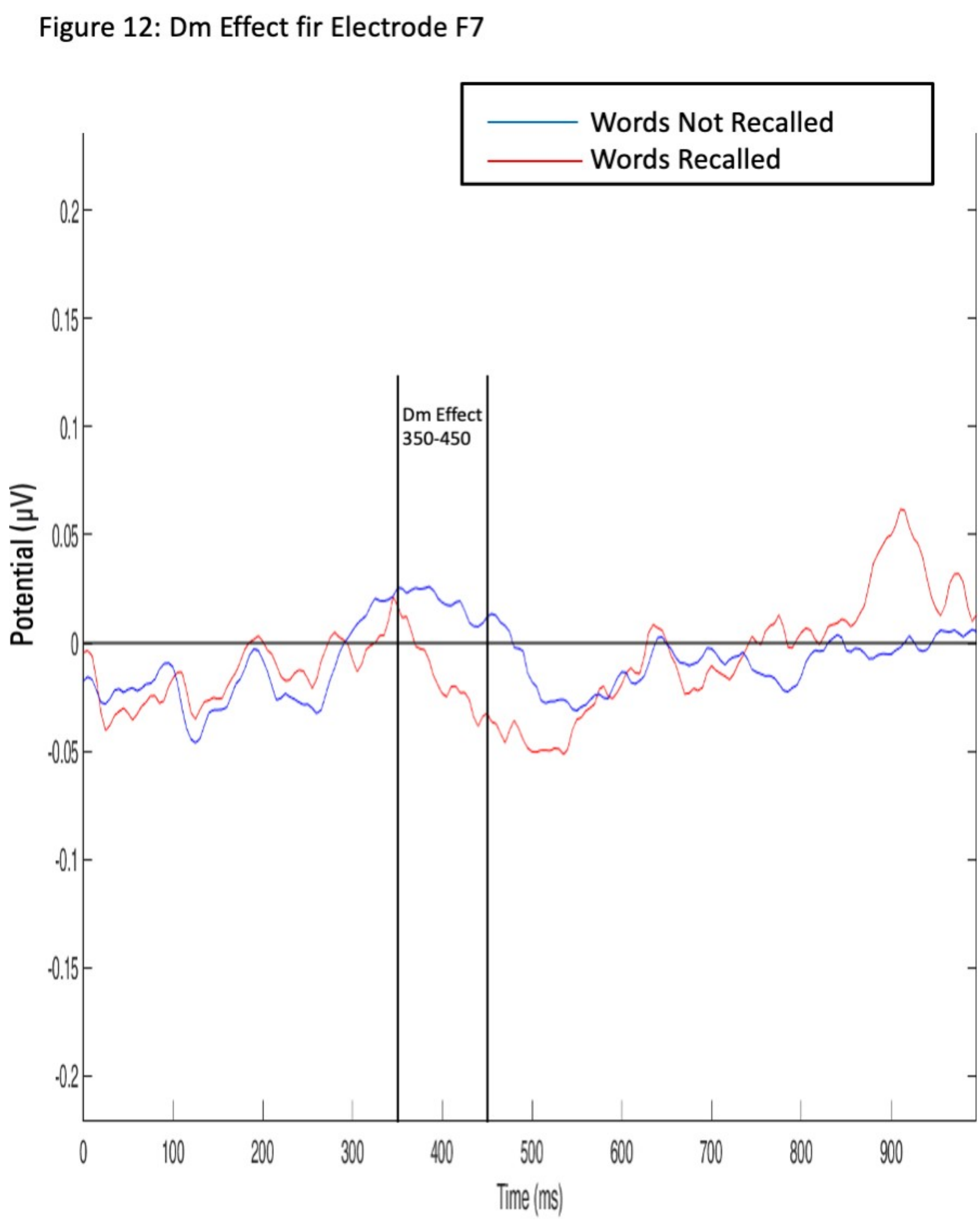

Figure 12. Dm Effect for Electrode F7**.**

Figure 13: Dm Effect for Electrode F8

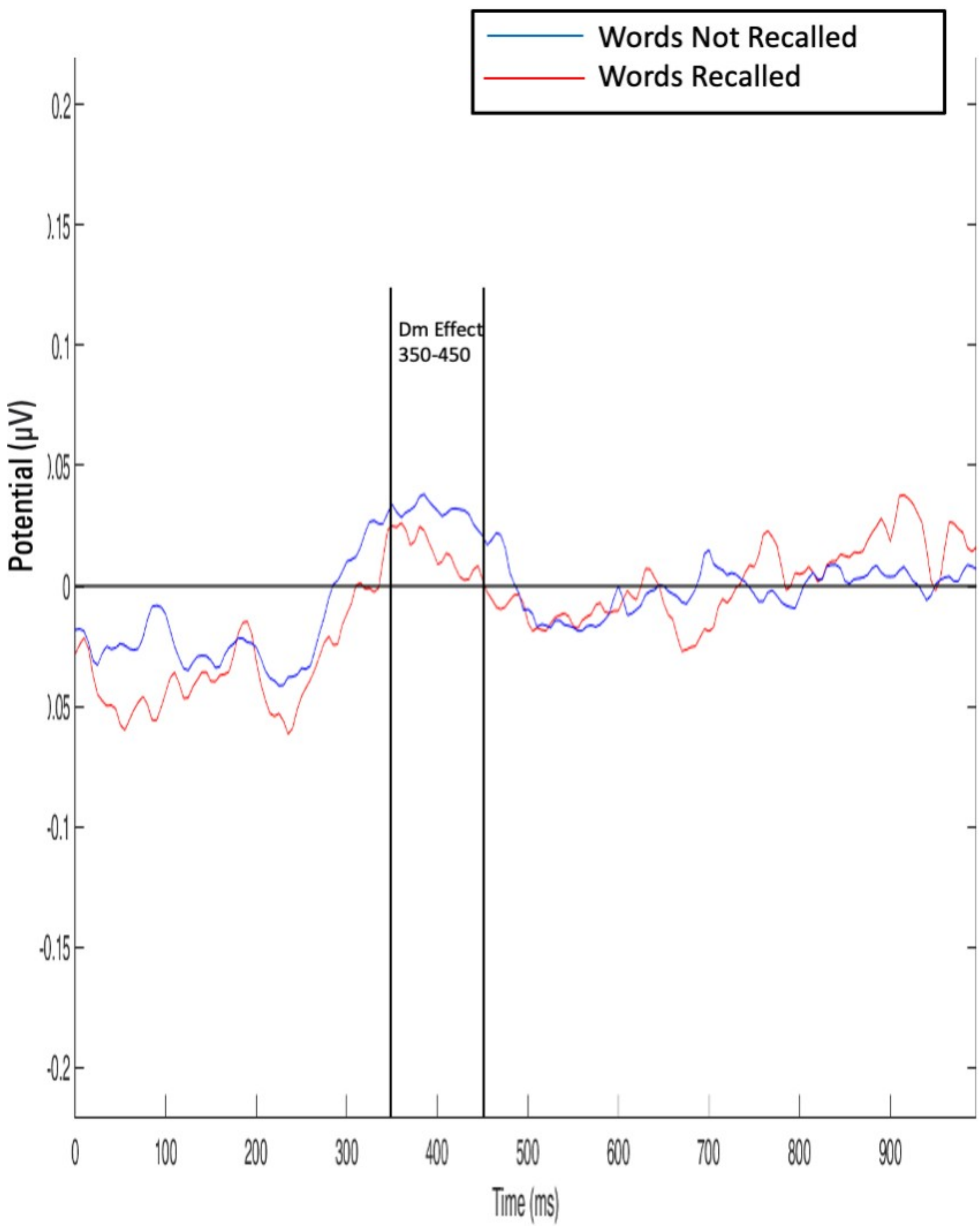

Figure 13. Dm Effect for Electrode F8**.**

Figure 14: Dm Effect for Electrode T3

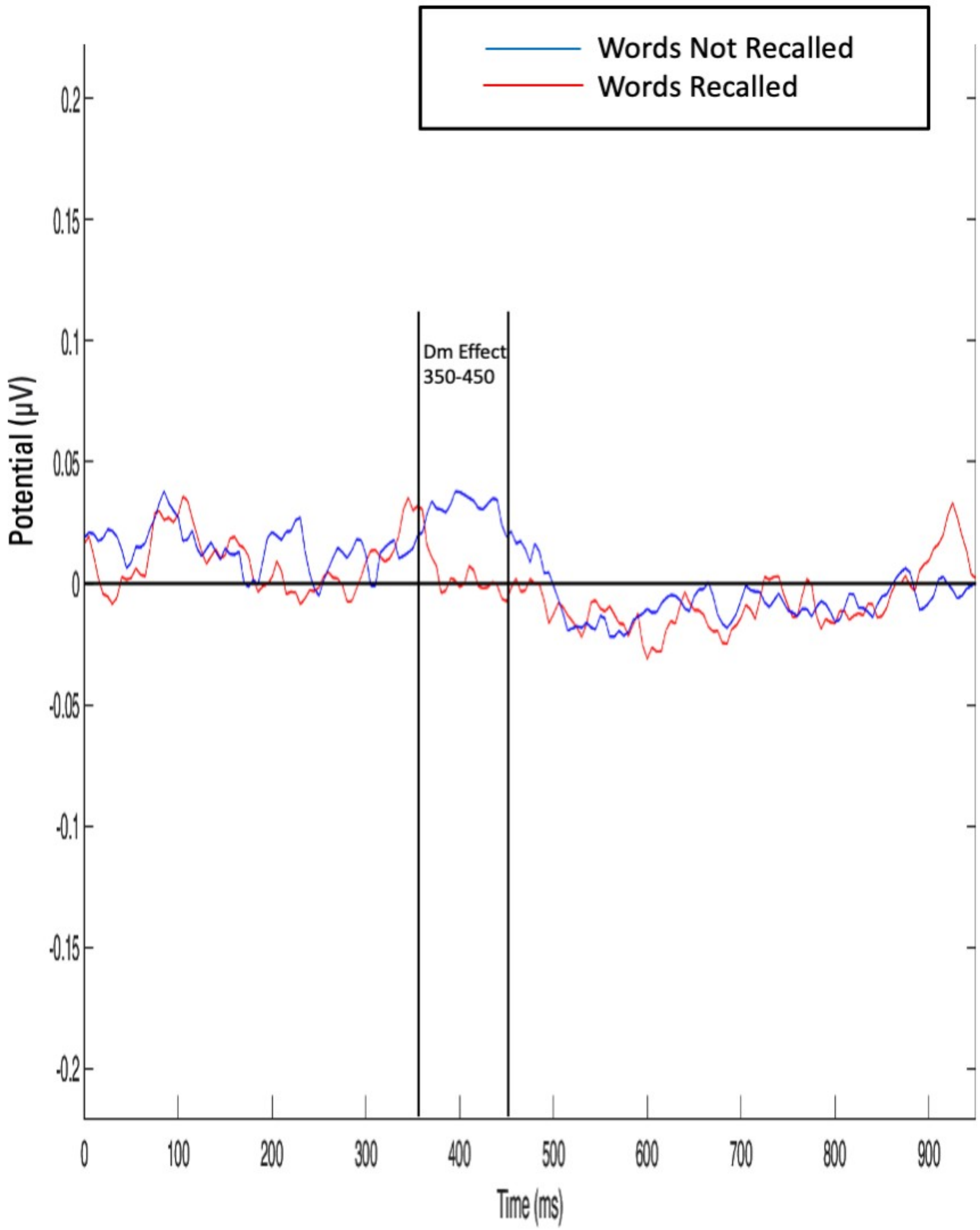

Figure 14. Dm Effect for Electrode T3**.**

Figure 15: Dm Effect for Electrode PZ

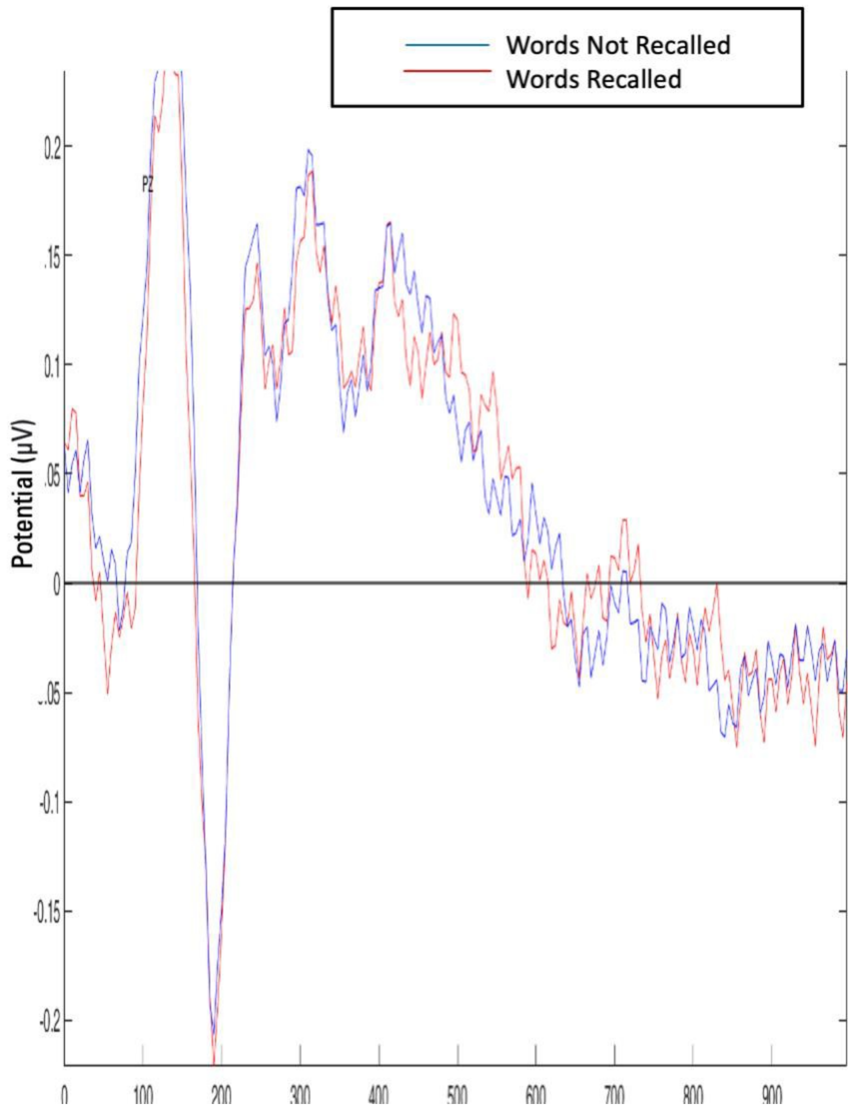

Figure 15. Dm Effect for Electrode PZ**.**

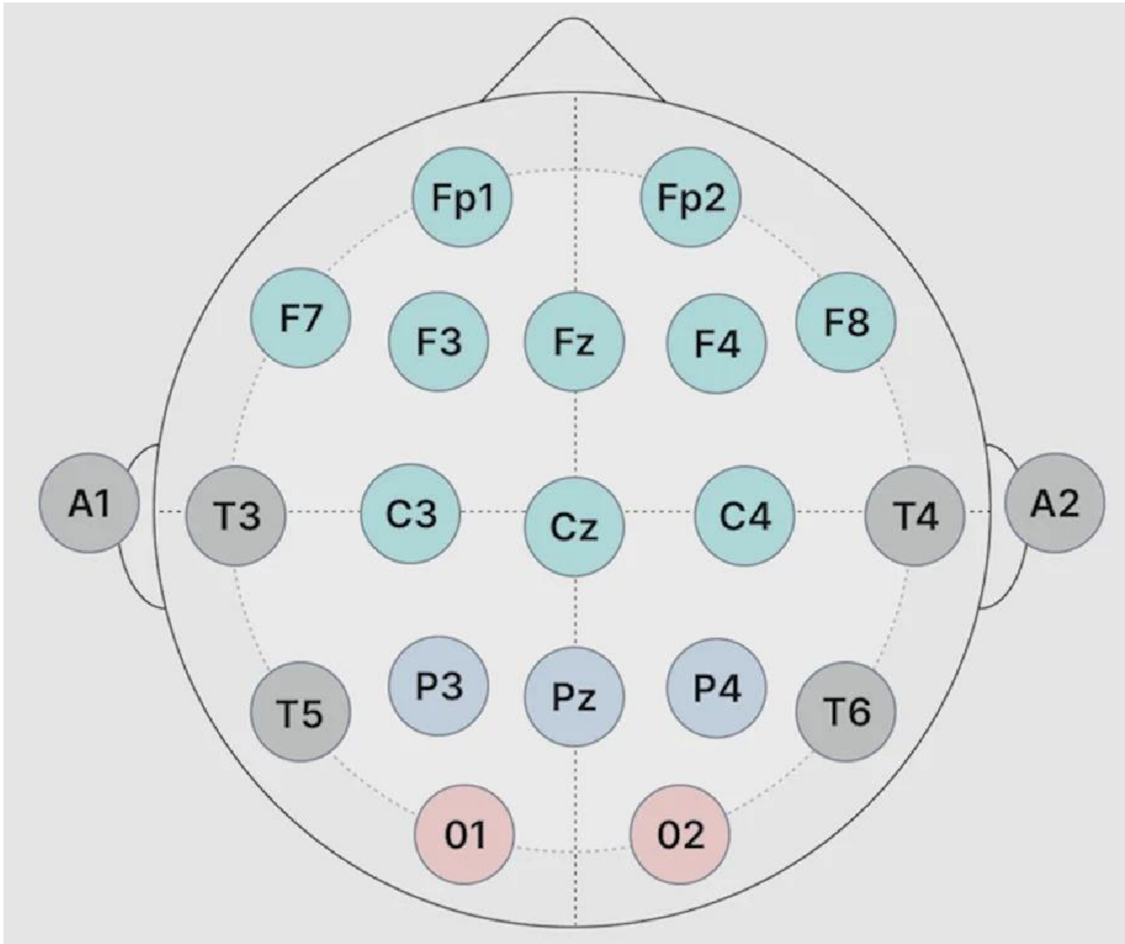

Figure 16. Standard 10-20 EEG electrodes placement used in the study, showing key electrode sites (PZ, FZ, T3, T4, FP1, FP2, F7, F8) with CZ as the reference, relevant to the analysis of Dm ERP effects.

Appendix B:

SONA Recruitment

SONA Recruitment

You will be asked to fill out stress, anxiety, impulsiveness, and sleep disturbance surveys and to participate in a memory task. In the memory task, you will be given a list of words and then asked to recall as many words as you can. Your brain waves will also be recorded using an electroencephalogram (EEG) machine. Your hairstyle may get disarrayed, so you may want to bring a hat. Your participation is voluntary, and you have the right to stop your participation at any time without penalty. You must be 18 years or older to participate.

Appendix C:

Consent Form

Consent Form

Hello, my name is Hodavia Kaseya. I am a graduate student in the Psychology Department at Eastern Kentucky University. Today, you will be asked to perform a memory task and fill out surveys about your typical daily experiences. Your participation should take approximately one hour. You will receive two SONA credits for participating. Your participation is voluntary, and responses will be kept confidential. If you have any questions, feel free to contact me at hodavia_kaseya@mymail.eku.edu

During this study, you will be asked to fill out the four surveys and perform a memory task. With the memory task, you will be given 30 words to study for memorization. After studying, you will be asked to solve some basic math problems, including addition and subtraction. Afterward, you will be given 5 minutes to recall as many words as possible from the study. You will be asked to write them down on a blank sheet of paper; the order of the words is not important. During the tasks, both your accuracy and response times will be recorded. Also, during the 5-minute study phase, electroencephalography (EEG, i.e., brain waves) data will be collected from your scalp with 4 electrodes fitted in the elastic EEG cap. The EEG cap can be worn for long periods without discomfort, and all materials touching the skin are hypoallergenic and electrically shielded.

Your participation is expected to provide benefits to others by increasing the literature's understanding of working memory and how everyday activity can influence someone's memory. If you do not wish to answer a question, you may skip it and go to the next question. No identifying information will be collected. Your signed consent form will be kept separate from your study data, and responses will not be linked to you. If you would like to participate, please sign, and print your name.

Appendix D:

Surveys, Memory Task, and Demographic Form

1. Surveys/Questionnaires

a. **Stress**

Perceived Stress Scale

The questions in this scale ask you about your feelings and thoughts **during the last month**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.

Name ____ Date _________

Age ________ Gender (*Circle*): **M F** Other __________________________________

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	**0**	**1**	**2**	**3**	**4**
2. In the last month, how often have you felt that you were unable to control the important things in your life?	**0**	**1**	**2**	**3**	**4**
3. In the last month, how often have you felt nervous and "stressed"?	**0**	**1**	**2**	**3**	**4**
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	**0**	**1**	**2**	**3**	**4**
5. In the last month, how often have you felt that things were going your way?	**0**	**1**	**2**	**3**	**4**
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	**0**	**1**	**2**	**3**	**4**
7. In the last month, how often have you been able to control irritations in your life?	**0**	**1**	**2**	**3**	**4**
8. In the last month, how often have you felt that you were on top of things?	**0**	**1**	**2**	**3**	**4**
9. In the last month, how often have you been angered because of things that were outside of your control?	**0**	**1**	**2**	**3**	**4**
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	**0**	**1**	**2**	**3**	**4**

Please feel free to use the *Perceived Stress Scale* for your research.

b. **Anxiety**

SELF-EVALUATION QUESTIONNAIRE STAI Form Y-1

Please provide the following information:

Name________________________________Date____________S_____

Age________________ Gender (*Circle*) **M** **F** T_____

DIRECTIONS:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

© Copyright 1968,1977 by Charles D. Spielberger. All rights reserved.
Published by Mind Garden, Inc., 1690 Woodside Rd, Suite 202, Redwood City, CA 94061

STAIP-AD Test Form Y
www.mindgarden.com

Copyright 1968, 1977 by Charles D. Speilberger. All rights reserved.

c. **Sleep Disturbances**

5. During the past month, how often have you had trouble sleeping because you...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a) ...cannot get to sleep within 30 minutes	☐	☐	☐	☐
(b) ...wake up in the middle of the night or early morning	☐	☐	☐	☐
(c) ...have to get up to use the bathroom	☐	☐	☐	☐
(d ...cannot breathe comfortably	☐	☐	☐	☐
(e) ...cough or snore loudly	☐	☐	☐	☐
(f) ...feel too cold	☐	☐	☐	☐
(g) ...feel too hot	☐	☐	☐	☐
(h) ...had bad dreams	☐	☐	☐	☐
(i) ...have pain	☐	☐	☐	☐

(j) Other reason(s), please describe

____

____

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
How often during the past month have you had trouble sleeping because of this?	☐	☐	☐	☐

d. **Impulsiveness**

UPPS-P

Below are a number of statements that describe ways in which people act and think. For each statement, please indicate how much you agree or disagree with the statement. If you **Agree Strongly** circle **1**, if you **Agree Somewhat** circle **2**, if you **Disagree somewhat** circle **3**, and if you **Disagree Strongly** circle **4**. Be sure to indicate your agreement or disagreement for every statement below. Also, there are questions on the following pages.

	Agree Strongly	Agree Some	Disagree Some	Disagree Strongly
1. I have a reserved and cautious attitude toward life.	1	2	3	4
2. I have trouble controlling my impulses.	1	2	3	4
3. I generally seek new and exciting experiences and sensations.	1	2	3	4
4. I generally like to see things through to the end.	1	2	3	4
5. When I am very happy, I can't seem to stop myself from doing things that can have bad consequences.	1	2	3	4
6. My thinking is usually careful and purposeful.	1	2	3	4
7. I have trouble resisting my cravings (for food, cigarettes, etc.).	1	2	3	4
8. I'll try anything once.	1	2	3	4
9. I tend to give up easily.	1	2	3	4
10. When I am in great mood, I tend to get into situations that could cause me problems.	1	2	3	4
11. I am not one of those people who blurt out things without thinking.	1	2	3	4
12. I often get involved in things I later wish I could get out of.	1	2	3	4
13. I like sports and games in which you have to choose your next move very quickly.	1	2	3	4
14. Unfinished tasks really bother me.	1	2	3	4
15. When I am very happy, I tend to do things that may cause problems in my life.	1	2	3	4
16. I like to stop and think things over before I do them.	1	2	3	4
17. When I feel bad, I will often do things I later regret in order to make myself feel better now.	1	2	3	4
18. I would enjoy water skiing.	1	2	3	4
19. Once I get going on something I hate to stop.	1	2	3	4
20. I tend to lose control when I am in a great mood.	1	2	3	4
21. I don't like to start a project until I know exactly how to proceed.	1	2	3	4

Please go to the next page

	Agree Strongly	Agree Some	Disagree Some	Disagree Strongly
22. Sometimes when I feel bad, I can't seem to stop what I am doing even though it is making me feel worse.	1	2	3	4
23. I quite enjoy taking risks.	1	2	3	4
24. I concentrate easily.	1	2	3	4
25. When I am really ecstatic, I tend to get out of control.	1	2	3	4
26. I would enjoy parachute jumping.	1	2	3	4
27. I finish what I start.	1	2	3	4
28. I tend to value and follow a rational, "sensible" approach to things.	1	2	3	4
29. When I am upset I often act without thinking.	1	2	3	4
30. Others would say I make bad choices when I am extremely happy about something.	1	2	3	4
31. I welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional.	1	2	3	4
32. I am able to pace myself so as to get things done on time.	1	2	3	4
33. I usually make up my mind through careful reasoning.	1	2	3	4
34. When I feel rejected, I will often say things that I later regret.	1	2	3	4
35. Others are shocked or worried about the things I do when I am feeling very excited.	1	2	3	4
36. I would like to learn to fly an airplane.	1	2	3	4
37. I am a person who always gets the job done.	1	2	3	4
38. I am a cautious person.	1	2	3	4
39. It is hard for me to resist acting on my feelings.	1	2	3	4
40. When I get really happy about something, I tend to do things that can have bad consequences.	1	2	3	4
41. I sometimes like doing things that are a bit frightening.	1	2	3	4
42. I almost always finish projects that I start.	1	2	3	4
43. Before I get into a new situation I like to find out what to expect from it.	1	2	3	4
44. I often make matters worse because I act without thinking when I am upset.	1	2	3	4
45. When overjoyed, I feel like I can't stop myself from going overboard.	1	2	3	4

Please go to the next page

	Agree Strongly	Agree Some	Disagree Some	Disagree Strongly
46. I would enjoy the sensation of skiing very fast down a high mountain slope.	1	2	3	4
47. Sometimes there are so many little things to be done that I just ignore them all.	1	2	3	4
48. I usually think carefully before doing anything.	1	2	3	4
49. When I am really excited, I tend not to think of the consequences of my actions.	1	2	3	4
50. In the heat of an argument, I will often say things that I later regret.	1	2	3	4
51. I would like to go scuba diving.	1	2	3	4
52. I tend to act without thinking when I am really excited.	1	2	3	4
53. I always keep my feelings under control.	1	2	3	4
54. When I am really happy, I often find myself in situations that I normally wouldn't be comfortable with.	1	2	3	4
55. Before making up my mind, I consider all the advantages and disadvantages.	1	2	3	4
56. I would enjoy fast driving.	1	2	3	4
57. When I am very happy, I feel like it is ok to give in to cravings or overindulge.	1	2	3	4
58. Sometimes I do impulsive things that I later regret.	1	2	3	4
59. I am surprised at the things I do while in a great mood.	1	2	3	4

e. **Words Used in the Memory Task**

1. Ready
2. Adapt
3. Fault
4. Occur
5. Dream
6. Clear
7. Pause
8. Moral
9. Lower
10. Doubt
11. Allow

12. Offer
13. Basis
14. Labor
15. Habit
16. Apple
17. Light
18. Screw
19. River
20. Table
21. Round
22. Brick
23. Hotel
24. Cable
25. Waste
26. Pupil
27. Juice
28. Paper
29. Party
30. Cloud

The memory task will be used to test participants' memory. Participants will be given 30 words. They will be given 5 minutes to study the words and afterwards they will be asked to recall as many words as they can.

f. **Demographic questions**

SONA ID #: ___________________

How do Anxiety, Stress, Impulsiveness, and Sleep Quality Affect Memory?

Demographics Questionnaire (**All responses are anonymous**)

(*Please print clearly and do not write your name anywhere on this form*)

Age: ________

Gender:

Male Female

Handedness:

Left Right Ambidextrous

Level of Education:

______Undergraduate freshman or sophomore

______Undergraduate junior or senior

______Graduate student

Yes No History of neurological disorder or head trauma?

Yes No Do you have a prior history of severe learning disabilities?

Yes No Do you have a history of prosopagnosia or face blindness?

Yes No Do you have 20/20 vision or corrected vision?

Yes No Are you currently taking any medication or drug that diminishes your ability to think or learn?

Yes No Have you taken any mind-altering substance (legal or illegal) in the last week?

Yes No Do you use tobacco?

Yes No Did you have any caffeine today?

Yes No Including tobacco, caffeine, and any other type of stimulant, was the amount you took today normal for you?

Appendix E:

Debriefing Form

Debriefing Form

Thank you for participating in this study. Your time and effort are appreciated. The purpose of my research is to determine college students' immediate memory and how everyday experiences can influence their memory. This study tested the hypotheses that stress, anxiety, impulsiveness, and sleep disturbances would all exhibit negative associations with memory performance. Additionally, it examined whether a Dm ERP effect could differentiate recalled from not recalled words, and whether this Dm ERP effect would be related to factors impacting college students, such as stress, sleep disturbances, anxiety, and impulsiveness. The dependent variables were memory accuracy and EEG alpha activity. EEG alpha activity measures attention, with lower alpha levels as you become more focused. Alpha activity is higher when you are sleepy, so it may be higher for participants with higher sleep disturbance. The independent variables were stress, anxiety, impulsiveness and sleep disturbances.

With this information, we hope to understand better how everyday activities affect memory and brain arousal that is needed for forming memories. We hope that participating in this study will help you understand the importance of memory and how you can improve it. If you have any questions, do not hesitate to contact the Primary Investigator, Hodavia Kaseya at hodavia_kaseya@mymail.eku.edu and the faculty mentor, Dr. Adam Lawson at adam.lawson@eku.edu. To learn more about the concepts of this study, you can read the following:

Baddeley, A. (2010). Working memory. *Current Biology*, *20*(4), R136–R140. https://doi.org/10.1016/j.cub.2009.12.014

Gradisar, M., Terrill, G., Johnston, A., & Douglas, P. (2008). Adolescent sleep and working memory performance. *Sleep and Biological Rhythms, 6*(3), 146–154. https://doi.org/10.1111/j.1479-8425.2008.00353.x

Lukasik, K. M., Waris, O., Soveri, A., Lehtonen, M., & Laine, M. (2019). The relationship of anxiety and stress with working memory performance in a large non-depressed sample. *Frontiers in Psychology, 10*. https://doi.org./10.3389/fpsyg.2019.00004

Paller, K. A., Kutas, M., & Mayes, A. R. (1987). Neural correlates of encoding in an incidental learning paradigm. *Electroencephalography and Clinical Neurophysiology, 67*(4), 360–371. https://doi.org/10.1016/0013-4694(87)90124-6

Paller, K. A., McCarthy, G., & Wood, C. C. (1988). ERPs predictive of subsequent recall and recognition performance. *Biological Psychology, 26*(1–3), 269–276, https://doi.org/10.1016/0301-0511(88)90023-3

Spinella, M. (2004). Neurobehavioral correlates of impulsivity: Evidence of prefrontal involvement. *International Journal of Neuroscience*, *114*(1), 95–104. https://doi.org./10.1080/00207450490249347

Appendix F:

EEG Data Preprocessing and Analysis

EEG Data Preprocessing and Analysis

Tutorial on Creating ERPs in ERPLAB with EEG Data

Stage 1: Preprocessing Raw EEG Data

- Navigate to the folder storing your raw Acqknowledge data by…
    - Open the folders library
    - Click the arrow next to This PC
    - Click the arrow next to Documents
    - Select the folder Kaseya's Folder
- Open the first file by double-clicking on a participant's data (for ex: Participant 001)
- It should open in ACQKnowledge
- If prompted, click Analyze Only
- Click File then Save as…
- Under File Name type your name before Participant 001 *(ex: ViaaParticipant 001)*
- Under Save as Type select MATLAB Mat-File (*.mat)
- On the left side, navigate to and select the Kaseya's folder
- Select Save
- Go back to the Kaseya's folder
- You should see your newly named file there
- It should say Microsoft Access… under Type and 106,501 KB under Size
- You now need to open your second file
- Go back into AcqKnowledge, then click File then Open…

- Navigate to the Kaseya's folder and select Participant 002 then Open
- Select File then Save as…
    - Under File Name type your name before Participant 002
    - Under Save as Type select MATLAB Mat-File (*.mat)
    - Select Save
- Go back to the Kaseya's folder
    - You should see your second file there
    - It should say 74,079 KB under Size
- Now left-click and highlight your two newest files and select Copy to then Choose location…
    - Select the Kaseya2 folder and click Copy
- Navigate to the Kaseya2 folder
    - You should see your two copied files there
- Copy the copied files to a jump drive
- Your files are now ready for Stage 2!

Stage 2: Renaming Channels in MATLAB (For Participant 002, make sure your files are all named 002 and not 001)

- Plug in the jump drive from stage 1
- Open MATLAB
    - Type eeglab into the command window to open eeglab and hit enter
- Go to File, then Import data, then Using EEGLAB functions and plugins, then from BIOPAC MATLAB file
- Select your file, ViaaParticipant 001, and click Open

- Name the dataset YourNameTutorial001 (for example Viaa001) and then click Ok
- Go to Edit, then Select Data, Click … to see the list of channels
    - Make the channel screen bigger and screenshot all channels
- Exit out of the two pop-ups
- Go to File, then Import Event Info, then from data channel
    - For Event Channel(s), type 18.
    - For Transitions to extract? Change to down (trailing) and click it so that it turns blue
    - For Transition length, change it to 1
- Uncheck the box for Delete event channel(s)
- Uncheck the box for Delete old events if any
- Check the box All events of same type
- Select Ok
- Repeat the above step but change the event channel type to each channel (19, 20, 21, 22...so on, I had 22 event channels, your study may have more)
- Go to Edit, then Select epoch or events, click … and check all event channels are there *(18-22 for all participants depending on your study)*
- Select chan18, click Ok
- Uncheck the box Keep only selected events and remove all other events
- For Rename selected event type(s) as type, type in WordTargetOnset1
- Click Ok
- On the next pop-up, click Ok

- Repeat the above step with all channels, but for Rename selected event type(s) as type, type in the below name for each channel
    - Rename chan19 to BasicMathProblemInstructinsOnset2
    - Rename chan20 to Fixation Onset3
    - Rename chan21 to Target Onset4
    - Rename chan22 to RecallWordOnset5
- Go to File, Save current dataset as
    - Navigate to the Kaseya's folder
    - Name it ViaaEvents001
    - Hit Save
- Go to Edit, then Select Event Values
    - For each participant, look at their recall order and change the event values (1-63). For value 64, change it to BasicMathProblemInstructinsOnset2
    - Click Ok
    - Name the data set ViaaEventValues001
    - Click Ok
- Go to File, then Save current dataset as
    - Name it ViaaEventValues001
    - Then click Save
- Go to Edit, then Select Data
    - For Channel range, type 1:7 (this pertains to the electrode channels you are using)
    - Click Ok

- Name the data set ViaaElectrodes001
- Click Ok
- Go to File, then Save current dataset as
- Name it ViaaElectrodes001
- Then click Save
- Go to Edit, then Channel locations, then click Ok
- Delete the current channel label and retype the label *(has to be done because of a bug)*
- Click the arrow next to channel number 1 to go to the next channel
- Retype the channel labels up to channel 7
- Click Look up locs, select Ok
- Make sure every channel label has numbers filled in
- Click Ok
- Go to File, then Save current dataset as
- Name it ViaaLocations001
- Click Save
- Go to ERPLAB, then EventList, then Create EEG EventList
- It will give you a warning, click Continue
- Click Browse, Click the Kaseya's folder
- Rename it to Viaa001EventList
- Click Save
- Click Create
- It will give you a warning, click Proceed

- Repeat this entire stage with Participant 002

Stage 3: Cleaning the Data

- First open the folders library, then navigate to the Kaseya's folder
  - Click on Viaa001Eventlist.set
  - Click Copy to-, then click Kaseya's folder (the reason you have to copy the files is because when you make a study it edits the original files, so if you mess up, you want to have the original to go back to)
- Go into eeglab
- Go to File, then Create study, then Browse for datasets
  - A warning will pop up, hit Ok
  - Under browse click … for the first participant
    - Click Viaa001Eventlist– Copy (make sure you select the COPY)
    - Click Open
  - Under browse click … for the second participant
    - Click Viaa002Eventlist– Copy (make sure you select the COPY)
    - Click Open
  - At the top of the page:
    - For Study set name, enter ViaaStudy
    - For Study set task name, enter ViaaStudyX
    - For Study set notes, enter xxx
  - Under subject
    - For the first participant, type 001
    - For the second participant, type 002

    - Click Ok

- Go to Tools, then Filter the data, then Basic FIR filter (new, default)
    - For Lower edge of the frequency pass band (Hz), type 1
    - For Higher edge of the frequency pass band (Hz), type 80
    - Click Ok
    - It will give you a warning, read the warning and hit Proceed
    - Close the two figure pop-ups
- Go to File, then Save current study as, then Kaseya's Folder
    - Name it ViaaStudyBandpass
    - Click Save
    - It might ask you to rewrite your datasets, if it does click Yes
- Go to Tools, then Extract epochs
    - Next to Epoch limits, type (–1 2)
    - Click Ok
    - Click Proceed
    - Click Cancel
- Go to ERPLab, then Select Artifact detection in epoched data
    - Select Moving window peak-to-peak threshold
    - Click Accept
    - Wait
    - Click Ok
    - Click Norm
    - Then you'll go through and reject any eye blinks

- Click Update Marks
- Click Ok

- Go to File, then Save current study as
  - Name it ViaaStudyCleaned
  - Click Save
  - When asked, click Yes

Stage 4: Analyzing the Data

- Go into EEGlab if not already there
- Go to File, then Load existing study
  - Click Ok
  - Click on ViaaStudyCleaned
  - Click Open
- Go to Study, then Select/Edit study design(s)
  - Click Rename
  - Type in ViaaStudyDesign
  - Click Ok
  - Under Edit the independent variables for this design, select New
  - Click codelabel
  - Select the comparison conditions
  - On the keyboard press and hold ctrl, then click WordTargetOnset1 and click & RecallWordOnset5
  - Click Ok
  - Click Ok

- Go to Study, then Precompute channel measures
  - Uncheck the box Spherical interpolation of missing channels
  - It’ll give you a warning, click Ok
  - Check the box ERPs
  - Check the box Image ERPs
  - It’ll give a warning, click Ok
  - Click Ok
  - If it gives a warning, click Ok
  - Wait
- Go to Study, then Plot channel measures
  - Select All FZ in the first box
  - Select 001 FZ in the second box
  - Click Params next to Plot ERP
    - For frequency, type in 350 450
    - Click Ok
  - Click STATS
    - Check the box Compute 1st independent variable statistics if any
    - Check the box Compute 2nd independent variable statistics if any
    - Click the arrow next to Use parametric statistics
    - Click Use permutation statistics
    - Click the arrow next to Do not correct for multiple comparisons
    - Click Use FDR correction
    - For Statistical threshold, erase exact and type .05

    - Click Ok
        - Click Plot ERP under the second box
    - Go to Tools, then Data statistics
- To find the mean for recalled words, click on *Data1*. To find the mean for words not recalled, click on *Data2*
- Repeat this for every participant