THESIS

NEURAL CORRELATES OF PROSPECTIVE MEMORY IN COLLEGE STUDENTS WITH ANXIETY

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ABSTRACT

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Prospective memory is the ability to create and execute future tasks. It is comprised of two components: cue detection and intention retrieval. Prospective memory is essential for successfully performing high-level goals, a proficiency that is of extreme importance in college populations. Previous research has shown that prospective memory is vulnerable to deterioration in individuals with psychological disorders. Anxiety is a psychological disorder that has been associated with various cognitive deficits, including prospective memory impairment, and it is highly prevalent among undergraduate students. To date, no studies have investigated the relationship between prospective memory and anxiety using neurophysiology. The purpose of the present study is to fill this gap in the literature by examining prospective memory performance in college students with anxiety using an electroencephalogram (EEG). After recording anxiety levels via self-reported measures, participants completed a computerized prospective memory task while two types of event-related potentials were recorded from an EEG: the N300 to assess cue detection, and the prospective positivity to assess intention retrieval. The findings indicate that anxiety was not significantly related to prospective memory performance, although the data patterns suggest that accuracy decreased as anxiety increased. Intention retrieval was weakly positively correlated with accuracy, and weakly negatively correlated with state anxiety. Taken together, these results suggest intention retrieval could be a key component in supporting prospective memory for college students with high state anxiety.

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INTRODUCTION

Prospective memory (PM) is the ability to create and successfully perform future tasks and goals (Einstein & McDaniel, 1990). Examples of PM include remembering to take medication when you eat a meal, remembering to get groceries when you start to run low, and remembering to submit assignments for work or school (Einstein & McDaniel, 2005). According to Einstein and McDaniel (1990; McDaniel & Einstein, 1992), PM has two primary components: a prospective component and a retrospective component. The prospective component, also called cue detection, refers to one noticing the cue for carrying out an intended task. The retrospective component, also called intention retrieval, refers to one retrieving the intended task. If the overall PM goal was to take medication when eating a meal, the prospective component would be eating the meal, as this action would be the cue that one would have to recognize to complete their goal. The retrospective component would be remembering to then take the medication, as this would be retrieving the intended goal from memory.

PM plays an important role in autonomy and independence and is more generally indicative of everyday memory competence and functioning (Ramos et al., 2020; Kinsella et al., 2009). Impairments in PM can have serious ramifications for an individual's safety, health, independence, and quality of life (Guynn, et al., 1998; Ordemann et al., 2014). For example, if failure of PM were to occur in the example previously discussed, taking medication when eating a meal, this could result in the individual not taking their medication. Depending on the medication, this could have serious implications for the person's health, especially if this is a consistent issue. For this reason, understanding which populations are at risk for PM deficits is important, as it can help at-risk individuals receive the necessary intervention and reinforcement for their PM abilities, and ultimately support health and well-being. Furthermore, understanding the mechanisms behind PM impairments, whether it is cue detection or intention retrieval, is also valuable in remediating PM performance. If researchers can identify which component of PM with which a population is struggling, they can target interventions towards that specific component. This approach can help reduce harm and increase quality of life for populations with PM deficits.

Regarding which populations are at a greater risk for PM impairments, consistent deficits have been shown in chronically impairing disorders such as schizophrenia (Ordermann et al., 2014), dementia (Thompson et al., 2010), Parkinson's disease (Coundouris et al., 2020), and traumatic brain injuries (Gonzalez & Buchanan, 2019). While PM deficits have been well documented in these clinical populations, there is a lack of thorough research on how PM interacts with less debilitating psychological disorders, or even subclinical symptoms of psychological disorders. Anxiety and sub-clinical anxiety symptoms are examples of psychological symptoms that affect a large segment of the population during at least one point their lives, and can be associated with difficulties in everyday activities, but have not been well researched in regard to PM.

Anxiety is a physiological, affective, and cognitive response to a prolonged, unpredictable threat (Grillon et al., 1991; Grillon, 2008). It is characterized by feelings of tension, worry, distress, and trouble concentrating (Mayo Clinic, 2018). Individuals with anxiety endorse feelings of persistent worry and fear towards day-to-day situations (Mayo Clinic, 2018), and they may experience negative effects on job performance and interpersonal relationships (Vytal et al., 2013). Researchers are interested in anxiety because of its well-known harm on people's emotional and physical well-being, and because it is prevalent among undergraduate college students. According to the American College Health Association (2018; 2022), 63% of undergraduate students have reported experiencing overwhelming levels of anxiety, and 35% of undergraduates have been diagnosed with an anxiety disorder. Due to the high cognitive demands of being an undergraduate student, and the continuing cognitive growth that takes place during this time, it is important that researchers assess factors that could be influencing the psychological and cognitive capacities of students.

Further, previous studies have demonstrated negative effects of anxiety on PM in undergraduate students. Bowman et al. (2019) observed decreased PM performance in college students with high levels of trait anxiety, as measured by the Beck Anxiety Inventory (BAI). While this study provides results on how PM is generally affected by anxiety, it does not indicate the particular effects of anxiety on the different components of PM. This study design is standard for the majority of PM and anxiety studies, as will be discussed further in the literature review (Harris & Menzies, 1999; Harris & Cumming, 2003; Kliegel & Jäger, 2004; Cheie et al., 2014). Arnold et al. (2015) took a unique perspective by attempting to investigate the relationship between anxiety and the two components of PM using multinomial processing tree modeling. They observed a negative correlation between state anxiety, as measured by the State Trait Anxiety Inventory (STAI), and the cue detection component of PM (Arnold et al., 2015). These results were achieved using modeling, but there are no studies that have attempted to utilize neuroimaging to examine similar aims. Neuroimaging is an ideal complementary method to better understand the components of PM, since it can measure accuracy, response time, and neural correlates simultaneously. These neural correlates can be used to help determine the mechanism of cognitive dysfunction. Bowman et al. (2019) and Arnold et al. (2015) provide a framework for the potential relationship between PM and anxiety, but there is still a lack of studies that investigate the specific effects of anxiety on the different components of PM using neuroimaging.

Traditionally, behavioral PM tasks have measured overall PM performance based on reaction time and accuracy, but they have not provided insight into the separate PM components or the underlying physiology of the PM errors. Event-related potentials (ERPs), however, have the ability to capture neural activity associated with a behavioral response to a cognitive task. PM tasks measured with ERPs can be used to investigate the neural processes underlying the two components of PM with relative ease (Chen et al., 2015). ERPs will allow the current study to extend upon previous behavioral findings by examining neural correlates associated with the two components of PM in participants with anxiety.

Statement of Problem

The current literature demonstrates that: PM has two components (cue detection and intention retrieval), PM is important for academic and work success, health, and functional independence, anxiety levels are high among undergraduate students, and anxiety likely interferes with cognitive processes, including PM. The present literature does not utilize neurophysiology to indicate if anxiety interacts with the two components of PM differently. If researchers know how cue detection and intention retrieval are related to anxiety in college students, they can have an idea of how interventions for PM can be best applied for this population. Since anxiety levels are high among college students and PM is a critical aspect of independence, physical health, goal-directed behavior, and safety, understanding where interventions can be best applied to improve PM has the potential to improve functional outcomes and quality of life for students with anxiety.

LITERATURE REVIEW

Prospective Memory

PM allows for future-intentioned goals to be successfully carried out (Einstein & McDaniel, 1990; 2005). PM is critical for nearly every aspect of life, including work and academic endeavors (e.g., remembering to submit important assignments), social engagements (e.g., remembering to attend a friend's birthday party), and health needs (e.g., remembering to take medication when eating a meal; Einstein & McDaniel, 2005). There are two types of PM: event-based and time-based. Event-based PM occurs when the intended task is cued by a particular event. Time-based PM occurs when the intended task is cued by a specific time (Cona et al. 2012). Event-based PM will be the focus of this project. Time-based PM will not be measured in this study for two primary reasons: first, the current literature has not found an ideal way to measure time-based PM using EEG/ERPs. The continuous time monitoring that is necessary for successful time-based PM limits the ease and practicality of measuring this type of PM with ERPs. Second, researchers have theorized that more cognitive work is required in event-based PM, since the cue in event-based PM is more unpredictable and spontaneous than in time-based PM; this spontaneity of the cue could result in a greater amount of cognitive resources necessary for successful cue detection and intention retrieval (Cona et al., 2012). For these reasons, event-based PM is better suited to study the components of interest using ERPs. This notion is further supported by the fact that, to date, the behavioral studies investigating PM in college students with anxiety primarily measured event-based PM (Bowman et al., 2019; Arnold et al., 2015).

While PM is related to retrospective memory, there is an important difference separating the two types of memory: PM requires a greater degree of self-initiation than retrospective memory (Craik, 1986). To successfully perform retrospective memory, one must remember what the target task is, but they do not need to remember a specific cue in order to trigger the target task, as is the case in PM (Einstein & McDaniel, 1990; 2005; McDaniel & Einstein, 1992). In an experimental setting, retrospective memory is demonstrated by the experimenter indicating that it is time to recall the cue and perform the task in a retrospective memory task. PM tasks, on the other hand, do not involve the experimenter prompting recall. To successfully perform a PM task, participants must switch from viewing a word, object, or event as part of the ongoing task, to viewing the word, object, or event as a cue to perform a particular action (Einstein & McDaniel, 1990; 2005; McDaniel & Einstein, 1992).

PM is further differentiated from retrospective memory based on the two components of PM: cue detection and intention retrieval. For PM to be activated, one must be able to successfully recognize the appropriate prompt (i.e., cue detection), oftentimes while carrying out other tasks or experiencing other distractions. Once they have recognized the cue, they must then remember what the future-intentioned goal was, pause from the ongoing task or distraction, and successfully perform the PM goal (i.e., intention retrieval). The combination of these processes allows for effective PM performance. Failure in either of these components, whether it is failure to detect the appropriate cue, or failure to retrieve the necessary goal from one's memory, would result in impaired PM performance (Einstein & McDaniel, 1990).

Prospective Memory and ERPs

In this novel study, using ERPs to measure PM will extend upon behavioral and modeling findings by examining neural correlates associated with the two components of PM in participants with anxiety. Previous literature has demonstrated that the N300 and the prospective positivity allow for the two components of PM, cue detection and intention retrieval, to be identified and characterized (West & Krompinger, 2005). The N300 is characterized by phasic negativity over the occipital–parietal region between 200 and 400 ms after stimulus presentation (West et al., 2001). The N300 amplitude increases for correct PM responses in comparison to incorrect PM responses, indicating that it is implicated in the cue detection component of PM (West et al., 2003; West & Ross-Munroe, 2002). The prospective positivity is characterized by sustained positivity over the parietal region between 500 and 1000 ms after stimulus presentation (West et al., 2001). The amplitude of the later segment of the prospective positivity increases when there are multiple intended actions associated with a cue, in comparison to when there is one intended action associated with a cue, indicating that it is implicated in the intention retrieval component of PM (West & Ross-Munroe, 2002).

The N300 and prospective positivity have been used in a previous study to examine PM impairments in a clinical population. Chen and colleagues (2015) investigated PM deficits in patients with schizophrenia. They were able to identify intention retrieval as the mechanism behind PM deficits in this population with the N300 and prospective positivity ERP components. Based on their findings, Chen and colleagues (2015) suggested that specific interventions directed at remediating intention retrieval could improve overall PM performance, functional outcomes, and quality of life for patients with schizophrenia. This study demonstrates how identifying which component of PM (cue detection or intention retrieval) is affecting a population can be beneficial in better understanding the PM impairment and can potentially help to develop a successful intervention targeted at that component (Chen et al., 2015). Chen and colleagues (2015) argue that the results from their study can aid in reducing harm and increasing quality of life for individuals with schizophrenia.

Importance of Prospective Memory

While the theory behind PM provides interesting insights into the cognitive and neural underpinnings of PM, it is critical to remember the everyday functionality and importance of PM in daily life, particularly in the life of a college student. During college, students must be able to balance their class assignments, personal lives, mental and emotional health, physical health, and possibly work a part-time or full-time job. Juggling these moving pieces involves a high number of cognitive resources, including PM. For example, to succeed academically, students must be able to set and maintain future intentions regarding attending class, completing and submitting assignments, and consistently studying. Further, to maintain physical and emotional health, college students must be able to create and carry out future goals of attending important appointments, following through on retrieving prescriptions, and taking medication at appropriate times. Properly functioning PM is necessary to complete all of the tasks described above, and failure of PM in these instances can result in negative, long-lasting consequences.

Further, previous research has demonstrated a connection between PM skills and student behaviors related to academic performance and health, with time management linking the relationship. Strong time management abilities are related to successful PM (Macan et al., 2010) and college student behaviors associated with enhanced academic performance and health (Kearns & Gardiner, 2007). Time management skills are necessary for college students to study effectively (Krause & Coates, 2008), sleep an appropriate amount, eat a healthy diet, exercise, and maintain a social life (O'Connell, 2014). All of these factors contribute to academic success (Horton & Snyder, 2009), as well as emotional, cognitive, and physical health (Burrows et al., 2017; Miller et al., 2008). PM is related to time management, as both cognitive abilities share the ultimate goal of creating and carrying out future intentioned goals (Macan et al., 2010). This similarity between the abilities, as well as the other skills involved in time management (i.e., retrospective memory, making lists, following schedules, focusing on tasks), suggest that PM is a critical aspect of time management capabilities (Macan et al., 2010). If a student experiences a failure of PM, they will likely also undergo impairments in time management abilities, which can result in detriments to behaviors such as a regular sleep schedule, exercise, diet, social engagement, and general self-care. These detriments in behaviors can lead to negative outcomes for college students regarding academic success and health, demonstrating the importance of successful PM for college students.

Effectively supporting PM abilities has implications for academic outcomes and physical, cognitive, and emotional health. Clearly, understanding which populations are at risk for PM deficits, as well as the mechanism of the impairment, is critical. While Chen and colleagues' (2015) results described in the previous section are applicable to individuals with schizophrenia, this psychological disorder that is not highly prevalent among college students. General anxiety, on the other hand, is a disorder that is strongly prevalent in undergraduate students, and has received less rigorous research regarding its relationship with PM. To support the cognitive well-being and success of college students, it is necessary for researchers to thoroughly investigate factors that could be negatively influencing PM capabilities, and *how* these factors could be impairing cognition. In examining the neural mechanisms of PM performance in college students with anxiety, the current study will be able to address these research goals.

Anxiety

Anxiety disorders are the most common mental health issue in the United States (ADAA, 2021), with 19.1% of people having a clinical anxiety diagnosis (NAMI, 2017). Further, subclinical anxiety symptoms are extremely widespread, possibly even more so than a diagnosed anxiety disorder. Anxiety is highly relevant to undergraduate students, as they are particularly susceptible to anxiety: 63% of undergraduate students have reported experiencing overwhelming levels of anxiety, and 35% of undergraduates have been diagnosed with an anxiety disorder (American College Health Association, 2018; 2022). Symptoms and consequences of general anxiety disorder are both physiological and cognitive. Affective, cognitive, and physiological symptoms of anxiety are thought to arise from a perceived unpredictable and long-term threat (Grillon et al., 1991; Grillon, 2008). Individuals with anxiety have reported experiencing negative effects on job performance and interpersonal relationships, which could be attributed to persistent worry and fear towards daily life (Mayo Clinic, 2018; Vytal et al., 2013). According to the DSM-5, symptoms of general anxiety include excessive, uncontrollable worry, restlessness, irritability, trouble concentrating, sleep disturbance, and/or significant distress and impairments in social, occupational, or other personal environments (American Psychiatric Association, 2013). While the affective and physiological symptoms and implications of anxiety are important, this project will focus more specifically on the cognitive ramifications of anxiety.

Several studies have suggested that anxiety may interfere with cognitive processes, including memory. This could be explained by the persistent fear and worry involved in anxiety, as this fear and worry causes anxious individuals to be on constant alert for potentially threatening information (Bar-Haim et al., 2007). The attentional bias towards threat detection could lead to limited cognitive resources for non-threat relevant information, which could ultimately result in difficulties with concentrating on day-to-day tasks and impaired performance of goal-directed tasks (Eysenck and Calvo, 1992; Eysenck et al., 2007). Since PM is a key component of successfully carrying out goal-directed tasks, this framework suggests that anxiety impairs PM performance.

While the high prevalence of anxiety, particularly among undergraduate students, has already been discussed, it is important to note the increased reports of anxiety diagnoses and symptoms due to COVID-19. Son et al. (2020) found that 71% of students in their study reported increased anxiety symptoms and stress following the pandemic outbreak. The students attributed their increased anxiety to several pandemic-related issues, including fear for their health, fear for the health of their loved ones, concerns for their academic performance due to changes in their classes, decreased social interactions and social support, and interruptions to their regular sleep patterns (Son et al., 2020). Another study by Browning and colleagues (2021) demonstrated that 45% of students in their sample experienced high psychological impact from the pandemic, and 40% experienced moderate psychological impact. The most reported psychological symptoms were increased stress, lack of motivation, and isolation, which are all indicative of increased anxiety (Browning et al., 2021). Under normal circumstances, undergraduate students are a population that are experiencing high levels of anxiety (American College Health Association, 2018; 2022), and these anxiety levels have clearly been heightened due to the COVID-19 pandemic. For these reasons, undergraduate students are an optimal population to study anxiety. Understanding the cognitive impact of anxiety on undergraduate students can help researchers, professors, and higher education administrators to facilitate intervention strategies for the struggles that students may be facing.

Anxiety and ERPs

While current research has not examined ERP responses associated with PM and anxiety, other studies have demonstrated anxiety-related modulations of ERPs associated with various cognitive abilities. For example, Gupta and colleagues (2021) demonstrated that the P1 and P2 ERP components, which are both measurements of allocating attention resources (Clark & Hillyard, 1996; Bar-Haim et al., 2005), were enhanced when attending to happy and neutral faces, respectively, in adults with anxiety. Several other studies have indicated modulations of the P1 and P2 in adults with anxiety during emotional-face attention tasks (Helfinstein et al., 2008; Mueller et al., 2009; Eldar et al., 2010; Rossignol et al., 2013). Further, Wu et al. (2021) demonstrated that the contingent negative variation component, which measures task preparation and maintenance (Walter et al. 1964), differed in amplitude between a high anxiety group and a low anxiety group when completing the Stroop task. Finally, the error-related negativity, an ERP component indexing error detection (Falkenstein et al., 1991), has been shown to be enhanced in high anxiety individuals (Aarts & Pourtois, 2010). These studies indicate that ERPs are sensitive to neurocognitive disruptions connected to anxiety. The temporal resolution and sensitivity of ERPs makes them a prime neuroimaging technique for capturing the neurocognitive correlates of individuals with anxiety, as will be done in this project with the N300 and prospective positivity.

Prospective Memory and Anxiety

Previous studies have investigated the connection between anxiety and behavioral PM performance with mixed results. Cockburn & Smith (1994) reported that older adults demonstrated enhanced time-based and event-based PM performance in a naturalistic PM task associated with increased anxiety levels, as measured by a Visual Analogue Scale. Nigro & Cicogna (1999) indicated that undergraduate students had decreased reaction times in computerized event-based and time-based PM tasks associated with increased anxiety levels, as measured by the STAI. Kliegel & Jäger (2006) found both negative and positive results, as is discussed further in the next paragraph. Regarding the positive results, Kliegel & Jäger (2006) demonstrated that high levels of anxiety were associated with improved performance of a naturalistic PM task in undergraduates. Notebaert and colleagues (2018) found no relationship between a lexical-decision PM task and anxiety in undergraduate students.

While these studies present the possibility that PM and anxiety may have a positive relationship or no relationship, a greater number of studies demonstrate a different pattern. As discussed previously, Bowman and colleagues (2019) indicated impaired event-based PM performance in a PM living/nonliving decision task, PM lexical decision task, and PM semantic categorization task in undergraduates with anxiety, as measured by the BAI. Arnold and colleagues (2015) also demonstrated decreased event-based PM abilities, measured by a PM color-matching task, in undergraduate students with state anxiety, indicated by the STAI. Further, Arnold and colleagues (2015) used multinomial processing tree modeling to show that cue detection appeared to be more implicated in the PM impairment than intention retrieval. Harris and Menzies (1999) reported that increased anxiety levels, as measured by the Depression, Anxiety, and Stress Scale, predicted impaired performance on a semantic association event-based PM task. Harris and Cummings (2003) also indicated impaired performance on a semantic association task in undergraduate students with high levels of state anxiety, measured by the STAI. Regarding the negative results for Kliegel & Jäger (2006), they found that adults with high levels of anxiety, measured by the Hospital Anxiety and Depression Survey, demonstrated impaired performance on an n-back event-based PM task. Cuttler and Graff (2009) reported decreased event-based and time-based PM on naturalistic measures in participants with anxiety symptoms of high compulsive checking. Finally, Cheie and colleagues (2014) indicated event-based laboratory and naturalistic PM impairments in pre-school children with high levels of anxiety, measured by the Spence Preschool Anxiety Scale.

Overall, the literature on PM and anxiety suggests that PM performance is more likely to be impaired in anxious individuals, as opposed to enhanced or not related. Importantly, none of these studies include neurophysiology. Integrating EEG into this field of research can help to better elucidate the relationship between PM and anxiety by providing data on the neural correlates associated with behavioral PM responses. The current study will provide a clearer picture on how the components of PM, cue detection and intention retrieval, interact with anxiety levels. Due to the greater likelihood that PM abilities are diminished in individuals with high anxiety symptoms, this information could help guide interventions for improving PM by focusing on the specific component of PM that could be enhanced.

Statement of the Purpose

The purpose of this study is to examine the relationship between PM and anxiety in undergraduate students using EEG/ERPs. Undergraduate students with varying levels of anxiety performed a PM task while neural activity was recorded via EEG, addressing two primary research questions. First, this study explores how college students with anxiety symptoms perform on an event-based PM task. PM is an important cognitive function that could be impaired in different pathologies and emotional states, including anxiety. Since college is a time of high anxiety, and there have been increased levels of anxiety due to the pandemic, determining potential anxiety-related PM impairments could enhance understanding on the cognitive and functional challenges faced by college students.

Second, this study investigates whether anxiety symptoms interact differently with the two components of PM (cue detection and intention retrieval) as measured by ERPs. This methodology allows researchers to parse apart the mechanism behind PM deficits in college students with anxiety. If the results indicate that individuals with high anxiety perform poorly on the behavioral PM task, and this decreased performance is associated with N300 amplitudes, these results will show that issues with cue detection are likely the mechanism behind impaired PM for high anxiety individuals. If the results indicate that decreased PM performance in anxious individuals is associated with amplitudes of the prospective positivity, these results will demonstrate that issues with intention retrieval are likely the mechanism behind impaired PM for high anxiety individuals. If the results report no significant differences in ERP data, these results will suggest that there could be another mechanism explaining the PM deficits, such as attention. To my knowledge, this study is the first to examine the relationship between anxiety in college students and the neural activity associated with the two components of PM. By addressing these objectives, the results from this study could guide how researchers and clinicians support the cognitive and emotional health of undergraduate students with anxiety.

Hypothesis 1

A greater number of previous studies have demonstrated PM impairments in individuals associated with increased anxiety symptoms measured via the BAI and State Subscale of the STAI (STAI-S; Bowman et al., 2019; Arnold et al., 2015), as opposed to positive effects or no relationship. While the Trait Subscale of the STAI (STAI-T) has historically not been shown to relate to PM performance, overall anxiety levels have increased as a result of the COVID-19 pandemic (Son et al., 2020; Browning et al., 2021). Also, the symptomatology and behavioral framework suggests that anxiety is associated with limited attentional and cognitive resources, ultimately resulting in impairments in goal-directed behavior (Eysenck and Calvo, 1992; Eysenck et al., 2007; Vytal et al., 2013). Based on these findings, I hypothesize that the BAI, STAI-S, and STAI-T will be negatively associated with PM performance. As anxiety increases, PM performance will decrease.

Hypothesis 2

Using modeling, Arnold and colleagues (2015) suggest that cue detection is more impaired than intention retrieval in undergraduate students with anxiety. I hypothesize that the amplitude of the N300 for PM trials will be negatively associated with anxiety symptoms, as measured by the STAI-S, STAI-T, and the BAI. As anxiety increases, the amplitude of the N300 will decrease.

Hypothesis 3

Further based on Arnold and colleagues' (2015) findings, I hypothesize that the amplitude of the N300 for PM trials will be positively associated with PM performance, as indicated by accuracy and reaction time. As PM performance decreases, the amplitude of the N300 will decrease. These results will suggest that cue detection is the mechanism for PM deterioration in college students experiencing anxiety.

METHODS

Participants

Data for this study was collected from Department of Psychology undergraduate students at Colorado State University. Prior to coming to the lab, potential participants completed a demographics survey assessing biological sex, gender, age, race, ethnicity, handedness, history of epilepsy, attention deficit hyperactivity disorder (ADHD) symptoms, and anti-anxiety medication history. Exclusion criteria included not having normal or corrected hearing and vision and a history of seizures. Corrected hearing and vision were necessary for participants to receive the instructions and carry out the task. Individuals with a history of epilepsy were excluded due to the irregularity in neural electrical activity associated with seizures, which could lead to irregular EEG readings. Medication history was not used to exclude participants; anti-anxiety medications may decrease alpha waveforms and increase beta waveforms, but they have not been shown to interact with particular ERPs (Benzoci, 2005). To account for attention as an important cognitive function involved in PM (Anderson et al., 2017), the present study included a measure of ADHD to assess potential interactions.

To establish variability in anxiety levels in the sample, potential participants were screened into the study based on the trait anxiety scores. Potential participants reported their general anxiety symptoms via the STAI-T (Spielberger et al., 1983). The STAI-T was used as a screener to assess longstanding, characteristic anxiety (Xia et al., 2020; Julian, 2011; Notebaert et al., 2019). To ensure that the sample was representative of anxiety levels among college students, individuals scoring in the upper and lower quartile of the distribution of anxiety scores were included in the study (Xia et al., 2020). Based on 456 screener responses, the high anxiety quartile score was 55, and the lower anxiety quartile score was 39. Based on the STAI-T, the upper quartile anxiety score fell in the high anxiety category. The lower quartile anxiety score fell in the moderate anxiety category.

In total, 78 participants completed the EEG portion of the study. Six participants were excluded due to not understanding the task, with an accuracy lower than 10% on the PM trials. Eleven participants were excluded due to no longer fitting in the upper or lower anxiety quartiles, since the cutoff scores shifted as more potential participants completed the screener. With these exclusions, there was final *n* of 61 (M_{age}=19.8, SD_{age}=2.86, 7 left-handed, biological sex: 45 females, gender identity: 40 women, 4 gender fluid individuals, 1 transgender woman, 1 transgender man). See Table 1 for the full demographics of the sample. The EEG sessions were run during the 2022 Spring Semester, 2022 Summer Term, and 2022 Fall Semester. Data was not collected during final examination weeks, Spring Break, Fall Break, or Winter Break. Nine EEG sessions were carried out in the morning (between 9am and 11am), and 52 were completed during the afternoon (between 12pm and 6pm).

General Procedure

The study was reviewed and approved by Colorado State University's Social, Behavioral, and Educational Research Institutional Review Board. Participants were consented and then completed the following surveys: the Motivation to Participate in Psychological Research Scale, the Beck Anxiety Inventory (BAI; Beck & Steer, 1993), both subscales of the STAI (Spielberger et al., 1983), the Beck Depression Inventory II (BDI-II; Beck, Steer, & Brown, 1996), the Positive and Negative Affect Scale (PANAS; Watson et al., 1988), and the Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990). Participants also reported their hours of sleep from the previous night. The Motivation to Participate in Psychological Research Scale was included to measure the engagement that students had with psychological research; a lack of motivation from participants has been suggested to result in inattentiveness and low-effort response during task performance (Huang et al., 2012; Freng 2020). The BDI-II was used, as opposed to the BDI or Ia, due to the higher internal consistency of the BDI-II (Smarr & Keefer, 2011). Data on depression and affect were collected, as depressive disorders are highly comorbid with anxiety disorders (Goldstein-Piekarski et al., 2016), and negative affect is associated with anxiety symptomology (Clark & Watson, 1991). Participants' sleepiness levels and hours of sleep from the previous night were collected due to previous research demonstrating decreased PM performance following sleep deprivation (Grundgeiger et al., 2014). Depression, affect, sleep, and motivation were analyzed as exploratory measures of the study to assess potential interactions, comorbidities, or influences on PM in the sample. The BAI and STAI were used due to previous research utilizing these measures that has demonstrated a relationship between anxiety and behavioral PM performance (Bowman et al., 2019; Arnold et al., 2015).

Following completion of the surveys, the participants were fitted with the EEG cap and provided with task instructions to complete the PM task. Following completion of the task, participants were debriefed and provided with course credit/extra credit.

Measures

Motivation to Participate in Psychological Research Scale (Freng, 2020): Participants reported their motivation to participate in the psychology study by indicating "1 = Does not correspond at all", "2 = Corresponds very little", "3 = Corresponds a little", "4 = Corresponds moderately", "5 = Corresponds enough", "6 = Corresponds a lot", or "7 = Corresponds exactly" to a series of thirty statements (e.g., "Enjoyment that comes from a better understanding of psychology", "For the joy I feel when learning about new psychological research", "Because research in psychology is important to me"). This measure has high internal reliability (α range = .91–.97; Freng, 2020). See Appendix A for a reproduction of the measure.

Beck Anxiety Inventory (BAI; Beck & Steer, 1993*)*: Participants reported their general anxiety levels by indicating "0 = Not at all", "1 = Mildly but it didn't bother me much", "2 = Moderately - it wasn't pleasant at times", "3 = Severely it bothered me a lot" to a series of twenty-two statements (e.g., "Wobbliness in legs", "Fear of worst happening", "Fear of losing control"). The BAI has high internal reliability (α = .92), and convergent and discriminant validity (Beck et al., 1988; Fydrich et al., 1992). See Appendix A for a reproduction of the measure.

State-Trait Anxiety Inventory (STAI*;* Spielberger et al., 1983): Participants reported their state anxiety by indicating "1 = Not at all", "2 = Somewhat", "3 = Moderately so", "4 = Very much so" to a series of twenty statements (e.g., "I feel calm", "I feel satisfied", "I feel nervous"). Participants also reported their trait anxiety levels by indicating "Not at all", "Somewhat", "Moderately so", "Very much so" to another series of twenty statements (e.g., "I am content", "I lack self-confidence", "I have disturbing thoughts"). The STAI has high internal reliability (α = .86-.95), test-retest reliability (α = .65-.75), and concurrent validity (Spielberger et al., 1983). See Appendix A for a reproduction of the measure.

Positive and Negative Affect Scale (PANAS*;* Watson et al., 1988*)*: Participants reported their general affective state by indicating "1 = Very slightly or not at all", "2 = A little", "3 = Moderately", "4 = Quite a bit so", "5 = Extremely" to a series of twenty emotional stated (e.g., "Proud", "Scared", "Determined"). The PANAS high internal reliability (positive affect subscale: α = .86 - .90; negative affect scale: .85 - .87; Watson et al., 1988). See Appendix A for a reproduction of the measure.

Beck Depression Inventory II (BDI-II; Beck et al., 1996*)*: Participants reported their general depression levels by indicating if they experience depressive symptoms (e.g., "Self-dislike"), and the severity of those symptoms (e.g., "0 = I feel the same about myself as ever", "1 = I have lost confidence in myself", "2 = I am disappointed in myself", "3 = I dislike myself"). The BDI has high internal reliability (α = .92 - .93; Smarr & Keefer, 2011). See Appendix A for a reproduction of the measure.

ADHD Self-Report Screening Scale (Ustun et al., 2017): Participants reported their ADHD symptoms by indicating "1 = Never", "2 = Rarely", "3 = Sometimes", "4 = Often", and "5 = Very Often" to a series of six questions (e.g., "How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?"). This is a shortened version of the Adult ADHD Self-Report Scale, which has a high internal reliability (α = 0.88; Adler et al., 2006). This shortened version is consistent with ADHD diagnoses and has high sensitivity (Adler et al., 2006; Ustun et al., 2017). See Appendix A for a reproduction of the measure.

Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990*)*: Participants reported their sleepiness levels by indicating if they are feeling "1 = Extremely alert", "2 = Very alert", "3 = Alert", "4 = Rather alert", "5 = Neither alert nor sleepy", "6 = Some signs of sleepiness", "7 = Sleepy, but no effort to keep awake", "8 = Sleepy, but some effort to keep awake", "9 = Very sleepy, great effort to keep awake, fighting sleep", or "10 = Extremely sleepy, can't stay awake". The KSS has a high validity (Kaida et al., 2006). See Appendix A for a reproduction of the measure.

Visual Search PM Task: This task was created using PsychoPy3 Experiment Builder (v2021.2.3; Peirce et al., 2019). The task was adapted from West and Wymbs (2004) and has three essential components: an ongoing visual search task, a cue detection component, and an intention retrieval component. During the ongoing visual search task, participants were shown a target letter in the center of the computer screen, followed by two test letters on the left and right sides of the display. If the target letter is present in the test letters, the participant presses V with their left index finger. If the target letter is not present in the test letter, the participants press B with their right index finger. The PM components were introduced to the visual search task after the participants completed a block of the isolated visual search task. The letters D and M serve as the cue detection components of PM task. If the letters D or M are present in the test letters, the participants must remember to select N with their right middle finger. Remembering to select N when prompted with D or M is the intention retrieval component of the PM task. This PM paradigm has been validated in previous research to elicit the desired ERP components (West & Wymbs, 2004). See Appendix B for a reproduction of the task stimulus and instructions.

The task began with instructions for the visual search task, without the PM components: there was 1 practice block of 10 trials and 1 test block of 96 trials. The practice block without PM included 5 target-present trials and 5 target-absent trials. The test block without PM included 24 target-present trials shown on the left side, 24 target-present trials shown on the right side, and 48 target absent trials.

The instructions for incorporating the PM task were shown and explained by the researcher, and the participants continued the task. The task included 1 practice block of 10 trials, and 3 test blocks of 168 trials each. The practice block included 2 prospective-cue trials, 4 target-present trials, and 4 target-absent trials. The test block included 36 target-present trials shown on the left side, 36 target-present trials shown on the right side, and 72 target absent trials, 12 prospective-cue trials shown on the left side, and 12 prospective cue-trials on the right side.

For prospective-cue trials, a non-target letter was presented in the display opposite the cue. The prospective-cue and target were never presented together in a trial. The task ended with another test block of 96 trials for the visual search task without the PM component.

In the task, each trial included a target, a fixation, and a rest period. For the target display, the target letter was presented in the center of the computer monitor for 150 ms. The target was replaced by a fixation cross for 850 ms, followed by the test display. The test display included two letters presented on the left and right sides, with a fixation cross in the middle. The letters were presented in white, Arial font, 1/10 the size of the screen. They were separated by 35 mm of gray space. The test display was presented for 400 ms and then replaced by a blank gray screen until the response was made. If the participants did not respond after 5,000 ms, the task continued. The screen remained blank for 500 ms after the response, and then the target letter for the next trial was presented. For the first trial of each block, the screen was blank for 1,000 ms after the space bar was pressed to initiate the block (West & Wymbs, 2004).

EEG Procedure

EEG was recorded at a rate of 1000hz using SynAmps2/RT 64 Channel system (Curry7, Compumedics NeuroScan, USA) (acquisition bandwidth = 1000 Hz, sampling rate = 100 Hz) and a 64 electrode Quik-cap Neo Net with sewn-in or affixed to skin via an adhesive patch silver-chloride sintered electrodes (Diameter = 1.5 cm; Compudics USA, Inc. Model: C190). The electrodes are placed in the cap based on the extended 10/20 electrode placement standard. A .01 Hz high-pass filter and a 100 Hz low-pass filter were used during recordings. Electrode placements followed the Quik-cap 64 system and included all electrodes (Fpz, Fz, Pz, Poz, Oz, Fp1, Fp2, Af3, Af4, F1, F2 F3, F4, F5, F6 F7, F8, F11, F12, Fc1, Fcz, Fc2, Fc3, Fc4 Fc5, Fc6, Ft11, Fc12, C1, Cz, C2, C3, C4, C5, C6, T7, T8, Tp7, Tp8, Cp1, CPz, Cp2, Cp3, Cp4, Cp5, Cp6, P1, P2, P3, P4, P5, P7, P6, P8, Po3, Po4, O1, O2, Po7, Po8, Cb1, Cb2, left mastoid M1, right mastoid M2, VEOU, VEOL, HEOL, HEOR). Eye movement was monitored with electrode placement on the lateral and superior of the left eye for vertical electrooculogram (EOG), and the outer corner of each eye for horizontal EOG. The reference electrode was placed between Cz and CPz. The ground electrode was AFz. During recording, all electrodes were referenced to the electrode between Cz and CPz.

Data Analysis

Quantification of Anxiety

Anxiety was quantified as three continuous variables calculated from the total scores on the BAI, STAI-S, and STAI-T. Items 1, 2, 5, 8, 11, 15, 16, 19 and 20 on the STAI-S, and items 3, 6, 7, 10, 14, 16, and 19 on the STAI-T were reverse scored. High scores on the three measures indicate high levels of anxiety. More specifically, for the BAI, a score of 0 - 9 indicates no anxiety, 10 - 18 indicates mild to moderate anxiety, 19 - 29 indicates moderate to severe, and 30 - 63 indicates severe anxiety. For both subscales of the STAI, a score of 20-37 indicates low/no anxiety, 38 - 44 indicates moderate anxiety, 45 – 80 indicates high anxiety.

Quantification of Depression

Depression was quantified as a single continuous variable calculated from the total scores on the BDI-II. High scores on the BDI-II indicate high levels of anxiety. More specifically, a score of 0 - 13 indicates minimal to no depression, 14 – 19 indicates mild depression, and 20 – 28 indicated moderate depression, and 29 – 63 indicates severe depression.

Quantification of Affect

Affect was quantified as two continuous variables calculated by summing specific items on the PANAS for negative and positive affect. Items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20 measure negative affect. Items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19 measure positive affect. High scores on the PANAS indicate high levels of positive or negative affect.

Quantification of Motivation

Motivation was quantified as a single continuous variable calculated from the total scores on the MPPRS. Items 26, 27, 28, 29, 30, and 31 are reverse scored. High scores on the MPPRS indicate high levels of motivation.

Quantification of ADHD

ADHD symptoms were quantified as a single continuous variable calculated from the total scores on the ADHD Self-Report Screening Scale. High scores on the ADHD Self-Report Screening Scale indicate high levels ADHD.

Quantification of Sleepiness

Sleepiness was quantified as a single continuous variable, based on the score on the KSS. A high score on the KSS indicates a high level of sleepiness.

Quantification of Hours of Sleep from the Previous Night

Hours of sleep from the previous night were quantified as a single continuous variable, based on the estimated number of hours of sleep self-reported by the participants.

Quantification of PM Performance

PM performance was quantified as two continuous variables: accuracy and reaction time. Accuracy was calculated by averaging the number of correct prospective-cue trials. Reaction time was calculated by averaging the response times (ms) for the correct prospective-cue trials.

Quantification of Cue Detection and Intention Retrieval

Cue detection was quantified as a single continuous variable calculated from the average amplitude (μV) of the N300 for correct prospective-cue trials between 200 and 400 ms, from electrodes O1, Oz and O2. When the amplitude of the N300 becomes more negative, it is considered to be increasing, as a larger N300 response should be characterized by a larger negative peak. A more negative amplitude indicates an enhanced N300/cue detection response.

Intention retrieval was quantified as a single continuous variable calculated from the average amplitude (μV) of the prospective positivity for correct prospective-cue trials between 500 and 1000 ms, from electrodes P3, Pz and P4. When the amplitude of the prospective positivity becomes more positive, it is considered to be increasing, as a larger prospective positivity response should be characterized by a larger positive peak. A more positive amplitude indicates an enhanced prospective positivity/intention retrieval response. The electrodes measuring the N300 and prospective positivity were averaged in order to correlate the electrode clusters with the other measures, as has been performed in previous literature (Chen et al., 2015; Groot & Strien, 2018; Zhang et al., 2019).

Primary Analyses

In total, 16 correlational analyses were run to address the hypotheses. To address Hypothesis 1, six Pearson *r* correlational analyses were run on average scores from the BAI, STAI-T, and STAI-S, as well as accuracy and reaction time. To address Hypothesis 2, six Pearson *r* correlational analyses were run on average scores from the BAI, STAI-T, and STAI-S, and ERP amplitudes for the N300 and prospective positivity. To address Hypothesis 3, four more Pearson *r* correlational analyses were run on the amplitude of the N300 and prospective positivity, and the PM accuracy and response time. Within the results of these tests, a larger correlation coefficient indicates a stronger relationship between the variables. To account for a potential negative effect of running multiple tests, a False Discovery Rate (FDR) correction was conducted (Benjamini & Hochberg, 1995; Noble, 2009; Groppe et al., 2011). Confidence intervals were reported for all correlations. According to the power analysis via G*Power, needed group size was 48 to detect a moderate relationship at a power of .80, and the study included 61 participants (Faul et al., 2009). The power analysis to determine sample size was based on a study using a similar population, subclinical college population grouped by STAI, and measured via similar ERP components (Xia et al., 2020).

Exploratory Analyses

Calculation of Direct and Indirect Effects. To determine if the ERP components could mediate any potential relationship between anxiety and PM performance, direct and indirect effects were calculated for a mediation model. The results of the primary analyses suggest the possibility that the prospective positivity or the N300 could serve as mediating variables for the relationship between the anxiety measures and PM accuracy or reaction time. In this study, the anxiety measures acted as the predictor variables, and PM accuracy or reaction time were the outcome variables. The ERP components were the mediator variables that facilitated the relationship between anxiety and PM performance.

In mediation models, the direct effect (*c*) indicates the strength of the relationship between the predictor (X) and the outcome (Y). The *a* path communicates the relationship of X on the proposed mediator variable (M). The *b* path indicates the relationship of M on Y. The indirect effect (*ab*) demonstrates the extent of mediation carried out by M in the relationship between X and Y (Edwards, 2012). The Baron & Kenny (1986) criteria for mediation analyses state that a mediation exists if the *c, a*, and *b* path are significant, and *c* is significantly smaller than the total effects of the model (*ab* + *c*). A larger value for the *c* and *ab* regression coefficients suggests larger direct and indirect effects. The relationship between X and Y could be fully or partially mediated by M. If the model were to be fully mediated, the direct effect would be nonsignificant, and indirect effect would be significant. A full mediation suggests that the entire effect of X on Y could be explained by M. If the model were to be partially mediated, both the direct and indirect effects would be significant. A partial mediation indicates that M influences Y, but the relationship between X and Y still exists without M (Edwards, 2012). The predictor, outcome, and mediator variables were determined by the results of the primary analyses.

Calculation of Correlations and Partial Correlations. To determine if depression, affect, motivation, ADHD symptoms, and sleep were related to the anxiety levels in the sample, 21 Pearson *r* correlational analyses were run on average scores from the BDI-II, PANAS, MPPRS, ADHD Self-Report Screening Scale, KSS, hours of sleep from the previous night, and the BAI, STAI-T, and STAI-S. To determine if depression, affect, motivation, ADHD symptoms, or sleep were related to PM performance, 14 Pearson *r* correlational analyses were run on average scores from the BDI-II, PANAS, MPPRS, ADHD Self-Report Screening Scale, KSS, hours of sleep from the previous night, and PM accuracy and reaction time. To determine if depression, affect, motivation, ADHD symptoms, or sleep were related to cue detection and intention retrieval, 14 Pearson *r* correlational analyses were run on average scores from the BDI-II, PANAS, MPPRS, ADHD Self-Report Screening Scale, KSS, hours of sleep from the previous night and ERP amplitudes for the N300 and prospective positivity.

To determine if depression, affect, motivation, ADHD symptoms, or sleep could underly any significant relationships found in the primary analyses, Pearson product partial correlations were computed when appropriate. A partial correlation was calculated if any of the exploratory variables were significantly related to or was marginally significant with the anxiety measures and the PM performance variables or ERP components, and if the corresponding anxiety measure was significantly related to or was marginally significant with the same PM performance variables or ERP components. The partial correlation coefficient and *p*-value indicate the strength and significance of the relationship when accounting for another variable. Confidence intervals were reported for all correlations and partial correlations.

Data Processing

ERP Processing

The recorded EEG signals was separated into epochs 200 ms before and 1000 ms after stimulus presentation. Data was analyzed in MATLAB using EEGLab with the ERPLab plug-in. A 0.1–30 Hz zero-phase-shift bandpass filter was applied. Ocular artifacts were corrected using the Independent Component Analysis feature in EEGLab. The EEG data were re-referenced to an average reference and trials exceeding a voltage of +/- 100 μV were removed from trials. The ERP epoch included -200 to 1200 ms of activity around stimulus onset. ERPs were averaged for trials associated with correct responses where response time was less than 5000 ms. The amplitude of the N300 was measured as mean voltage between 200 and 400 ms after stimulus onset at electrodes O1, Oz, O2. The selection of these electrodes was based on the distribution of the N300 reported in prior research (West et al., 2001; West et al., 2003; West & Ross-Munroe, 2002; Chen et al., 2015). The amplitude of the prospective positivity was measured as the mean voltage between 500 and 1000 ms after stimulus onset at electrodes P3, Pz, P4. The selection of these electrodes was based on the distribution of the prospective positivity reported in prior research (West et al., 2001; West & Ross-Munroe, 2002; Chen et al., 2015).

Missing Data

Missing data was accounted for using single imputation and mean imputation. If a participant missed an item on a questionnaire, the blank response was replaced with the average score of their item responses. Single imputation was a reliable method for addressing missing data on the BAI, STAI, BDI-II, MPPRS, ADHD Self-Report Survey, and PANAS, as these questionnaires were scored by summing the item responses, and a missing response would slightly skew a participant's overall score (Zhang, 2016). In the case of the KSS and hours of sleep from the previous night, which only had one item, mean imputation was performed by replacing the blank response with the overall average score of the item for the sample (Dziura et al., 2016). Mean imputation allowed for partial correlations to be computed. There were four instances of missing data: one participant missed one item on the STAI-S, one participant missed one item on the STAI-T, and one participant did not respond to the KSS nor hours of sleep from the previous night. While single and mean imputation were valid and appropriate methods to address missing data for this study, it is important to note that they likely underestimate variability (Dziura et al., 2016).

Calculation of Standard Error

For the mediation model, bootstrap standard error for the estimates were computed. The bootstrap standard errors indicate the accuracy of the bootstrapped sample means in estimating the population means. A smaller bootstrap standard error suggests more accuracy in estimating the population mean, and vice versa (Efron & Tibshirani, 1986).

Interpretation of Analyses

For all analyses, confidence intervals and effect sizes were used to communicate the extent and strength of the relationships. While *p*-values will be reported and used to determine significance, more emphasis will be placed on effect sizes and confidence intervals. Significance testing via *p*-values indicates the likelihood that any findings are due to chance, but this form of analysis does not describe the magnitude of the findings and is more dependent on sample sizes (Sullivan & Feinn, 2012). Confidence intervals and effect sizes provide critical information not described by *p*-values. For the correlations and partial correlations, Pearson *r* coefficients indicate the effect sizes, while in the mediation model, standardized betas indicate the effect sizes. With both methods, the following effect size cutoffs were used: Small/weak effect = 0.1, Medium/moderate effect = 0.3, Large/strong effect = 0.5 (Cohen, 1988). These effect sizes indicate the strength of the relationship if the study was appropriately powered to detect statistical significance. The confidence intervals demonstrate the potential range of the correlation coefficients and mediation model estimates, which provide further information on the possible effect sizes. A range that does not contain zero is considered significant. For this study, 95% confidence intervals (95% CI) were calculated, indicating the likelihood that there is a 95% chance that the true effect size is captured in the range (Davies & Crombie, 2009). For the mediation model, the confidence intervals were computed using 1,000 bootstrapped samples, producing bias-corrected bootstrapped confidence intervals.

Due to the importance of confidence intervals and effect sizes, the interpretation of the results will not focus on the FDR corrected *p*-values, although the FDR corrected *p*-values for the primary analyses will be reported. The exploratory analyses did not employ a *p*-value correction for multiple comparisons, as these analyses were not central components of the study, and the mediation model in particular was underpowered (Friz & MacKinnon, 2007). When reporting *p*-values, a value of ($\alpha = 0.05$) will indicate statistical significance, and a value of ($\alpha = 0.10$) will indicate marginal significance.

RESULTS

Descriptive statistics were calculated and are reported in Table 1. The R script that was created to perform the primary analyses is available in Appendix C. Most notably, average anxiety scores for the BAI, STAI-T, and STAI-S were 20.28, 46.66, and 40.20, respectively. These scores indicate that on average, the sample demonstrated moderate to severe anxiety on the BAI, and high anxiety on the STAI.

Primary Analyses

Hypothesis 1: Association between Prospective Memory Performance and Anxiety Measures

Pearson product-moment correlation coefficients were computed to assess the linear relationship between the BAI and accuracy for the PM task and the BAI and reaction time for the PM task. There was a nonsignificant, weak, negative correlation between the BAI and accuracy, $r(59) = -.012$, 95% CI [-.263, .240], $p = .925$. The FDR-corrected p-value was calculated, $p = .925$. There was a nonsignificant, weak, positive correlation between the BAI and reaction time $r(59) = .111$, 95% CI [-.144, .353], $p = .392$. The FDR corrected p-value was calculated, $p = .471$. These findings suggest that anxiety as measured by the BAI is not significantly related to PM performance.

Pearson product-moment correlation coefficients were computed to assess the linear relationship between the STAI-T and accuracy for the PM task, and the STAI-T and reaction time for the PM task. There was a nonsignificant, weak, negative correlation between the STAI-T and accuracy, $r(59) = -.116$, 95% CI [-.358, .140], $p = .372$. The FDR corrected p-value was calculated, $p = .471$. There was a nonsignificant, weak, negative correlation between the STAI-T and reaction time, $r(59) = -.175$, 95% CI [-.409, .080], $p = .178$. The FDR corrected p-value was calculated, p = .471. These findings suggest that trait anxiety as measured by the STAI-T is not significantly related to PM performance.

Pearson product-moment correlation coefficients were computed to assess the linear relationship between the STAI-S and accuracy for the PM task, and the STAI-S and reaction time for the PM task. There was a nonsignificant, weak, negative correlation between the STAI-S and accuracy $r(59) = -.198$, 95% CI [-.429, .056], p = .125. The FDR corrected p-value was calculated, p = .471. There was a nonsignificant, weak, negative correlation between the STAI-S and reaction time, $r(59) = -.144$, 95% CI [-.382, .112], p = .269. The FDR corrected p-value was calculated, p = .471. These findings suggest that state anxiety as measured by the STAI-S is not significantly related to PM performance. Taken together, these six correlations indicate that anxiety is not significantly related to overall PM performance. Results for Hypothesis 1 are presented in Table 2.

Hypothesis 2: Association between Anxiety Measures and ERP Components

Pearson product-moment correlation coefficients were computed to assess the linear relationship between the BAI and the N300, and the BAI and the prospective positivity. There was a nonsignificant, weak, negative correlation between the BAI and the N300, $r(59) = -.105$, 95% CI [-.348, .150], p = .419. The FDR corrected p-value was calculated, p =. 621. There was a nonsignificant, weak, negative correlation between the BAI and the prospective positivity, $r(59) = -.196$, 95% CI [-.426, .059], p = .131. The FDR corrected p-value was calculated, p = .282. These findings suggest that anxiety as measured by the BAI is not significantly related to the cue detection as measured by the N300, nor intention retrieval as measured by the prospective positivity.

Pearson product-moment correlation coefficients were computed to assess the linear relationship between the STAI-T and the N300, and the STAI-T and the prospective positivity. There was a nonsignificant, weak, negative correlation between the STAI-T and the N300, $r(59) = -.043$, 95% CI [-.292, .210], $p = .737$. The FDR corrected p-value was calculated, $p = .737$. There was a nonsignificant, weak, negative correlation between the STAI-T and the prospective positivity, $r(59) = -.191$, 95% CI [-.422, .064], $p = .141$. The FDR corrected p-value was calculated, p =. 282. These findings suggest that trait anxiety as measured by the STAI-T is not significantly related to the cue detection as measured by the N300, nor intention retrieval as measured by the prospective positivity.

Pearson product-moment correlation coefficients were computed to assess the linear relationship between the STAI-S and the N300, and the STAI-S and the prospective positivity. There was a nonsignificant, weak, negative correlation between the STAI-S and the N300, $r(59) = -.044$, 95% CI [-.311, .191], $p = .626$. The FDR corrected p-value was calculated, $p = .737$. There was a significant, weak, negative correlation between the STAI-S and the prospective positivity, $r(59) = -.296$, 95% CI [-.510, -.047], $p = .021$. The FDR corrected p-value was calculated, $p = .124$. These findings suggest that state anxiety as measured the STAI-S is significantly related to intention retrieval as measured by the prospective positivity, but not cue detection as measured by the N300. As state anxiety increases, the amplitude of the prospective positivity decreases. Taken together, these six correlations indicate that only state anxiety is significantly related to the intention retrieval component of PM. Results for Hypothesis 2 are presented in Table 2, Figure 1, and Figure 2.

Hypothesis 3: Association between Prospective Memory Performance and ERP Components

Pearson product-moment correlation coefficients were computed to assess the linear relationship between accuracy for the PM task and the N300, and reaction time for the PM task and the N300. There was a marginally significant, weak, positive correlation between accuracy and the N300, $r(59) = .230$, 95% CI [-.023, .455], $p = .075$. The FDR corrected p-value was calculated, $p = .149$. There was a nonsignificant, weak, positive correlation between reaction time and the N300, $r(59) = .163$, 95% CI [-.092, .399], $p = .209$. The FDR corrected p-value was calculated, $p = .279$. These findings suggest that cue detection as measured by the N300 is not significantly related to PM performance, although the relationship between cue detection and accuracy trended towards significance, with accuracy increasing as the amplitude of the N300 became more positive.

Pearson product-moment correlation coefficients were computed to assess the linear relationship between accuracy for the PM task and the prospective positivity, and reaction time for the PM task and the prospective positivity. There was a significant, weak, positive correlation between accuracy and the prospective positivity, $r(59) = .271$, 95% CI [.020, .489], $p = .035$. The FDR corrected p-value was calculated, $p = .139$. There was a nonsignificant, weak, positive correlation between reaction time and the prospective positivity, $r(59) = .013$, 95% CI [-.239, .265], $p = .916$. The FDR corrected p-value was calculated, $p = .916$. These findings suggest that intention retrieval as measured by the prospective positivity is significantly related to PM performance, with accuracy increasing as the amplitude of the prospective positivity increased. Taken together, these four correlations indicate that only the intention retrieval component of PM is significantly related to PM performance. Results for Hypothesis 3 are presented in Table 2.

Summary of Primary Analyses

Results did not support Hypotheses 1 that the BAI, STAI-T, and STAI-S would be significantly negatively correlated with PM performance. While none of the correlations reached statistical significance for Hypothesis 1, it is important to note that correlation coefficients for the three anxiety measures and accuracy demonstrated the expected patterns, with accuracy decreasing as anxiety scores increased. This pattern is strongest for accuracy and the STAI-S, although this association is nonsignificant. Hypothesis 2 was also not supported, as the BAI, STAI-T, and STAI-S were not significantly negatively correlated with cue detection as measured by the N300. Contrary to Hypothesis 2, the STAI-S was significantly negatively correlated to intention retrieval as measured by the prospective positivity, although this correlation was weak. Finally, results did not support Hypothesis 3 that PM performance would be significantly positively correlated with cue detection. Instead, accuracy on the PM task was significantly positively correlated with intention retrieval, although this relationship was weak. None of the significant correlations remained so following the FDR correction. In summary, these findings suggest that intention retrieval is connected to both state anxiety and PM performance.

Exploratory Analyses

Mediation Analysis

To further characterize the relationship between intention retrieval, state anxiety, and PM performance, the amplitude of the prospective positivity was entered into a path analysis model as the mediating variable between STAI-S scores and accuracy on the PM task. The indirect effect was examined to assess the role of the intention retrieval components within the relationship between state anxiety and PM accuracy. The direct effect of state anxiety on PM accuracy (i.e., *c* path) was not statistically significant (b = -.245, p = .393, r = -.130, 95% CI [-

.836, .340]). The *c* path indicated that for every one unit increase in PM accuracy, there was a .245 unit decrease on the STAI, although this relationship was insignificant. The effect of state anxiety on intention retrieval (i.e., *a* path) was statistically significant (b = -.042, p = .026, r = -.296, 95% CI [-.082, -.007]). The *a* path indicated that for every one µV increase in the amplitude of the prospective positivity, there was a .042 unit decrease on the STAI, but this effect size was small. The effect of intention retrieval on PM accuracy (i.e., *b* path) was statistically significant (b = 3.063, p = .041, r = .232, 95% CI [.201, 6.227]). The significant *b* path indicated that for every one unit increase in PM accuracy, there was 3.063 µV increase in amplitude of the prospective positivity, although the effect size was small. The indirect effect was not statistically significant (b = -.130, p = .191, r = -.069, 95% CI [-.392, .005]). While the direct and indirect effects of the mediation were not significant, both pathways were trending in the expected direction, with accuracy decreasing as the amplitude of the prospective positivity decreased and state anxiety increased. Both effect sizes were marginal to small. These results suggest that there was no significant mediated relationship of intention retrieval on state anxiety and PM accuracy. Results for the mediation analysis are presented in Table 3 and Figure 3.

Depression

To determine if depression levels were related to anxiety levels in the sample, Pearson product-moment correlation coefficients were computed to assess the linear relationship between the BDI-II and the BAI, the BDI-II and the STAI-T, and the BDI-II and the STAI-S. There were significant, strong, positive correlations between the BDI-II and the BAI, STAI-T, and STAI-S, $r(59)$ = .739, 95% CI [.598, .835], $p < .001$; $r(59)$ = .917, 95% CI [.865, .950], $p < .001$; $r(59)$ = .823, 95% CI [.721, .890] $p < .001$, respectively. These findings suggest that depression as measured by the BDI-II was significantly related to anxiety measured by the BAI, STAI-T, and

STAI-S. As anxiety levels increased, so did depression levels. Results for the relationship between depression and anxiety are presented in Table 4.

To determine if depression symptoms related to PM performance and ERP components, Pearson product-moment correlation coefficients were computed to assess the linear relationship between BDI-II scores and PM task accuracy, BDI-II scores and PM task reaction time, BDI-II scores and N300 amplitude, and BDI-II scores and prospective positivity amplitude. There was a nonsignificant, weak, negative correlation between the BDI-II and accuracy, $r(59) = -.049$, 95% CI [-.297, .205], $p = .706$, and the BDI-II and reaction time, $r(59) = -.209$, 95% CI [-.438, .045], $p = .106$. There was a nonsignificant, weak, negative correlation between the BDI-II and the N300, $r(59) = -.082$, 95% CI [-.327, .173], $p = .530$, and the BDI-II and the prospective positivity, $r(59) = -.152$, 95% CI [-.389, .104], $p = .243$. Taken together, these findings suggest that depression as measured by the BDI-II was not significantly related to PM performance as measured by accuracy and reaction time, nor with cue detection as measured by the N300 and intention retrieval as measured by the prospective positivity. Results for the relationship between depression and PM performance are presented in Table 5. Results for the relationship between depression and the ERP components are presented in Table 6.

Affect

To determine if positive and negative affect were related to anxiety levels in the sample, Pearson product-moment correlation coefficients were computed to assess the linear relationship between the PANAS and the BAI, the PANAS and the STAI-T, and the PANAS and the STAI-S. There was a significant, weak, negative correlation between positive affect and the BAI, $r(59) = -.298$, 95% CI [-.511, -.049], $p = .020$. There was a significant, strong, negative correlation between positive affect and the STAI-T, $r(59) = -.573$, 95% CI [-.721, -.375], $p < .001$. There was a significant, moderate, negative correlation between positive affect and the STAI-S, $r(59) = -.467$, 95% CI [-.643, -.244], $p < .001$. There were significant, strong, positive correlations between negative affect and the BAI, STAI-T, and STAI-S, $r(59) = .699$, 95% CI [.543, .809], $p < .001$; $r(59) = .747$, 95% CI [.611, .841], $p < .001$; $r(59) = .810$, 95% CI [.701, .882], $p < .001$, respectively. These findings suggest that both positive and negative affect as measured by the PANAS are significantly related to anxiety as measured by the BAI, STAI-T, and STAI-S. As anxiety levels increased, positive affect decreased, and negative affect increased. Results for the relationship between affect and anxiety are presented in Table 4.

To determine if positive and negative affect related to PM performance and ERP components, Pearson product-moment correlation coefficients were computed to assess the linear relationship between the PANAS PM task accuracy, PANAS scores and PM task reaction time, PANAS scores and the N300 amplitude, and PANAS scores and prospective positivity amplitude. There was a nonsignificant, weak, positive correlation between positive affect and accuracy, $r(59) = .056$, 95% CI [-.198, .205], $p = .666$, and positive affect and reaction time, $r(59) = .192$, 95% CI [-.063, .423], $p = .139$. There was a nonsignificant, weak, positive correlation between positive affect and the N300, $r(59) = .103$, 95% CI [-.153, .345], $p = .432$, and positive affect and the prospective positivity, $r(59) = .184$, 95% CI [-.071, .417], $p = .156$. There was a nonsignificant, weak, negative correlation between negative affect and accuracy, $r(59) = -.054$, 95% CI [-.302, .201], $p = .68$, and negative affect and reaction time, $r(59) = -.098$, 95% CI [-.341, .158], $p = .453$. There was a nonsignificant, weak, negative correlation between negative affect and the N300, $r(59) = -.033$, 95% CI [-.283, .220], $p = .798$. There was a marginally significant, weak, negative correlation between negative affect and the prospective positivity, $r(59) = -.237$, 95% CI [-.461, .016], $p = .066$. These findings suggest that positive affect as measured by the PANAS was not significantly related to PM performance as measured the accuracy and reaction time, nor with cue detection as measured by the N300 and intention retrieval as measured by the prospective positivity. Negative affect as measured by the PANAS was not significantly related to PM performance as measured the accuracy and reaction time, nor with cue detection as measured by the N300, but the relationship between negative affect and intention retrieval was trending towards significance, with the amplitude of the prospective positivity decreasing as negative affect increased. Results for the relationship between affect and PM performance are presented in Table 5. Results for the relationship between affect and the ERP components are presented in Table 6.

Due to the significant relationship between negative affect and state anxiety, and the marginally significant relationship between negative affect and the prospective positivity, a Pearson product partial correlation was computed to assess the significant relationship between state anxiety and the prospective positivity while accounting for negative affect. When controlling for negative affect, there was nonsignificant, weak, negative partial correlation between the STAI-S and the prospective positivity, $r(59) = -.182$, 95% CI [-.415, .073], $p = .163$. This differed from the original significant, weak, negative correlation between the STAI-S and the prospective positivity, $r(59) = -.296$, 95% CI [-.510, -.047], $p = .021$. These findings suggest that negative affect partially explains the significant relationship between state anxiety and intention retrieval. Results for the relationship between state anxiety and the prospective positivity accounting for negative affect are presented in Table 7.

Motivation

To determine if motivation levels were related to anxiety levels in the sample, Pearson product-moment correlation coefficients were computed to assess the linear relationship between scores on the MPPRS and the BAI, the MPPRS and the STAI-T, and the MPPRS and the STAI-S. There was a nonsignificant, weak, positive correlation between the MPPRS and the BAI, $r(59) = .027$, 95% CI [-.226, .277], $p = .834$, and the MPPRS and the STAI-T, $r(59) = .004$, 95% CI [-.248, .256], $p = .974$. There was a nonsignificant, weak, negative correlation between the MPPRS and the STAI-S, $r(59) = -.146$, 95% CI [-.384, .110], $p = .261$. These findings suggest that there was no significant relationship between motivation as measured by the MPPRS and anxiety as measured the BAI, STAI-T, and STAI-S. Results for the relationship between motivation and anxiety are presented in Table 4.

To determine if motivation related to PM performance and ERP components, Pearson product-moment correlation coefficients were computed to assess the linear relationship between MPPRS scores and PM task accuracy, MPPRS scores and PM task reaction time, MPPRS scores and N300 amplitude, and MPPRS scores and prospective positivity amplitude. There was a nonsignificant, weak, negative correlation between the MPPRS and accuracy, $r(59) = -.158$, 95% CI [-.394, .098], $p = .225$. There was a nonsignificant, weak, positive correlation between the MPPRS and reaction time, $r(59) = .085$, 95% CI [-.170, .330], $p = .514$. There was a nonsignificant, weak, positive correlation between the MPPRS and the N300, $r(59) = .101$, 95% CI [-.155, .344], $p = .441$, and the MPPRS and the prospective positivity, $r(59) = .050$, 95% CI [-.204, .298], $p = .701$. Taken together, these findings suggest that motivations as measured by the MPPRS was not significantly related to PM performance as measured by accuracy and reaction time, nor with cue detection as measured by the N300 and intention retrieval as measured by the prospective positivity. Results for the relationship between motivation and PM performance are presented in Table 5. Results for the relationship between motivation and the ERP components are presented in Table 6.

ADHD Symptoms

To determine if ADHD levels were related to anxiety levels in the sample, Pearson product-moment correlation coefficients were computed to assess the linear relationship between scores on the ADHD Self-Report Screening Scale and the BAI, the ADHD Self-Report Screening Scale and the STAI-T, and the ADHD Self-Report Screening Scale and the STAI-S. There was a significant, moderate, positive correlation between the ADHD Self-Report Screening Scale and the BAI, $r(59) = .467$, 95% CI [.243, .643], $p = .000$. There was a significant, strong, positive correlation between the ADHD Self-Report Screening Scale and the STAI-T, $r(59) = .501$, 95% CI [.286, .669], $p < .001$. There was a significant, moderate, positive correlation between the ADHD Self-Report Screening Scale and the STAI-S, $r(59) = .325$, 95% CI [.079, .533], $p = .011$. These findings suggest that ADHD symptoms as measured by ADHD Self-Report Screening Scale were significantly related to anxiety measured by the BAI, STAI-T, and STAI-S, with trait anxiety demonstrating the strongest relationship. As anxiety levels increased, so did ADHD symptoms. Results for the relationship between ADHD and anxiety are presented in Table 4.

To determine if ADHD symptoms related to PM performance and ERP components, Pearson product-moment correlation coefficients were computed to assess the linear relationship between scores on the ADHD Self-Report Screening Scale and PM task accuracy, ADHD Self-Report Screening Scale scores and PM task reaction time, ADHD Self-Report Screening Scale scores and N300 amplitude, and ADHD Self-Report Screening Scale scores and prospective positivity amplitude. There was a nonsignificant, weak, negative correlation between the ADHD Self-Report Screening Scale and accuracy, $r(59) = -.006$, 95% CI [-.258, .246], $p = .961$. There was a nonsignificant, weak, positive correlation between the ADHD Self-Report Screening Scale and reaction time, $r(59) = .050$, 95% CI [-.205, .298], $p = .703$. There was a marginally significant, weak, negative correlation between the ADHD Self-Report Screening Scale and the N300, $r(59) = -.225$, 95% CI [-.451, .028], $p = .081$. There was a nonsignificant, weak, positive correlation between the ADHD Self-Report Screening Scale and the prospective positivity, $r(59) = .002$, 95% CI [-.250, .254], $p = .986$. Taken together, these findings suggest that ADHD symptoms as measured by the ADHD Self-Report Screening Scale were not significantly related to PM performance as measured by accuracy and reaction time, nor with intention retrieval as measured by the prospective positivity. The relationship between cue detection as measured by the N300 and ADHD symptoms was trending towards significance, with the amplitude of the N300 becoming more negative as ADHD symptoms increased. Results for the relationship between ADHD and PM performance are presented in Table 5. Results for the relationship between ADHD and the ERP components are presented in Table 6.

Sleep

Sleepiness. To determine if sleepiness was related to anxiety levels in the sample, Pearson product-moment correlation coefficients were computed to assess the linear relationship between scores on the KSS and the BAI, the KSS and the STAI-T, and the KSS and the STAI-S. There was a nonsignificant, weak, positive correlation between the KSS and the BAI, $r(59) = .209$, 95% CI [-.045, .438], $p = .106$. There were significant, moderate, positive correlations between the KSS and the STAI-T, $r(59) = .301$, 95% CI [.054, .514], $p = .018$, and the KSS and the STAI-S, $r(59) = .418$, 95% CI [.185, .606], $p < .001$. These results suggest that sleepiness as measured by the KSS was significantly related to anxiety as measured by the STAI-S and STAI-T. As reports of sleepiness levels increased, so did anxiety levels. Results for the relationship between sleepiness and anxiety are presented in Table 4.

To determine if sleepiness related to PM performance and ERP components, Pearson product-moment correlation coefficients were computed to assess the linear relationship between KSS scores and PM task accuracy, KSS scores and PM task reaction time, KSS scores and N300 amplitude, and KSS scores and prospective positivity amplitude. There were marginally significant, weak, negative correlations between the KSS and accuracy, $r(59) = -.224$, 95% CI [-.450, .029], $p = .083$, and the KSS and reaction time, $r(59) = -.226$, 95% CI [-.452, .027], $p = .079$. There was a significant, moderate, negative correlation between the KSS and the N300, $r(59) = -.339$, 95% CI [-.545, -.096], $p = .007$. There was a marginally significant, weak, negative correlation between the KSS and the prospective positivity, $r(59) = -.233$, 95% CI [-.458, .020], $p = .071$.Taken together, these results indicate that the relationship between sleepiness as measured by the KSS and PM performance as measured by accuracy and reaction time was trending towards significance. As sleepiness levels increased, accuracy and reaction time on the PM task decreased. Further, the relationship between sleepiness and intention retrieval was also trending towards significance, with sleepiness levels increasing as the amplitude of the prospective positivity decreased. The relationship between sleepiness and cue detection was significant; sleepiness levels increased as the amplitude of the N300 became more negative. Results for the relationship between sleepiness and PM performance are presented in Table 5. Results for the relationship between sleepiness and the ERP components are presented in Table 6.

Due to the marginally significant relationship between sleepiness and accuracy, and the significant relationship between sleepiness and the N300, a Pearson product partial correlation was computed to assess the marginally significant relationship between accuracy and the N300 while accounting for sleepiness. When controlling for sleepiness, there was nonsignificant, weak, positive correlation between the accuracy and the N300, $r(59) = .168$, 95% CI [-.088, .403], $p = .200$. This differs from the original marginally significant, weak, positive correlation between accuracy and the N300, $r(59) = .230$, 95% CI [-.023, .455], $p = .075$. These findings suggest that sleepiness partially explains the marginally significant relationship between accuracy and cue detection. Results for the relationship between accuracy and the N300 accounting for sleepiness are presented in Table 8.

Due to the marginally significant relationship between sleepiness and accuracy, and the marginally significant relationship between sleepiness and the prospective positivity, a Pearson product partial correlation was computed to assess the significant relationship between accuracy and the prospective positivity while accounting for sleepiness. When controlling for sleepiness, there was a marginally significant, weak, positive correlation between the accuracy and the prospective positivity, $r(59) = .231$, 95% CI [-.022, .456], $p = .076$. This differs slightly from the original significant, weak, positive correlation between accuracy and the prospective positivity, $r(59) = .271$, 95% CI [.020, .489], $p = .035$. These findings suggest that sleepiness partially explains the significant relationship between accuracy and intention retrieval, although the relationship was still trending towards significance when controlling for sleepiness. Results for the relationship between accuracy and the prospective positivity accounting for sleepiness are presented in Table 8.

Due to the significant relationship between sleepiness and state anxiety, and the marginally significant relationship between sleepiness and the prospective positivity, a Pearson product partial correlation was computed to assess the significant relationship between state anxiety and the prospective positivity while accounting for sleepiness. When controlling for sleepiness, there was a marginally significant, weak, negative correlation between the STAI-S and the prospective positivity, $r(59) = -.225$, 95% CI [-.451, .029], $p = .084$. This differs from the original significant, weak, negative correlation between the STAI-S and the prospective positivity, $r(59) = -.296$, 95% CI [-.510, -.047], $p = .021$. These findings suggest that sleepiness partially explains the significant relationship between state anxiety and intention retrieval, although the relationship was still trending towards significance when controlling for sleepiness. Results for the relationship between state anxiety and the prospective positivity accounting for sleepiness are presented in Table 8.

Hours of Sleep. To determine if hours of sleep from the previous night were related to anxiety levels in the sample, Pearson product-moment correlation coefficients were computed to assess the linear relationship between hours of sleep from the previous night and BAI scores, hours of sleep from the previous night and STAI-T scores, and hours of sleep from the previous night and STAI-S scores. There was a nonsignificant, weak, negative relationship between hours slept and the BAI, $r(59) = -.111$, 95% CI [-.353, .145], $p = .395$, and hours slept and the STAI-T, $r(59) = -.182$, 95% CI [-.415, .073], $p = .160$. There was a marginally significant, weak, negative correlation between hours slept and the STAI-S, $r(59) = -.235$, 95% CI [-.460, .017], $p = .068$. These results suggest that the relationship between hours of sleep from the previous night and state anxiety as measured by the STAI-S was trending towards significance, with anxiety increasing as hours of sleep decreased. Results for the relationship between hours of sleep and anxiety are presented in Table 4.

To determine if hours of sleep from the previous night could have influenced PM performance and ERP components, Pearson product-moment correlation coefficients were computed to assess the linear relationship between hours of sleep from the previous night and PM task accuracy, hours of sleep from the previous night and PM task reaction time, hours of sleep from the previous night and N300 amplitude, and hours of sleep from the previous night and prospective positivity amplitude. There was a nonsignificant, weak, positive correlation between hours slept and accuracy, $r(59) = .054$, 95% CI [-.201, .301], $p = .682$, and hours slept and reaction time, $r(59) = .151$, 95% CI [-.105, .388], $p = .245$. There was a nonsignificant, weak, positive correlation between hours slept and the N300, $r(59) = .152$, 95% CI [-.104, .389], $p = .241$, and hours slept and the prospective positivity, $r(59) = .043$, 95% CI [-.211, .292], $p = .741$. These findings suggest that hours of sleep from the previous night were not significantly related to PM performance, nor with cue detection and intention retrieval. Results for the relationship between sleep hours and PM performance are presented in Table 5. Results for the relationship between sleep hours and the ERP components are presented in Table 6.

Summary of Exploratory Analyses

Regarding the mediation analysis, neither the indirect nor direct paths were significant, and the effect sizes were marginal to small. While intention retrieval did not appear to significantly mediate the relationship between state anxiety and PM accuracy, the data trends indicated the expected pattern, with accuracy on the PM task decreasing as the amplitude of the prospective positivity decreased and state anxiety increased.

Depression, affect, motivation, ADHD symptoms, and sleep had varying relationships with the primary analyses of the study. While depression was shown to be strongly positively correlated with the anxiety measures, it was not related to PM performance nor the ERP components. Positive affect was negatively correlated with the anxiety measures, but the strength of the relationship changed depending on the anxiety measure. Positive affect was not related to PM performance nor the ERP components. Similarly, ADHD symptoms were positively correlated with the anxiety measures, but the strength of the association was different for each measure. ADHD symptoms were not related to PM performance nor the prospective positivity, but the weak, negative correlation between the N300 and ADHD symptoms was trending towards significance. The relationship between hours of sleep from the previous night and state anxiety was marginally negatively correlated, although the strength of the relationship was weak. Hours of sleep from the previous night were not significantly related to PM performance nor the ERP components. Motivation was not related to anxiety, PM performance, nor the ERP components. Negative affect was strongly positively correlated with the anxiety measures, and marginally significant with the prospective positivity. Based on these results, a partial correlation was computed, which demonstrated that the original significant relationship between state anxiety and the prospective positivity became nonsignificant when accounting for negative affect. The partial correlation suggested that negative affect partially explained the significant relationship between state anxiety and intention retrieval. Negative affect was not related to accuracy, reaction time, nor the N300.

Reports of sleepiness were significantly positively correlated to state and trait anxiety, with moderate effect sizes. Sleepiness demonstrated a significant, moderate, negative correlation with the N300. Further, sleepiness was trending towards a significant, negative correlation with PM accuracy, reaction time, and the prospective positivity. Based on these results, partial correlations were calculated: the original marginally significant relationship between accuracy and the N300 became nonsignificant when accounting for sleepiness. The original significant relationships between accuracy and the prospective positivity, and state anxiety and the prospective positivity remained marginally significant when accounting for sleepiness. Taken together, these findings suggest that sleepiness could partially explain the relationships between cue detection and accuracy. The relationship between accuracy and intention retrieval, and state anxiety and intention retrieval could also be partially explained by sleepiness, but the weak, positive correlations remained trending towards significance. Sleepiness was not significantly related to the BAI. In summary, both negative affect and sleepiness increased as anxiety increased, and negative affect and sleepiness could partially explain the connection between intention retrieval, state anxiety, and PM performance.

DISCUSSION

To live independently, achieve personal and professional goals, and maintain healthy habits, individuals must be able to successfully create and perform future-intentioned tasks. This ability is captured in PM and is especially critical for the lives of college students as they must juggle multiple future-oriented goals. PM has been shown to be impaired in various psychopathologies, including anxiety, which is highly prevalent among college students. Previous research has not elucidated how the two components of PM, cue detection and intention retrieval, interact with anxiety using electrophysiology. It is crucial for researchers and clinicians to investigate and understand this relationship, as it could aid in addressing memory issues associated with anxiety. Using electrophysiology to characterize cue detection and intention retrieval allows researchers to recognize the aspect of PM with which anxious college students are struggling; clinicians and students can then specialize intervention strategies to target that aspect of PM. By supporting PM performance in college students, researchers and clinicians can support students' ability to perform activities and goals that maintain their health, quality of life, and personal success.

The current study employed EEG/ERPs to examine the relationship between PM performance, the two components of PM, and anxiety. Findings do not support the hypotheses, nor are they consistent with previous literature. Regarding Hypothesis 1, there was no significant relationship between anxiety levels and PM performance, although the correlations for the three anxiety measures and accuracy demonstrated the expected patterns. For Hypothesis 2, cue detection, as measured by the N300, was not shown to be related to anxiety levels. Instead, intention retrieval, as measured by the prospective positivity, demonstrated a weak negative relationship with state anxiety. As state anxiety increased, the amplitude of the prospective positivity decreased. This decrease in the prospective positivity likely reflects that individuals with high state anxiety experience difficulties with intention retrieval, as the amplitude of the prospective positivity should be characterized by an increased positive peak. Hypothesis 3 was also not fully supported, as the N300 only had a marginally significant, positive relationship with PM accuracy. The prospective positivity, on the other hand, demonstrated a weak positive relationship with accuracy on the PM task. As accuracy during the task decreased, so did the amplitude of the prospective positivity, reflecting difficulties with intention retrieval. This positive association between the prospective positivity and PM accuracy further supports the idea that individuals with high state anxiety experience challenges with intention retrieval, as their prospective positivity amplitude is more likely to decrease. Taken together, these results suggest that intention retrieval could play a connecting role between state anxiety and PM accuracy, although the relationship between state anxiety and accuracy was not significant.

Prospective Memory and State Anxiety

While not statistically significant, PM accuracy decreased as anxiety scores increased, most notably for state anxiety. When viewing this relationship in the context of the significant association between state anxiety and intention retrieval, and the significant association between intention retrieval and PM accuracy, there is potential for intention retrieval to mediate the relationship between state anxiety and PM accuracy. The exploratory analyses further support this idea, as the mediation model suggests that intention retrieval could mediate the relationship between state anxiety and accuracy on the PM task. According to the mediation model, accuracy on the PM task decreased as the amplitude of the prospective positivity decreased and state anxiety increased. Based on these data patterns, the influence of state anxiety on PM accuracy could be partially determined by variability in intention retrieval. While the effect sizes of the mediation model are small, and the model did not reach significance, this pattern suggests that continued research should be carried out to better understand the relationship between state anxiety and PM, and the role of intention retrieval in this relationship.

It is possible that as state anxiety increases, college students struggle specifically with the intention retrieval component of PM, which could result in impairments in successfully performing a PM task. Based on the results of the current study, it appears that participants with high levels of state anxiety are more easily able to recognize when a future-intentioned task must be performed (i.e., cue detection), but they have more difficulty remembering what the task is (i.e., intention retrieval). This pattern could play out in the real world and have important implications for an anxious individual's well-being. For example, an individual may set an alarm to remind themself to take a specific medication; while they can easily recognize the cue to carry out their task, during a period of high state anxiety they might have more difficulty remembering what the alarm means, or which medication to take. Since cue detection was only marginally related to PM accuracy reflected by the N300, and the N300 had no relationship to any of the anxiety measures, intention retrieval could be a more effective cognitive component to focus on for enhancing PM abilities for individuals with state anxiety. Overall, the current data trends suggest that state anxiety has a particular relationship with intention retrieval, and this relationship could underly PM impairments in college students with high levels of state anxiety.

Prospective Memory and the Exploratory Variables

Not surprisingly, increased anxiety levels in the sample were associated with increased levels of depression, negative affect, and ADHD symptoms, as well as decreased positive affect. These constructs were not related to PM performance. The exploratory analyses also demonstrate the potential role that negative affect could play in explaining the relationship between state anxiety and intention retrieval. The partial correlation between state anxiety and intention retrieval while accounting for negative affect suggests that there could be specific aspects of state anxiety related to unpleasant emotions and mood states that interact with intention retrieval, as opposed to overall state anxiety. Future research should address this possibility by investigating the different types of emotion and mood states captured in the STAI-S. While ADHD symptoms were trending towards significance with cue detection, the negligible relationship between ADHD symptoms and PM performance, as well as the negligible relationships between the N300 and the anxiety measures do not merit further discussion on the interaction of these variables. The relationships between PM performance, sleepiness, and anxiety demonstrated several interesting patterns, as will be discussed further.

Prospective Memory, Sleep, and Anxiety

Further based on the exploratory analyses, subjective sleepiness levels could explain some of the significant relationships for the primary variables. When accounting for sleepiness, the association between accuracy and the N300 became nonsignificant. While causality cannot be drawn from the current study, these partial correlations suggest that sleepiness levels could be influencing the ERP components and PM performance separately from anxiety. It is also possible that sleepiness and anxiety interact in a unique manner that facilitates the relationships between anxiety, sleepiness, and PM performance and the ERP components. The current study demonstrates a relationship between sleepiness and anxiety, but it does not indicate the specific relationship that these variables may have. For example, do the participants experience anxiety particularly associated with their sleepiness? Does sleepiness enhance psychological or physiological symptoms of anxiety? Are the cognitive deficits associated with sleepiness and sleep deprivation (Grundgeiger et al., 2014) overpowering in comparison to the potential deficits associated with anxiety? If the negative influences of sleep are greater than that of anxiety, it is possible that sleepiness acted as a confounding variable in the study. Importantly, sleepiness was the only variable that was trending towards significance with PM performance, supporting the idea that sleepiness is a critical cognitive hindrance (Grundgeiger et al., 2014). Interestingly, hours of sleep from the previous night did not demonstrate these same relationships, suggesting that subjective sleepiness is more important than hours of sleep when determining the relationship between sleep and PM.

Further, the original significant relationships between accuracy and the prospective positivity, and state anxiety and the prospective positivity remained marginally significant when accounting for subjective sleepiness. When viewed in the context of the relationship between the N300 and sleepiness, these findings suggest that sleepiness may have a particular relationship with cue detection but not intention retrieval. These results are consistent with previous research on the relationship between the components of PM and sleep: Böhm and colleagues (2021) found that cue detection deteriorated more strongly following a period of wakefulness as opposed to a period of sleep. The current study is the first investigation of the relationship between sleep and PM using neurophysiology, and it should be further explored. Taken together, these findings demonstrate that sleepiness could be specifically related to cue detection, while state anxiety could be specifically related to intention retrieval, and there may be important interactions occurring between sleepiness and anxiety that further impact PM performance.

Source Localization

While this study focused on the temporal resolution of the N300 and prospective positivity, it is important to also address the spatial context of these components. Source localization studies utilizing the N300 and prospective positivity have attempted to elucidate the potential brain areas involved in cue detection, measured by the N300, and intention retrieval, measured by the prospective positivity. Cruz and colleagues (2016) utilized the same conceptual framework as the current study to determine the source localization of the N300 and prospective positivity during event-based PM tasks. They found that occipital and parietal regions were likely responsible for the N300, more specifically a right occipital cluster with a region in the caudal portion of the fusiform face gyrus, and a centro-parietal cluster with a region in the superior parietal cortex that is part of the dorsal attentional network (Cruz et al., 2016; Corbetta & Shulman, 2002). The source localization of the prospective positivity was slightly different based on the type of event-based PM task, which was attributed to the demands of the task. When the task required participants to employ perceptual processes (e.g., press a key when an upper-case letter appeared) as opposed to conceptual processes (e.g., press a key when two related words appeared), a part of the tempo-parietal junction in a right-parietal cluster was active. Regardless of the demands of perceptual or conceptual demands the task, the ACC was involved in the prospective positivity (Cruz et al., 2016). This topic has not been thoroughly studied, and more work should be done to explore the regions that generate the N300 and prospective positivity. Comprehending the source localization of these components can allow researchers to understand how psychopathologies that affect these brain areas may interact with the underlying PM components.

Other types of Cognition Involved in PM

When discussing the components that underly PM, it is critical to discuss the other aspects of cognition that contribute to PM, and how PM is unique to these cognitive capacities. Attention and working memory are two such processes that are related to PM. Previous research has established that attention is an important aspect of PM (Anderson et al., 2017; Smith, 2003; Smith et al., 2007; Einstein et al., 1997). As described by Smith et al. (2007), if an individual is unable to detect the appropriate cue in their environment using preparatory and attentional processes, then successfully retrieving information and performing the target task could be extremely challenging. Working memory is also likely important for performing PM, as working memory capacity is necessary for an individual to monitor their environment with the appropriate cue in mind (Einstein & McDaniel, 2005). Regarding both forms of cognition, previous studies have shown that increasing attention demands, dividing attention, or increasing working memory demands during a PM task reduces PM performance (Einstein et al., 1997; Brewer et al., 2010). PM is a complex, multi-component cognitive process that is supported by the combination of attentional processes and working memory capacity, but it can still occur without these processes, demonstrated by research on spontaneous retrieval during PM.

Previous studies have demonstrated that spontaneous detection and retrieval can occur, allowing for successful PM performance without the use of attention and working memory processes (Einstein et al., 2005; Mullet et al., 2013). Spontaneous processes are thought to be indicated by participants performing successfully on the PM task without any deficits to the ongoing task (Einstein et al., 2005). An important theory behind spontaneous PM performance is the associative retrieval model, which theorizes that an associative link is formed between the cue and the intended action when the PM task is planned and encoded. This associative link allows for quick, seemingly automatic, retrieval of the intended task when the cue is encountered and detected (Moscovitch, 1994; Anderson et al., 2017). It is likely that individuals can employ attentional, working memory, and spontaneous retrieval processes at combined and varying levels based on task demands (Anderson et al., 2017; Einstein et al., 2005).

To further understand the cognitive processes involved in PM, previous researchers have divided PM into five phases, which capture cue detection and intention retrieval: 1) Intention formation/planning, 2) A delay period, 3) A performance interval where cue detection should occur, 4) Realization/retrieval of the intention, 5) Monitoring/assessment to determine success or failure of the intended task (Ellis, 1996). While attention and working memory processes are likely involved during the performance interval phase (phase 3) and the realization/retrieval of the intention (phase 4), the other phases do not necessarily rely on attention and working memory to the same degree. Additional processes are also involved, including, but not limited to, self-initiated retrieval (Craik, 1986), time management (Macan et al., 2010), motivation (Walter & Meier, 2014), and metacognition (Schnitzspahn et al., 2011). Overall, PM is a dynamic cognitive ability comprised of multiple other processes and forms of cognition, with attention, working memory, and spontaneous retrieval appearing to be the primary concepts. The interaction of these components makes PM a unique and nuanced form of cognition.

To ensure that the current PM task did not rely too heavily on attentional and working memory capacities, the PM task employed was a focal PM task, as opposed a non-focal task. In a focal PM task, the prospective cue overlaps with the ongoing task, and it does not require an additional level of monitoring or processing (Anderson et al., 2017). For example, in the current PM task, the ongoing visual search task involved the presentation of a target letter, and the participants had to determine if the target letter was present in a pair of letters. The PM components were very similar to the ongoing task, with participants pressing a different key when prompted by a specific letter being present in the pair of letters. Since both the ongoing task and prospective cue required participants to evaluate the presence of specific letters, this task did not require an additional level of conceptual processing to successfully complete the PM components. On the other hand, a non-focal task would require participants to employ an additional level of processing. An example of a non-focal PM task could be participants completing a lexical decision task as the ongoing task, and participants to indicating with a different key whether a specific syllable is present in the words/non-words for the PM aspect. Since the prospective cue would involve an additional level of syllabic processing not required in the ongoing lexical decision task, this task would be classified as a non-focal PM task (Anderson et al., 2017). Utilizing a focal PM task reduces the amount of additional monitoring, attentional, and working memory processes necessary to complete the task, which allows PM to be the central component elicited by the task (Anderson et al., 2017). While some level of attention and working memory will always be involved in PM, considering the demands of the task can ensure that PM is the primary cognitive construct utilized in the task.

To determine the level of attentional processes employed by the current task, additional ERPs could be extracted. The N2pc has been utilized as a measure of attention in studies investigating the neural correlates of PM, and it has been shown to be elicited by the task used in this study (West & Wymbs, 2004). This component is characterized by steep peaks over the occipital-parietal region, 200 - 300 ms after stimulus presentation (Luck & Hillyard, 1994). It is associated with selection of a target stimuli during a visual search task (Luck & Hillyard, 1994). Due to ADHD levels in the sample not demonstrating a significant relationship with PM performance, it appears that different levels of attention capacities were not a factor in overall PM capabilities for the present study. For this reason, the N2pc was not analyzed, but future research could extract this ERP component to more thoroughly characterize the attentional processes displayed by the sample.

Limitations

An important limitation of the current study is the lack of variability of anxiety levels demonstrated by the average anxiety scores in Table 1. While the screening procedures ensured that the sample was representative of anxiety levels among college students, it allowed the sample to be skewed towards high anxiety. This skew towards high anxiety means that low anxiety was not well represented in the sample, thus, this study does not have an accurate comparison of PM performance for low anxiety individuals and high anxiety individuals. Future studies should address this limitation by recruiting participants based on the cut-off scores of the anxiety measures, as opposed to using quartile distribution.

Second, all the psychopathology and emotion measures in this study were based on self-reporting, resulting in subjective measurements of anxiety, depression, affect, sleepiness, ADHD, and motivation. While each measure has been validated by previous research, it is possible that the self-report methodology could have introduced bias into the results. Self-report bias is the divergence between self-reported values and true values on a measure, and it is more likely to happen in sensitive questions such as mental health measures (Bauhoff, 2014). While self-reports are still a necessary way to measure many concepts, it could be beneficial for future studies to include non-self-report measures to limit this kind of bias. These measures could include mental health diagnoses, heart rate variability (Jung et al., 2019), or salivary cortisol (Vreeburg et al., 2010).

Third, this study is too underpowered to adequately carry out a mediation analysis and to detect weak to moderate correlation effect sizes. The sample size would need to be well over 100 to detect small effect sizes in the mediation model (Fritz & MacKinnon, 2007). Regarding the correlations, the original power analysis to determine the number of participants needed to detect moderate effect sizes at a power of .80 indicated that 48 participants would be appropriate (Faul et al., 2009). Based on the weak to moderate effect sizes found in this study, it is likely that more participants are needed to detect the true relationships with significance.

Fourth, the results of the current study cannot be appropriately applied to various demographics. Specifically, this study lacks racial and ethnic diversity. Out of the 61 participants, 3% identified as Black or African American, 5% identified as Asian, and 8% identified as Hispanic (see Table 1). This lack of diversity in the sample reduces the generalizability of the results for college students of diverse racial and ethnic identities. Race is a social construct that can result in individuals encountering unique life experiences, including discrimination, social segregation, and different access to resources (Roberts et al., 2020). These different life experiences can contribute to race playing a role in various psychological phenomena, including memory, emotions, executive functioning, neural activity, and psychological health (Roberts et al., 2020). For these reasons, it is important for researchers to consider the racial identities of their participants, especially when examining the influences of various psychopathologies and mood states. Research in the area of PM and anxiety should aim to recruit racially diverse participants, and the results of the present study should not necessarily be assumed to be applicable to individuals of all racial identities.

Another issue related to representation is the lack of self-identified biological males in the study, and the lack of diversity in gender identities. Due to biological sex and gender identity being two different concepts that influence people's lives in unique ways, it is important to consider these two variables separately. Sex refers to biological variations and distinctions regarding reproductive organs (Short et al., 2013). Similar to race, gender is a social construct that interacts with individual's economic, social, and institutional experiences, resulting in different psychological phenomena, including cognition and psychopathologies (Short et al., 2013; Cavanaugh & Hussein, 2020; Maeng & Milad, 2015; McLean et al., 2011). While sex and gender are separate concepts, physiological differences from biological sex can contribute to unique gendered experiences (Short et al., 2013). Based on this background, it is critical for researchers to measure both biological sex and gender identity, and to not assume that all sex and gender identities exhibit the same psychological and neural patterns. For biological sex, the sample was made up of 74% self-identified biological females. Regarding gender identifies, 2% of participants identified as transgender women, 2% identified as transgender men, and 7% identified as gender fluid (Table 1). Ideally, future studies should have a more equal distribution of biological males and females, and more diverse gender identities.

Fifth, the design of this study limits the ability to make causal conclusions about the relationship between anxiety and PM. Since anxiety was not manipulated, it cannot be assumed that anxiety directly causes any effects on PM performance or the ERP components. Instead, the present study allows for the inferences to be made about the relationships between the variables. An experimental adaptation of this study could be run by evoking anxiety in the participants in the laboratory, followed by participants performing the task and recording their ERPs.

The final limitation is also related to the design of the study, as the event-based PM task used in this study is not particularly realistic to real-world PM examples, and it does not thoroughly represent time-based PM abilities. While the task has been validated in previous research to elicit PM processes and components, the nature of the computerized task may not translate well to PM tasks that college students perform in their daily lives, such as taking medication at the appropriate time, remembering to go grocery shopping when driving home from work, and submitting assignments by the deadline. A computerized PM task is necessary to measure the desired ERP components, but it is important to consider how this type of task is limited in its ecological validity. Further, although event-based PM and time-based PM share the same underlying components, the computerized task used in the study does not include a time component, limiting the applicability of these results for time-based PM. It could be beneficial to have participants complete a questionnaire assessing their PM abilities in their day-to-day life, in addition to a computerized task that employs event and time-based PM.

Future Directions

While future research should improve upon the limitations, the implications of the study provide opportunities for further investigation. As stated previously, the findings indicate that intention retrieval is weakly related to both PM accuracy and state anxiety, suggesting that intention retrieval could be a target for intervention strategies aiming to mitigate the potential cognitive struggles associated with high state anxiety. As the prospective positivity increases, so does PM accuracy. Alternatively, as state anxiety increases, the prospective positivity decreases, indicating that individuals with high state anxiety are likely experiencing difficulties with intention retrieval. These struggles with intention retrieval associated with state anxiety could lead to issues in successfully performing a PM task. To reduce these challenges with intention retrieval, it could be beneficial for people with high state anxiety to provide themselves with cues that more obviously indicate their future-intentioned task. For example, individuals could ensure their alarm has a note telling them which medication to take, or they could keep their necessary medication next to their alarm as an additional reminder. Alternatively, future studies could attempt to reduce state anxiety through various coping and self-regulation strategies to mitigate any issues with intention retrieval. Intention retrieval, and overall PM performance, could be enhanced via memory support strategies or state anxiety reduction strategies, which should be investigated in future research.

Second, it is possible that different aspects of anxiety are related PM performance, which this study did not investigate. Instead, each anxiety measure was totaled to provide three different anxiety scores. Measuring anxiety in this manner could diminish the nuance of the different aspects of anxiety, and how these aspects of anxiety interact with PM. For example, it is possible that some individuals may experience increased levels of anxiety, but their anxiety is related to conscientiousness, self-awareness, and attention to detail. These facets of anxiety could help an individual perform better on a cognitive task. On the other hand, it is possible that a high anxiety individual may experience distress, negative physiological symptoms, and distraction, leading to worse performance on a cognitive task. This study does not account for these possibilities. The findings that negative affect may partially explain the relationship between state anxiety and intention retrieval further support the importance of examining the different mood, affective states, and symptoms captured by the anxiety measures. Future research should address this limitation by performing a factor analysis on the different facets of anxiety captured in the BAI and STAI.

A third area for further investigation is the relationship between sleep, anxiety, and PM. It is possible that sleepiness acted as a confounding variable, due to its marginal relationship with PM accuracy and reaction time. While it is not feasible to control for participants' subjective sleepiness levels, it is important to consider how their sleepiness levels could influence the results of a study. Since sleepiness and sleep deprivation are additional factors experienced by college students, it is particularly important to recognize and characterize how sleepiness interacts with the variables of interest. This study included the KSS and hours of sleep from the previous night as measures to assess sleepiness, but sleep was not intended as a primary measure of the study. While the KSS has been validated and utilized in previous research, a more thorough sleep quantification methodology is necessary to better investigate the relationship between sleep, anxiety, and PM. Previous studies have used a range of measures to assess sleep and sleepiness, including cognitive testing following a sleep period (Böhm et al., 2021), an actigraph to monitor sleep activity (Fabbri et al., 2014), and sleep quality indices (Böhm et al., 2020). Further, additional studies should be carried out to assess how sleepiness and anxiety may interact. It is possible that sleep-specific anxiety could have different symptoms or outcomes than general anxiety symptoms. It is also possible that anxiety and sleepiness could interact in a manner than enhances the negative cognitive outcomes of sleepiness. Future studies should attempt to parse the relationship between sleep and anxiety, as these findings could be used to further help improve anxiety and sleep-related cognitive decline.

Table 1
Descriptive Statistics

Variable Name	Percent	Mean	Standard Deviation	Standard Error	Minimum	Maximum	Range
Age	-	19.8	2.86	.36	18	34	16
Biological Sex		-	-	-	-	-	-
Male	25.23						
Female	74.77						
Gender Identity							
Man	24.59						
Woman	65.57						
Transgender Man	1.64						
Transgender Woman	1.64						
Gender Fluid	6.56						
Race		-	-	-	-	-	-
White	91.80						
Black or African							
American	3.28						
Asian	4.92	-	-	-	-	-	-
Ethnicity							
Not Hispanic of Latinx	91.80						
Hispanic or Latinx	8.20						
BAI Score	-	20.28	13.88	1.78	0	56	56
STAI-S Score	-	40.20	11.79	1.51	21	63	42
STAI-T Score	-	46.66	15.31	1.96	21	74	53
BDI-II Score	-	17.84	12.01	1.54	0	39	39
PANAS Score							
Positive Affect	-	29.62	7.41	.95	15	46	31
Negative Affect	-	18.67	7.33	.94	10	37	27
Motivation	-	150.13	20.08	2.57	113	192	79
ADHD Score	-	19.03	4.72	.60	9	30	21
KSS Score	-	5.16	1.66	.21	2	8	6
Hours of Sleep from	-						
Previous Night	-	6.86	1.46	.19	3	11	8
PM Accuracy	-	70.47	22.28	2.85	11.11	100	88.89
PM Reaction Time		1048.24	259.60	31.96	599.20	1921.17	1321.97

Table 2

Correlations for PM performance, Anxiety, and ERPs

Variable	*M*	*SD*	1	2	3	4	5	6
1. Accuracy	70.47	22.28						
2. Reaction Time	1048.24	249.60	.22					
			[-.04, .45]					
3. STAI-S	42.20	11.79	-.20	-.14				
			[-.43, .06]	[-.38, .11]				
4. STAI-T	46.66	15.31	-.12	-.17	.82**			
			[-.36, .14]	[-.41, .08]	[.71, .89]			
5. BAI	20.28	13.88	-.01	.11	.71**	.73**		
			[-.26, .24]	[-.14, .35]	[.56, .82]	[.59, .83]		
6. N300	0.34	3.71	.23	.16	-.06	-.04	-.11	
			[-.02, .46]	[-.09, .40]	[-.31, .19]	[-.29, .21]	[-.35, .15]	
7. Prospective positivity	2.15	1.69	.27*	.01	-.30*	-.19	-.20	.41**
			[.02, .49]	[-.24, .26]	[-.51,-.05]	[-.42, .06]	[-.43, .06]	[.18, .60]

Note. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.

Table 3

Model Results for State Anxiety Relating to PM Accuracy via Prospective Positivity

Variables	*b*	S.E.	*p*-value	Std. β	CI lower	CI upper
Accuracy on STAI-S	-.245	0.287	.393	-.130	-.836	.340
Accuracy on Prospective Positivity	3.063	1.501	.041	.232	.201	6.227
Prospective Positivity on STAI-S	-.042	.019	.026	-.296	-.082	.007
Indirect Effect	-.130	.099	.191	-.069	-.392	.005

Note. S.E. refers to the standard error, Std. β refers to the standardized beta CI refers to the confidence intervals.

Table 4

Correlations for Anxiety Measures, Sleep, Depression, Affect, Motivation, ADHD

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9
1. BAI	20.28	13.88									
2. STAI-S	40.20	11.79	.71** [.56, .82]								
3. STAI-T	46.66	15.31	.73** [.59, .83]	.82** [.71, .89]							
4. Sleep Hours	6.86	1.46	-.11 [-.35, .14]	-.24 [-.46, .02]	-.18 [-.41, .07]						
5. Sleepiness	5.16	1.66	.21 [-.05, .44]	.42** [.19, .61]	.30* [.05, .51]	-.45** [-.63, -.22]					
6. Depression	17.84	12.01	.74** [.60, .84]	.82** [.72, .89]	.92** [.87, .95]	-.20 [-.43, .05]	.33** [.09, .54]				
7. Positive Affect	29.62	7.41	-.30* [-.51, -.05]	-.47** [-.64, -.24]	-.57** [-.72, -.37]	.09 [-.17, .33]	-.33** [-.54, -.09]	-.50** [-.67, -.29]			
8. Negative Affect	18.67	7.33	.70** [.54, .81]	.81** [.70, .88]	.75** [.61, .84]	-.25 [-.47, .00]	.27* [.02, .49]	.78** [.66, .86]	-.28* [-.50, -.03]		
9. Motivation	150.13	20.08	.03 [-.23, .28]	-.15 [-.38, .11]	.00 [-.25, .26]	.11 [-.14, .36]	-.17 [-.40, .09]	-.01 [-.26, .25]	.35** [.11, .55]	.03 [-.22, .28]	
10. ADHD	19.03	4.72	.47** [.24, .64]	.32* [.08, .53]	.50** [.29, .67]	.01 [-.24, .26]	.03 [-.22, .28]	.45** [.23, .63]	-.33* [-.53, -.08]	.32* [.07, .53]	.12 [-.14, .36]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.

Table 5

Correlations for PM Performance, Sleep, Depression, Affect, Motivation, ADHD

Variable	*M*	*SD*	1	2
1. Accuracy	70.47	22.28		
2. Reaction Time	1048.24	249.60	.22 [-.04, .45]	
3. Sleep Hours	6.86	1.46	.05 [-.20, .30]	.15 [-.10, .39]
4. Sleepiness	5.16	1.66	-.22 [-.45, .03]	-.23 [-.45, .03]
5. Depression	17.84	12.01	-.05 [-.30, .21]	-.21 [-.44, .05]
6. Positive Affect	29.62	7.41	.06 [-.20, .30]	.19 [-.06, .42]
7. Negative Affect	18.67	7.33	-.05 [-.30, .20]	-.10 [-.34, .16]
8. Motivation	150.13	20.08	-.16 [-.39, .10]	.09 [-.17, .33]
9. ADHD	19.03	4.72	-.01 [-.26, .25]	.05 [-.20, .30]

Note. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$. Duplicate correlation coefficients between the exploratory measures have been removed for clarity.

Table 6

Correlations for ERPs, Sleep, Depression, Affect, Motivation, ADHD

Variable	*M*	*SD*	1	2
1. N300	0.34	3.71		
2. Prospective Positivity	2.15	1.69	.41** [.18, .60]	
3. Sleep Hours	6.86	1.46	.15 [-.10, .39]	.04 [-.21, .29]
4. Sleepiness	5.16	1.66	-.34** [-.54, -.10]	-.23 [-.46, .02]
5. Depression	17.84	12.01	-.08 [-.33, .17]	-.15 [-.39, .10]
6. Positive Affect	29.62	7.41	.10 [-.15, .35]	.18 [-.07, .42]
7. Negative Affect	18.67	7.33	-.03 [-.28, .22]	-.24 [-.46, .02]
8. Motivation	150.13	20.08	.10 [-.16, .34]	.05 [-.20, .30]
9. ADHD	19.03	4.72	-.22 [-.45, .03]	.00 [-.25, .25]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$. Duplicate correlation coefficients between the exploratory measures have been removed for clarity.

Table 7

Partial Correlation for State Anxiety and Prospective Positivity Accounting for Negative Affect

Variable	*M*	*SD*	1
1. STAI-S	40.20	11.79	
2. Prospective positivity	2.15	1.69	-.18 [-.42, .07]

Note. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.

Table 8

Partial Correlations for Accuracy and the N300, Accuracy and Prospective Positivity, and State Anxiety and the Prospective Positivity accounting for Sleepiness

Variable	*M*	*SD*	1	2	3
1. Accuracy	70.47	22.28			
2. N300	0.34	3.71	.17 [-.09, .40]		
3. Prospective Positivity	2.15	1.69	.23 [-.02, .46]	--	
4. STAI-S	42.20	10.77	--	--	-.22 [-.45, .03]

Note. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.

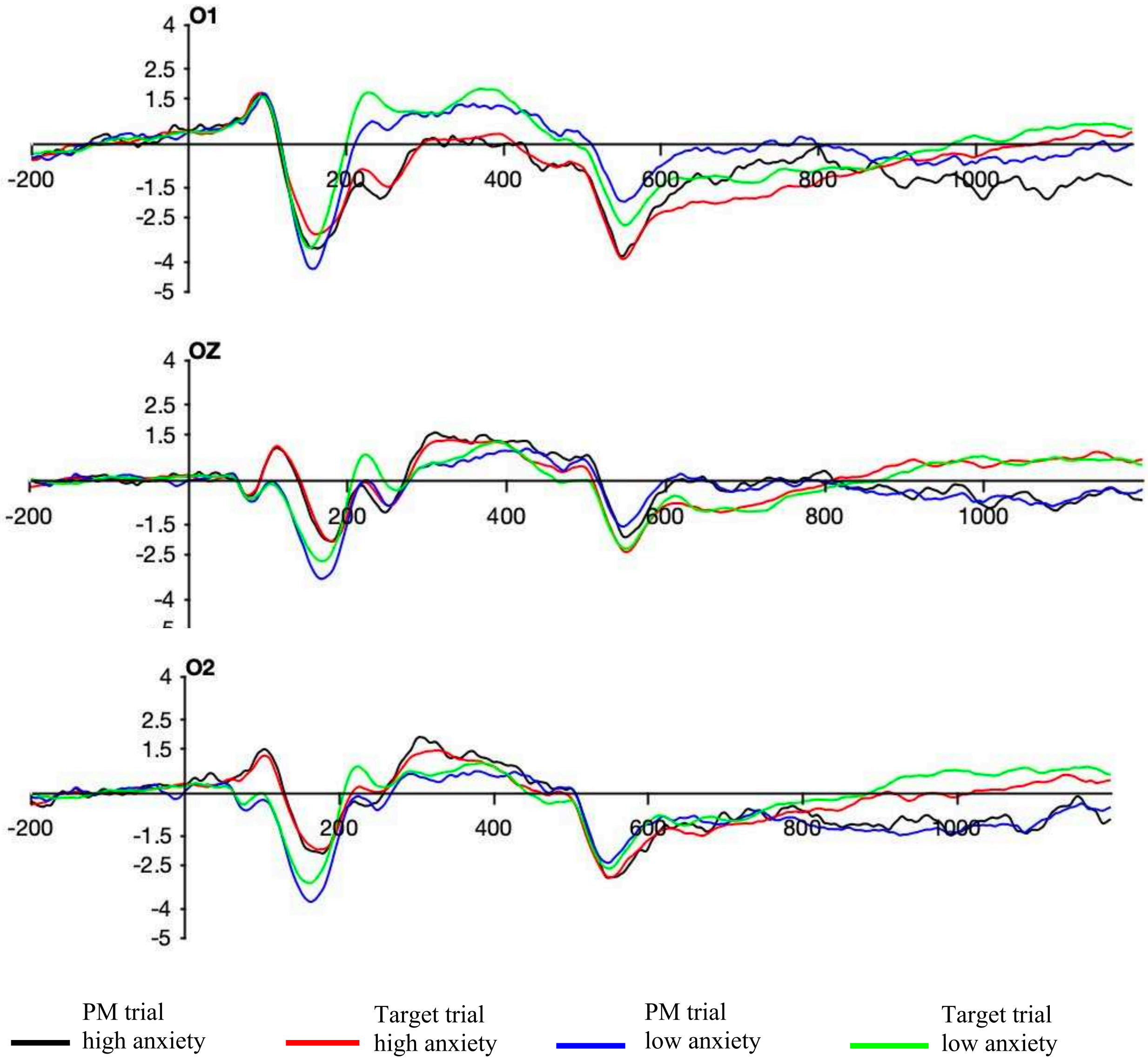

Figure 1. ERP results for the N300 at electrodes O1, Oz, and O2. Low and high anxiety are based on screener results from the STAI-T. The N300 is characterized by a brief negative peak 200 – 400 ms after stimulus onset. At electrode O1, the neural response during the PM trials for high anxiety participants is enhanced (more negative in amplitude) in comparison to the low anxiety participants. There is no discernible difference at electrodes O1 and O2. This lack of a consistent pattern across the electrode suggests a negligible relationship between anxiety and the cue detection component of PM.

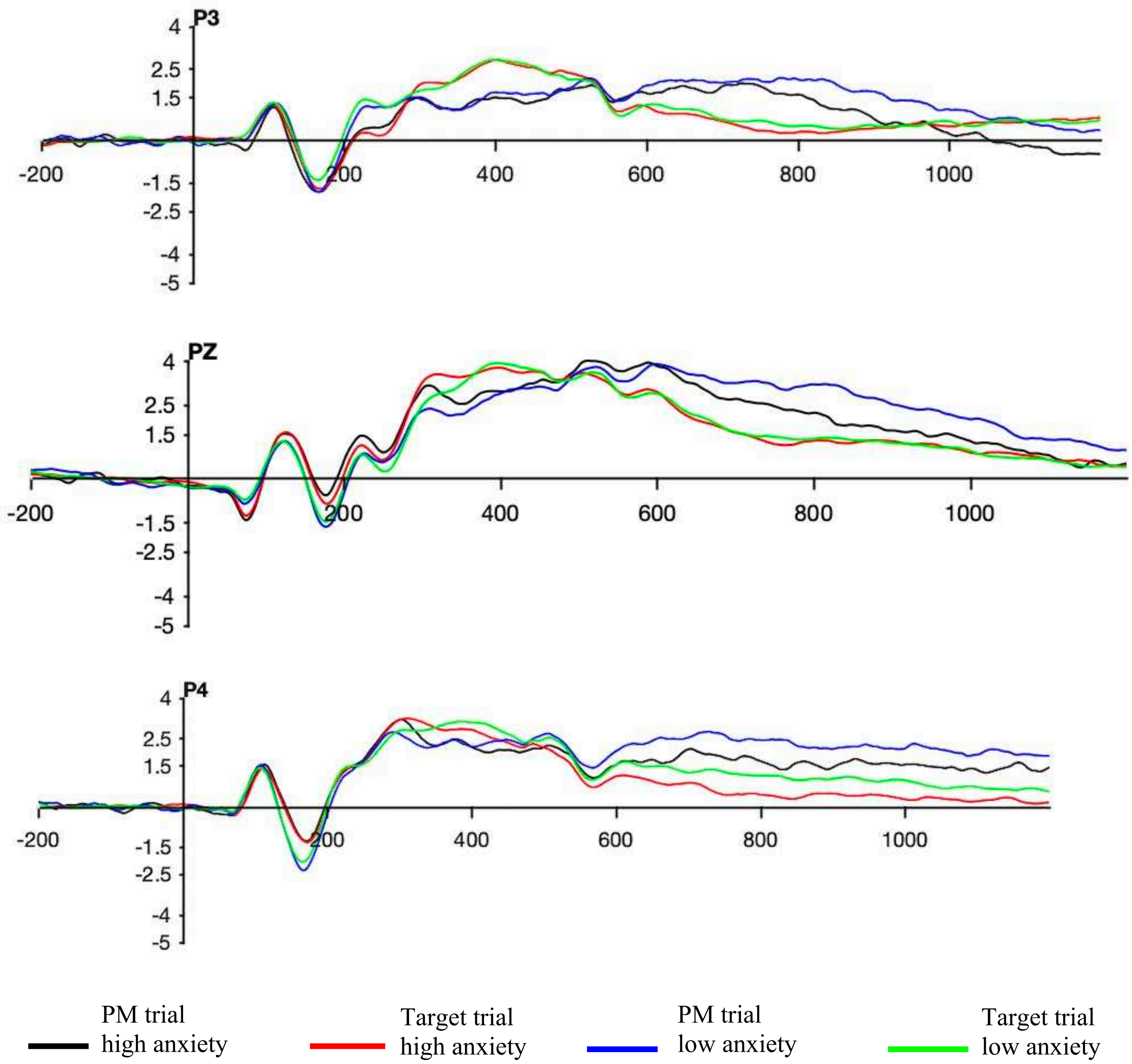

Figure 2. ERP results for the prospective positivity at electrodes P3, Pz, and P4. Low and high anxiety are based on screener results from the STAI-T. The prospective positivity is characterized by a sustained positive peak 500 – 1000 ms after stimulus onset. At all electrodes, the neural response during the PM trials for high anxiety participants is diminished (less positive in amplitude) in comparison to the low anxiety participants. This decreased amplitude suggests potential struggles with the intention retrieval component of PM for high anxiety participants.

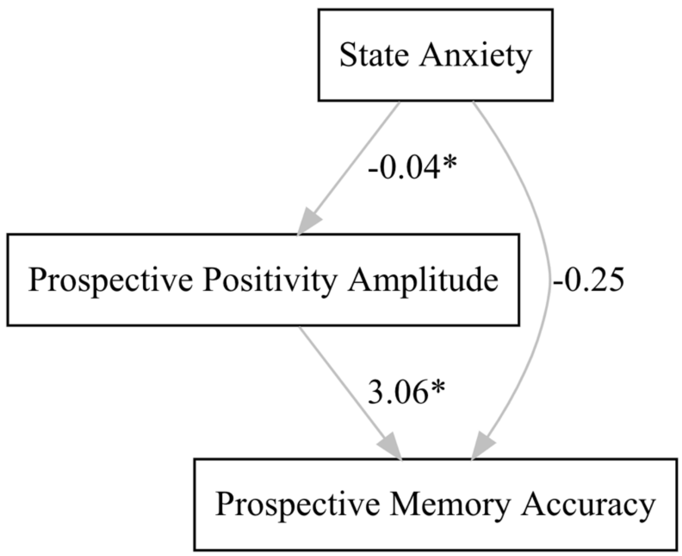

Figure 3. Model Results for State Anxiety Relating to PM Accuracy via the Prospective Positivity. The numerical values in the figure correspond to the unstandardized coefficients of the paths. Results indicate that the prospective positivity amplitude does not mediate the effect of state anxiety on PM accuracy, as evidenced by the products of the *c* path (r = -.130, 95% CI [-.836, .340]), *a* path (r = -.296, 95% CI [-.082, -.007]), *b* path (r = .232, 95% CI [.201, 6.227]) and the indirect effects (r = -.069, 95% CI [-.392, .005]). * indicates p < .05.

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APPENDIX A

Self-Report Measures

Motivation to Participate in Psychological Research
Please indicate if the following statements relate to your motivation for participating in psychological research.
Answer on a scale from 1-7, with 1=Does not correspond at all, 2=Corresponds very little, 3= Corresponds a little, 4= Corresponds moderately, 5= Corresponds enough, 6= Corresponds a lot, 7= Corresponds exactly

1. Enjoyment that comes from a better understanding of psychology.
2. Pleasure of discovery in psychological research.
3. For the joy I feel when learning about new psychological research
4. For the interest I feel when discovering ideas in psychology
5. For the pleasure I feel while learning about human behavior.
6. For the pleasure of discovering new information in psychology
7. I appreciate what understanding psychology adds to my life
8. Because I am psychologically-minded.
9. Because understanding research is an important part of who I am
10. Because understanding psychology is an important part of who I am.
11. Because being informed about psychology is important to me.
12. Because contributing to the understanding of psychology is important to me
13. Because I value research in psychology.
14. Because I admire people who conduct research in psychology.
15. I place importance on understanding the research process.
16. Because research in psychology is important to me.
17. Because if I don't participate, my grade in a class will suffer.
18. Because I will get a higher grade in a class if I participate in research.
19. Because I am supposed to participate in psychological research
20. Because it is something I have to do.
21. Because I feel that I have to do it.
22. Because fulfilling the obligations in my psychology class is something I should do.
23. Participating in research is something I should do since it is part of my psychology class
24. Because I would feel bad if I failed to earn research credit for my class.
25. I don't know why; I think it's pointless.
26. I don't know; it's not very important to me.
27. There may be good reasons to participate in research, but personally I don't see any.
28. I participate in psychological research, but I am not sure if it is worth it.
29. I don't know; I don't see what research participating does for me.
30. It is not clear to me anyone; I don't really think participating in research is important.

Beck Anxiety Inventory
Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during the past month, including today, by clicking the number that best aligns with your symptoms.
Answer on a scale from 0-3. 0=Not at all, 1=Mildly but it didn't bother me much, 2=Moderately - it wasn't pleasant at times, 3=Severely it bothered me a lot

1. *Numbness or tingling*
2. *Feeling hot*
3. *Wobbliness in legs*
4. *Unable to relax*
5. *Fear of worst happening*
6. *Dizzy or lightheaded*
7. *Heart pounding/racing*
8. *Unsteady*
9. *Terrified or afraid*
10. *Nervous*
11. *Feeling of choking*
12. *Hands trembling*
13. *Shaky / unsteady*
14. *Fear of losing control*
15. *Difficulty in breathing*
16. *Fear of dying*
17. *Scared*
18. *Indigestion*
19. *Faint / lightheaded*
20. *Face flushed*
21. *Hot/cold sweats*

State-Trait Anxiety Inventory
Trait subscale: A number of statements which people have used to describe themselves are given below. Rate each statement and select the appropriate number to indicate how you generally feel. There is no right or wrong answers. Do not spend too much time on any one statement, but give the answer which seems to describe how you generally feel.
Answer on a scale from 1-4, 1=Not at all, 2=Somewhat, 3=Moderately, 4=Very Much

1. I feel pleasant
2. I feel nervous and relentless
3. I feel satisfied with myself
4. I wish I could be as happy as others seem to be
5. I feel like a failure
6. I feel rested
7. I am "calm, cool, and collected"
8. I feel that difficulties are piling up so that I cannot overcome them
9. I worry too much over something that does not matter
10. I am happy
11. I have disturbing thoughts

12. I lack self-confidence
13. I feel secure
14. I make decisions easily
15. I feel inadequate
16. I am content
17. Somewhat unimportant thoughts run through my head and bother me
18. I take disappointment so keenly that I can't put them out of my mind
19. I am a steady person
20. I get in a state of tension or turmoil as I think over my recent concerns and interests

State Subscale: Read each statement and select the appropriate response to indicate how you feel right now, that is, at this very 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.
Answer on a scale from 1-4, 1=Not at all, 2=Somewhat, 3=Moderately, 4=Very Much

1. I feel calm
2. I feel secure
3. I feel tense
4. I feel strained
5. I feel at ease
6. I feel upset
7. I am presently worrying over possible misfortunes
8. I feel satisfied
9. I feel frightened
10. I feel uncomfortable
11. I feel self confident
12. I feel nervous
13. I feel jittery
14. I feel indecisive
15. I am relaxed
16. I feel content
17. I am worried
18. I feel confused
19. I feel steady
20. I feel pleasant

Positive and Negative Affect Scale
This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way today.
Answer on a scale from 1-4, 1=Very slightly or not at all, 2=A little, 3=Moderately, 4=Quite a bit

1. *Interested*
2. *distressed*
3. *excited*
4. *upset*

5. *strong*
6. *guilty*
7. *scared*
8. *hostile*
9. *enthusiastic*
10. *proud*
11. *irritable*
12. *alert*
13. *ashamed*
14. *inspired*
15. *nervous*
16. *determined*
17. *attentive*
18. *jittery*
19. *active*
20. *afraid*

Beck Depression Inventory II

Instructions: This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, and then pick out the one statement in each group that best describes the way you have been feeling during the past two weeks, including today. Click on the number beside the statement you have picked. If several statements in the group seem to apply equally well, click on the highest number for that group. Be sure that you do not choose more than one statement for any group, including Item 16 (Changes in Sleeping Pattern) or Item 18 (Changes in Appetite).

1. Sadness

0. I do not feel sad.
1. I feel sad much of the time.
2. I am sad all the time.
3. I am so sad or unhappy that I can't stand it.

2. Pessimism

0. I am not discouraged about my future.
1. I feel more discouraged about my future than I used to.
2. I do not expect things to work out for me.
3. I feel my future is hopeless and will only get worse.

3. Past Failure

0. I do not feel like a failure.
1. I have failed more than I should have.
2. As I look back, I see a lot of failures.
3. I feel I am a total failure as a person.

4. Loss of Pleasure

0. I get as much pleasure as I ever did from the things I enjoy.
1. I don't enjoy things as much as I used to.
2. I get very little pleasure from the things I used to enjoy.
3. I can't get any pleasure from the things I used to enjoy.

5. Guilty Feelings

0. I don't feel particularly guilty.
1. I feel guilty over many things I have done or should have done.
2. I feel quite guilty most of the time.
3. I feel guilty all of the time.

6. Punishment Feelings
0. I don't feel I am being punished.
1. I feel I may be punished.
2. I expect to be punished.
3. I feel I am being punished.

7. Self-Dislike
0. I feel the same about myself as ever.
1. I have lost confidence in myself.
2. I am disappointed in myself.
3. I dislike myself.

8. Self-Criticalness
0. I don't criticize or blame myself more than usual.
1. I am more critical of myself than I used to be.
2. I criticize myself for all of my faults.
3. I blame myself for everything bad that happens.

9. Suicidal Thoughts or Wishes
0. I don't have any thoughts of killing myself.
1. I have thoughts of killing myself, but I would not carry them out.
2. I would like to kill myself.
3. I would kill myself if I had the chance.

10. Crying
0. I don't cry anymore than I used to.
1. I cry more than I used to.
2. I cry over every little thing.
3. I feel like crying, but I can't.

11. Agitation
0. I am no more restless or wound up than usual.
1. I feel more restless or wound up than usual.
2. I am so restless or agitated, it's hard to stay still.
3. I am so restless or agitated that I have to keep moving or doing something.

12. Loss of Interest
0. I have not lost interest in other people or activities.
1. I am less interested in other people or things than before.
2. I have lost most of my interest in other people or things.
3. It's hard to get interested in anything.

13. Indecisiveness
0. I make decisions about as well as ever.
1. I find it more difficult to make decisions than usual.
2. I have much greater difficulty in making decisions than I used to.
3. I have trouble making any decisions.

14. Worthlessness
0. I do not feel I am worthless.

1. I don't consider myself as worthwhile and usefulas I used to.
2. I feel more worthless as compared to others.
3. I feel utterly worthless.

15. Loss of Energy
0. I have as much energy as ever.
1. I have less energy than I used to have.
2. I don't have enough energy to do very much.
3. I don't have enough energy to do anything.

16. Changes in Sleeping Pattern
0. I have not experienced any change in my sleeping.
1a I sleep somewhat more than usual.
1b I sleep somewhat less than usual.
2a I sleep a lot more than usual.
2b I sleep a lot less than usual.
3a I sleep most of the day.
3b I wake up 1-2 hours early and can't get back to sleep.

17. Irritability
0. I am not more irritable than usual.
1. I am more irritable than usual.
2. I am much more irritable than usual.
3. I am irritable all the time.

18. Changes in Appetite
0. I have not experienced any change in my appetite.
1a My appetite is somewhat less than usual.
1b My appetite is somewhat greater than usual. 2a My appetite is much less than before.
2b My appetite is much greater than usual.
3a I have no appetite at all.
3b I crave food all the time.

19. Concentration Difficulty
0. I can concentrate as well as ever.
1. I can't concentrate as well as usual.
2. It's hard to keep my mind on anything for very long.
3. I find I can't concentrate on anything.

20. Tiredness or Fatigue
0. I am no more tired or fatigued than usual.
1. I get more tired or fatigued more easily than usual.
2. I am too tired or fatigued to do a lot of the things I used to do.
3. I am too tired or fatigued to do most of the things I used to do.

21. Loss of Interest in Sex
0. Ihavenotnoticedanyrecentchangeinmy interest in sex.
1. I am less interested in sex than I used to be.
2. I am much less interested in sex now.
3. I have lost interest in sex completely.

ADHD Self-Report Screening Scale

Please answer the questions below, rating yourself on each of the criteria shown using the scale on the right side of the page. As you answer each question, place an X in the box that best describes how you have felt and conducted yourself over the past 6 months.
Answer by indicating Never, Rarely, Sometimes, Often, and Very Often
1. How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?
2. How often do you have difficulty getting things in order when you have to do a task that requires organization?
3. How often do you have problems remembering appointments or obligations?
4. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?
5. How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?
6. How often do you feel overly active and compelled to do things, like you were driven by a motor?

Karolinska Sleepiness Scale (KSS)

Extremely alert	1
Very alert	2
Alert	3
Rather alert	4
Neither alert nor sleepy	5
Some signs of sleepiness	6
Sleepy, but no effort to keep awake	7
Sleepy, but some effort to keep awake	8
Very sleepy, great effort to keep awake, fighting sleep	9
Extremely sleepy, can't keep awake	10

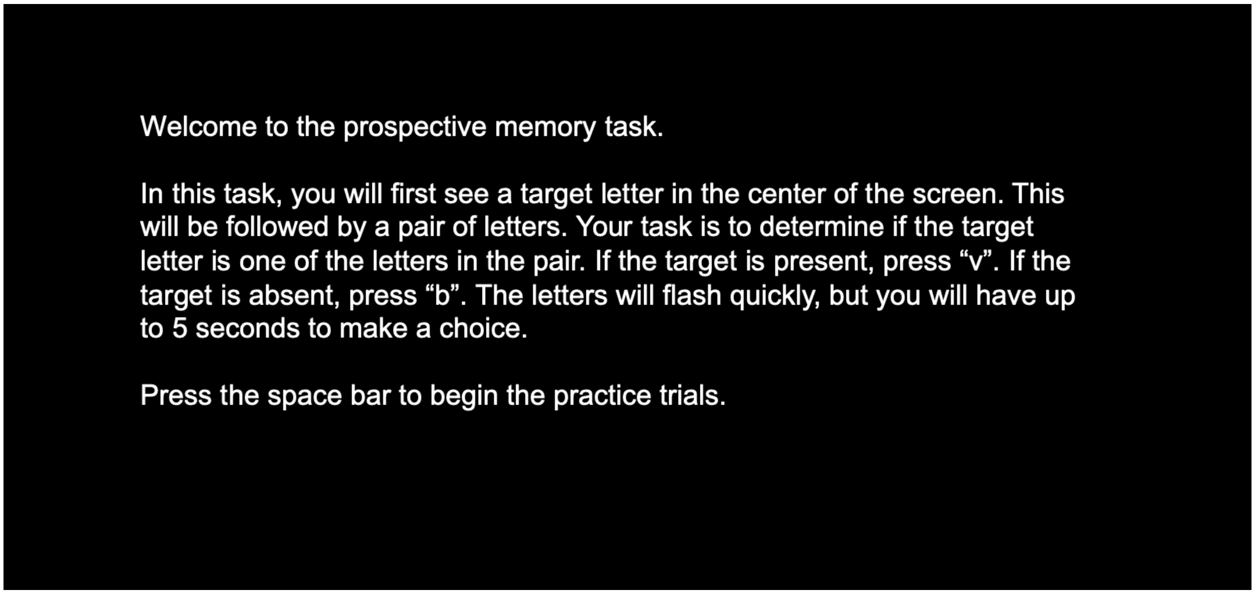
Hours of Sleep from the Previous Night

Last night, how many hours of actual sleep did you get at night?

APPENDIX B

Visual Search Prospective Memory Task

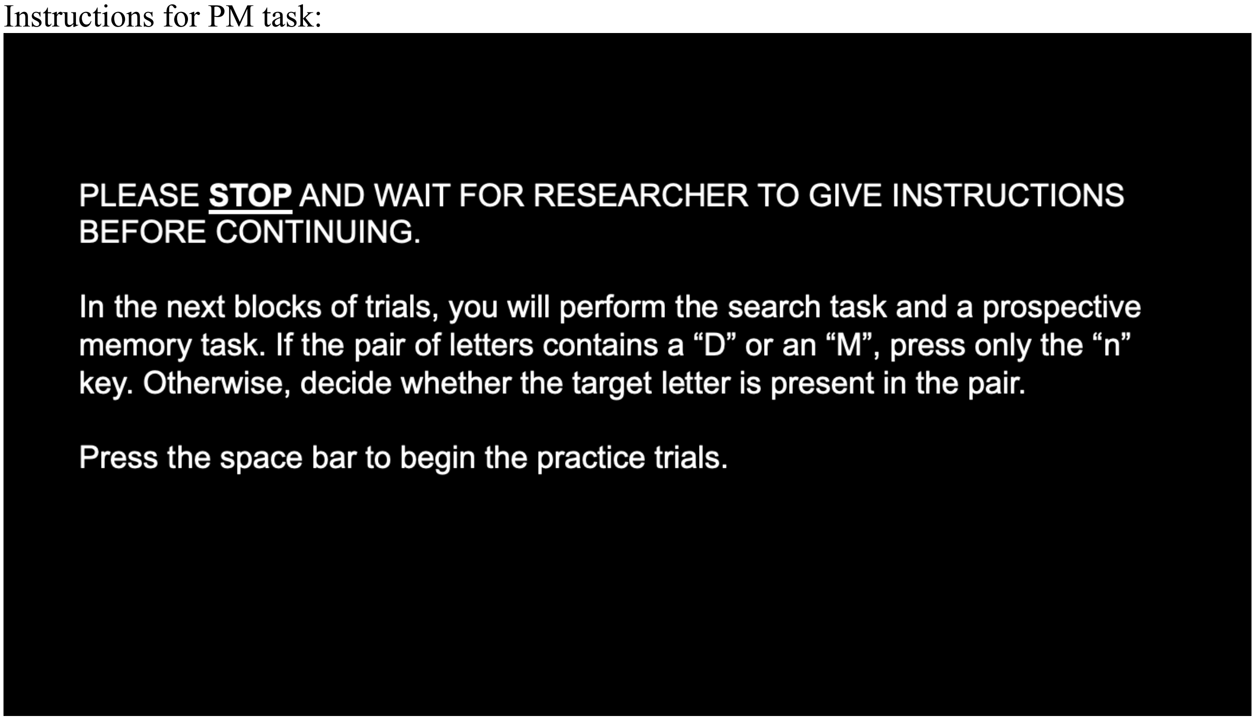
Task Stimuli
Instructions for visual search task:



Target display:

Test display:

Instructions for PM task:



Test display with Prospective Memory cue:

Search Task Instructions (read by researchers)

Note: All participants should use the RIGHT hand.

Search task (first set of instructions): In this task, you will first see a target letter in the center of the screen. This will be followed by a pair of letters. Your task is to determine if the target letter is one of the letters in the pair. If the target is present, press "v" with your left index finger. If the target is absent, press "b" with your right index finger. The letters will flash quickly, but you will have up to 5 seconds to make a choice. Please try to answer as quickly as you can.

First you will complete practice trials, followed by the real trials.

Do you have any questions?

Press the space bar to begin the practice trials.

PM Task Instructions (read by researchers)

Note: All participants should use the RIGHT hand.

Prospective memory task (second set of instructions): In the next blocks of trials, you will perform the same search task as before and a prospective memory task. If the pair of letters contains a "D" or an "M", press only the "n" key with your right middle finger. Otherwise, decide whether the target letter is present in the pair.

The prospective letters and the target letter for a given trial will never appear together.

The letters will flash quickly, but you will have up to 5 seconds to make a choice. Please try to answer as quickly as you can.

First you will complete practice trials, followed by the real trials.

Do you have any questions?

Press the space bar to begin the practice trials.

APPENDIX C

R Script for Primary Analyses

```
# Load libraries
```{r}
install.packages("ppcor")
install.packages("apaTables")

library(ppcor)
library(psych)
library(tidyverse)
library(apaTables)
```
Read in data
```{r}
PM <- read_csv("PM_Data_removed.csv")

```

Hypothesis 1
select variables of interest
```{r}
PM_acc <- select(PM, Accuracy, STAIS, STAIT, BAI)
PM_RT <- select(PM, RT, STAIS, STAIT, BAI)
```
Get correlation of variables
Via cor() function
```{r}
cor(PM_acc)
cor(PM_RT)

cor.test( formula = ~ Accuracy + STAIS,
          data = PM_acc)
cor.test( formula = ~ Accuracy + STAIT,
          data = PM_acc)
cor.test( formula = ~ Accuracy + BAI,
          data = PM_acc)
cor.test( formula = ~ RT + STAIS,
          data = PM_RT)
cor.test( formula = ~ RT + STAIT,
          data = PM_RT)
cor.test( formula = ~ RT + BAI,
          data = PM_RT)
```
```

```
## FDR correction
```{r}
# Vector of unadjusted p values

p1 <- c(0.1252, 0.3723, 0.9245, 0.2691, 0.1776, 0.3924)

# Key:  Accuracy + STAIS, Accuracy + STAIT, Accuracy + BAI, RT + STAIS, RT + STAIT, RT + BAI

# FDR correction

FDR_Hyp1 <- p.adjust(p1, method = "fdr", n = length(p1))

FDR_Hyp1
```
```

```
# Hypothesis 2
## select variables of interest
```{r}
PM_N300 <- select(PM, N300, STAIS, STAIT, BAI)
PM_PP <- select(PM, PP, STAIS, STAIT, BAI)
```
Get correlation of variables
Via cor() function
```{r}
cor(PM_N300)
cor(PM_PP)

cor.test( formula = ~ N300 + STAIS,
          data = PM_N300)
cor.test( formula = ~ N300 + STAIT,
          data = PM_N300)
cor.test( formula = ~ N300 + BAI,
          data = PM_N300)

cor.test( formula = ~ PP + STAIS,
          data = PM_PP)
cor.test( formula = ~ PP + STAIT,
          data = PM_PP)
cor.test( formula = ~ PP + BAI,
          data = PM_PP)
```
```

```
## FDR correction
```{r}
# Vector of unadjusted p values

p2 <- c(0.6255, 0.7373, 0.4192, 0.0207, 0.141, 0.1307)

# Key:  N300 + STAIS, N300 + STAIT, N300 + BAI, PP + STAIS, PP + STAIT, PP + BAI

# FDR correction

FDR_Hyp2 <- p.adjust(p2, method = "fdr", n = length(p2))

FDR_Hyp2
```
```

```
# Hypothesis 3
## select variables of interest
```{r}
PM_N300_acc_RT <- select(PM, N300, Accuracy, RT)
PM_PP_acc_RT <- select(PM, PP, Accuracy, RT)
```
Get correlation of variables
Via cor() function
```{r}
cor(PM_N300_acc_RT)
cor(PM_PP_acc_RT)

cor.test( formula = ~ N300 + Accuracy,
          data = PM_N300_acc_RT)
cor.test( formula = ~ N300 + RT,
          data = PM_N300_acc_RT)

cor.test( formula = ~ PP + Accuracy,
          data = PM_PP_acc_RT)
cor.test( formula = ~ PP + RT,
          data = PM_PP_acc_RT)
```
```

```
## FDR correction
```{r}
# Vector of unadjusted p values

p3 <- c(0.07467, 0.2091, 0.03479, 0.9157)

# Key: N300 + Accuracy, N300 + RT, PP + Accuracy, PP + RT

# FDR correction

FDR_Hyp3 <- p.adjust(p3, method = "fdr", n = length(p3))

FDR_Hyp3
```
```