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The Effect of Acute Stress on Time-Based Prospective Memory

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TRINITY COLLEGE

THE EFFECT OF ACUTE STRESS ON TIME-BASED PROSPECTIVE MEMORY

BY

P Ross Sawka

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The Effect of Acute Stress on Time-Based Prospective Memory

BY

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Abstract

Time-based prospective memory (TBPM) is the ability to remember to perform an action at a specific point in time. During a stressful day, one usually encounters many instances where TBPM is required. The objective of this project was to see if acute stress (situational) has an effect upon TBPM. Trinity College undergraduates ages 18-22 were used in this study. The Socially Evaluated Cold Pressor Test (SECPT) was performed to induce acute stress and raise cortisol levels in participants. Each participant had an electroencephalogram recording collected during a computer-generated TBPM Paradigm. The resulting data were analyzed within group as well as compared to nonstressed students. Comparing the groups, there was a significant increase in response time on TBPM tasks. Additionally, comparisons of simple event related potentials recorded from 0-900 milliseconds post ongoing task response between control and stress groups indicated significant differences in frontal electrodes (FP1, F1). To our knowledge, this is the first study to investigate the electrophysiological correlates of TBPM in response to acute stress.

Introduction

The aim of the present study was to investigate the effect of acute stress on time-based prospective memory (TBPM) and electrophysiological measures in college-aged individuals. During a college semester high levels of stress have been reported for 52% of college students (Hudd et al., 2000). Acute stress, or situational stress, has been shown in previous studies to have either a disruptive or enhancing effect on prospective memory (PM) performance (Glienke & Piefke, 2016 & Nater et al., 2006). It is unclear whether a disruptive or enhancing effect upon PM would be a product of situational stress within the average college student. Therefore, it is important to measure the effects of stress on PM within this population.

Prospective Memory

PM is the ability to remember to perform an action at a future point in time – a mnemonic ability that is particularly critical to daily living (McFarland, 2009). An example of PM is being able to remember to take medication at a certain time or to deposit a check once you arrive at the bank. PM contains two main components: a retrospective and prospective component. The retrospective component is remembering the specific intended action while the prospective component is remembering to perform that action when a specific event or time occurs. PM has also been divided into differential consecutive phases of processing: (a) the planning phase, (b) the retention interval, and (c) the performance phase (Ellis, 1996). The planning phase comprises the formation and encoding of future-directed intentions and plans. The following retention interval is a delay between planning and performance in which intended actions are maintained until a designated point in time. If retention of an intended action is successful, then the performance phase of the action commences by retrieving and initiating the action. (Piefke & Glienke, 2017).

Beyond the different stages of PM processing there are two different types of prospective memory – time-based (TBPM) and event-based PM (EBPM). In an EBPM task, the critical moment of intention execution is indicated by the occurrence of an external cue. In contrast, a TBPM task intention has to be executed at a certain point of time or after a period of time has elapsed (Glieke & Piefke, 2016). Due to the absence of an external cue, TBPM is assumed to be particularly dependent on self-initiated mental activities, such as active time monitoring and spontaneous, or self-initiated, memory retrieval (d'Ydewalle et al., 2001, & Voigt et al., 2011). An example of time-based PM is remembering to call someone back two hours in the future, and an example of event based prospective memory is remembering to deposit a check when driving by a bank.

During the PM task paradigm, which requires the participant to switch attention from the ongoing task to thinking about the intended action and performing it, the underlying cognitive strategies have been described as a multiprocess framework (Einstein and McDaniel, 2000). Within this framework it is proposed that prospective memory retrieval can depend on strategic monitoring (top-down processing) and/or attention-demanding processes (bottom-up processing, spontaneous retrieval): they match people's experience of the action as it can simply 'pop into mind' (Einstein and McDaniel, 1990) or execution can require a thorough plan of self-reminding (Ellis and Nimmo-Smith, 1993). However, this model is not specific about the processes that strategic monitoring employs. The two-process model of strategic monitoring entails maintaining the cognitive system in a prospective memory retrieval mode while simultaneously checking whether the circumstances to execute the intended action are present (target checking): activation/retrieval mode and target checking (Guynn, 2010). Both of these models were proposed only considering event-based PM. Time-based prospective memory is assumed to involve more self-initiated activities than event-based prospective memory. Specifically, it has been proposed, under the two-process model of strategic monitoring, that both TBPM and EBPM both share the same retrieval mode but differ in target checking: checking the clock versus checking the environment for cues (Cona et al., 2011). The prospective interference effect has been used as evidence for the use of strategic processes in prospective memory (Marshe et al., 2003). This effect is an increase in response time when a prospective memory task is introduced to an ongoing trial (Marshe et al., 2003). The increase in response time is thought to result from a shift of working memory capacity away from the ongoing activity in order to meet the demands of the prospective memory component of the task (Smith, 2003).

Brain Regions Associated with Prospective Memory

It is widely believed that the frontal lobe structures support cognitive control processes involved in prospective memory (Cona et al., 2012). Specifically, Burgess et al. (2001) conducted a positron emission tomography study that found increased regional cerebral blood flow (rCBF) in the regional prefrontal cortex (rPFC) (BA 10) bilaterally (or rostrolaterally) in response to a PM task, implicating a role in PM function. In a separate study Burgess et al. (2003) found unilateral rCBF increases, on the left, in response to PM stimuli when investigating a more superior medial section of BA 10 (or rostromedial). They found that the differences in blood flow relied on the differences between trials: the condition that produced the greatest medial change was between the ongoing task and the practiced PM task, while the greatest lateral change was between the ongoing and the unpracticed PM task. They suggested that both lateral and medial sections of this rostral structure have two distinct function: lateral areas played a role in maintaining attention upon internal cognitions (effortful planning), while medial areas play a role in maintaining attention upon external stimuli (target checking) (Burgess et al., 2001 &

2003). Furthermore, Okuda et al. (2007), in another PET study, found rostro-medial activation differences in TBPM & EBPM, specifically increased activation in TBPM, and postulated that activation increases in TBPM might be explained by requirement for simultaneous engagement in the ongoing activity and checking the clock (time-monitoring).

TBPM tasks require many of the same processes as event-based tasks (recalling association between intention and cue, dividing attention between an ongoing task and the PM task), but time based tasks also place greater monitoring demands on an individual; time based tasks lack external cues to direct responding and thus require frequent time monitoring in order to determine when to perform the intended action (Piefke & Glieke, 2017). Previous literature heavily implicated the role of the frontal lobes in this more internally self-initiated process and one study, by comparing age and frontal lobe function through a battery of tests, found that both older and younger adults of higher frontal functioning produced significantly greater time monitoring behaviors than older lower frontal functioning adults (McFarland, 2009).

Electrophysiological Correlates of Prospective Memory

Previous studies using event related potentials (ERPs) to investigate prospective memory have shown enhanced negativity over the occipital/parietal regions of the brain and positivity over the frontal regions during differing time frames ranging from 130 to 800 milliseconds post stimulus (West et al., 2006 & Cona et al., 2012). This ERP is thought to reflect a mechanism of strategic monitoring that is equally engaged in both time and event based prospective memory – the frontal distribution is thought to specifically represent a retrieval mode that is executed by the frontal cortex. (Nyberg et al., 1995 & Cona et al., 2012). In a study conducted by Cona et al. (2012), they compared ERPs of both time and event based prospective memory using Guynn's strategic monitoring model. They found that within the ERPs there was a large/sustained frontal positivity around 140-800 ms post stimulus for both TBPM and EBPM representing a retrieval mode, and an enhanced positivity around 400-600 ms post stimulus in the parietal and occipital regions only in EBPM conditions. This additional activity in EBPM was attributed to the different type of target checking that occurs in EBPM – visual scanning of the ongoing task for the expected cue (Cona et al., 2012).

Acute Stress & Prospective Memory

There are also numerous classifications of stress. One primary distinction is between acute stress, which refers to a recent and transient occurrence of a single stressor, and chronic stress, which refers to an ongoing difficulty an individual that may or may not be a constant threat or presence in that individual's life (Sänger et al., 2014). Due to the nature of the collegiate experience including stressful aspects such as pressing deadlines, timed examinations, and presentations given to entire classrooms it is not unreasonable for one to assume that college students encounter situations that have the potential to trigger an acute stress response frequently.

The stress response involves two distinct stress axes involving a large number of neuronal circuits (prefrontal cortex, hippocampus, amygdala, and the hypothalamus): the sympathetic adrenal medullary system (SAM) and the hypothalamic pituitary adrenal axis (HPA) system (de Kloet et al., 2005). The response begins with the sympathetic nervous system releasing vasopressin (VP) and the hypothalamus releasing of corticotropin-releasing hormone (CRH) in response to stress from axon terminals in the hypothalamic median eminence. The released CRH interacts with VP which results in release of adrenocorticotropic hormone (ACTH) from the pituitary in response to stress. (Joëls et al., 2009). ACTH then stimulates the cortex of the adrenal gland located above the kidneys to synthesize and trigger the release of glucocorticoids (i.e. cortisol). These CRH- and VP- containing fibers project into brain areas implicated in the neuroanatomy of behavioral adaptation to stress. Specifically, the prefrontal cortex is considered to be a 'hot-spot' in which there are a plethora of stress mediator receptors (receptors that receive stimuli from neuropeptides that are making the stress response possible: β1R, CRHR1, CRHR2, MR GR) (Holsboer & Isling, 2010). This concentration of stress related neuropeptide receptors implicates the possibility of the stress response affecting functions related to the frontal cortices – namely, prospective memory.

There are a collection of studies investigating the effect of acute stress on both TBPM and EBPM. The majority of studies investigating the effect of stress upon EBPM found that there was a lack of effect (Nakayama et al., 2005, Nater et al., 2006, & Walser et al., 2013), while one study using a real-life related paradigm found an improvement (Glienk & Piefke, 2016). Additionally, Nater et al. (2006) and Glienke & Piefke (2016) both found significantly increase TBPM in response to stress. Piefke & Glienke (2017), by examining the results gathered in Nater et al. (2006) as well as Glienke and Piefke (2016) , hypothesized that EBPM and TBPM are affected by stress differently and further hypothesized that during PM paradigms where an ongoing task is used, TBPM is more cognitive demanding than EBPM. Furthermore, Piefke & Glienke (2017) also related the ERP findings of Cona et al. (2012) to their hypothesis – because EBPM had an extra ERP component (occipital activation), reflecting the need to scan the environment for an external PM cue, it is more in line with Guynn's strategic monitoring model than TBPM, which is thought to be more internally self-initiated and have a higher cognitive demand; making TBPM potentially more vulnerable to the effects of acute stress than EBPM.

Stressors used in studies investigating the effect acute stress on PM performance typically apply one of the two following experimental stressors: the Trier Social Stress Test (TSST) and the Socially Evaluated Cold Pressure Test (SECPT). The TSST uses a panel of three judges that perform a mock job interview; each participant is asked to imagine they have gotten an interview for their “dream job”. The TSST includes three phases: a preparatory period, a speech in which the participant argues why they are the best for their position, and a mental arithmetic task (Vors et al., 2018). This paradigm is considered to be psychosocial because it employs a non-metabolically demanding task. The SCEPT is an acute stressor that has participants submerge their hand for an undisclosed amount of time while a research assistant and camera observe their behavioral response. This method is much shorter and combines a physical component with psychosocial elements found in the TSST. In addition to being much shorter than the TSST, the SECPT has been shown to produce substantially higher cortisol/cognitive anxiety levels than the TSST (Schwabe & Schächinger, 2018).

Currently, only three studies have investigated the effect of acute stress on TBPM. Two of these studies have used the SECPT and produced results indicating a negligible effect on PM performance (Szőllősi et al., 2018) and an increase in PM performance (Glieke & Piefke, 2016). The only study investigating the effect of acute stress using the TSST found a significant PM performance increase in TBPM (Nater et al., 2006). Beyond the minimal presence of literature on the effect of acute stress on TBPM, it is believed that this study is the first to investigate the neural correlates of acute stress on TBPM. It is important to uncover the potential effects of stress on this necessary aspect of memory within a collegiate population due to their undeniable predisposition.

Method

This study was conducted at Trinity College's Cognitive Neuropsychological Lab in Hartford, CT and was approved by the Institutional Review Board (IRB) at Trinity.

Participants

Participants (n=12, stress=10, nonstress=2) were healthy individuals, aged 18-23 years old, with no neurological or psychological illness, English speaking, and with at least 12 years of education.

Materials

The stressor used in this experiment, the Socially Evaluated Cold Pressor Test, is modeled after Schwabe et al. (2018) and is thought to couple both a physical and psychosocial stress response. The psychosocial aspect of this stressor (observer and camera analyzing behavior) is speculated to trigger the HPA axis and result in the rise of cortisol levels 15-20 minutes post-stressor, while the physical aspect (hand in ice water) is thought to trigger a parasympathetic response that instantly raises salivary alpha amylase levels. The bowl used for hand submersion was approximately 10 inches in depth, which allowed all participants to insert their hand just beyond the wrist. The temperature of the ice bucket was measured using an Enviroglass Liquid Safe Glass Thermometer and consistently maintained between 0-2 °C.

Electrophysiological Recording

An electroencephalogram (EEG) machine was used to record electrophysiological measures of TBPM. A Compumedics® Neuroscan™ Quik-Cap with 64 sewn-in electrodes and six external electrodes was used to record electrophysiological data. The Quik-Cap with sewn-in electrodes had left and right eye movements (vertical and horizontal) and blinks recorded with four external electrodes secured with Compumedics® v-shaped electrode washers on the sides of the participants right (HEOR) eyes and left (HEOL) eyes, and both above (VEOU) and below (VEOL) the left eye. The two electrodes placed on both left (M1) and right (M2) mastoid processes of the participant were used to record the base connectivity of the scalp, which was subsequently subtracted from recordings during data analysis. The electrode within the center of the 64-electrode array, the reference electrode (REF), was used to reference all other recording electrodes. The electrodes of interest were the similar to those in Cona et al.: Fp1, F3, P1, & O2.

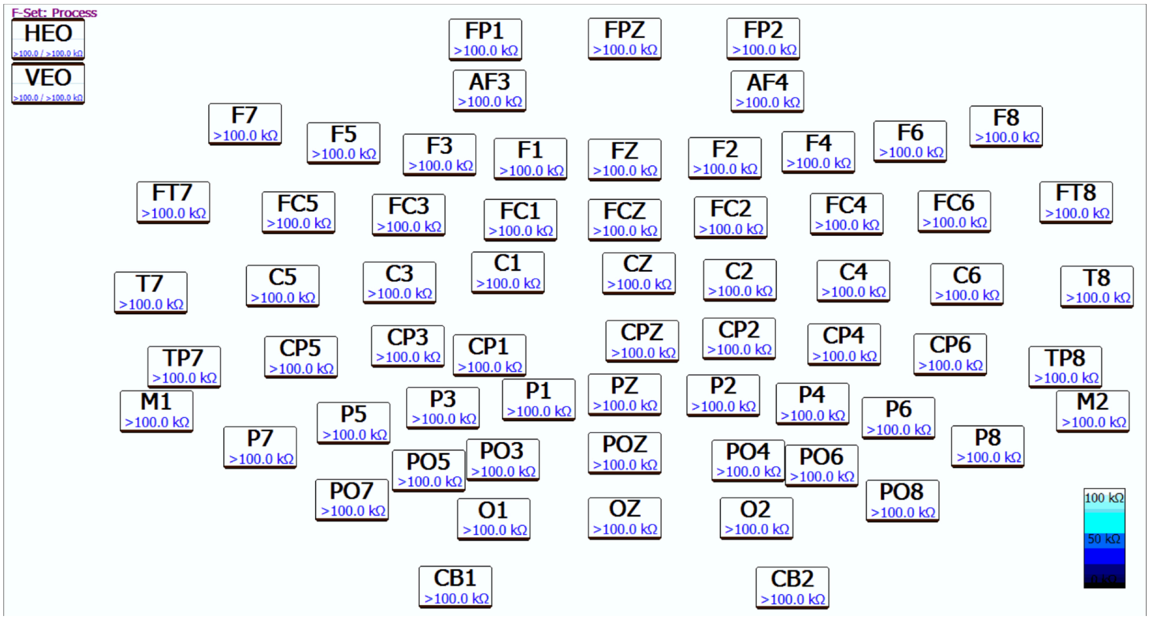

Figure 1. 64-electrode impedance map in Curry 7

The EEG cap used was connected to a Neuroscan^{TM} headbox, which was subsequently connected to the SynAmpRt amplifier. The amplifier used had DC-3500-Hz bandwidth that was filtered between 0.1 Hz – 100 Hz, with a low-pass 30 Hz filter, a maximum sampling rate of 1000 kHz, and was recording with 24-bit resolution. Curry 7 was then used to monitor electrode impedance and record the acquisitions. Before recording any electrophysiological data, the electrodes were brought to an impedance of 50 kΩ. All electrophysiological data preprocessing and artifact removal was done within EEGLAB, a toolbox within Matlab. The data was resampled at 256 Hz and epoched 1000 ms pre- and 998 ms post- ongoing task response.

Automagic, an opensource automated toolbox within EEGLAB created by Pedroni et al., was used to remove bad segments of data, determine/conduct channel removal and re-interpolation, and conduct MARA ICA regression for the removal artifacts from eye blinks and horizontal/vertical eye movements. Simple ERPs for electrodes Fp1, Fp

2, F3, F4, P3, P4, O1, & O2, were created in EEGLAB using the "create a study" option within the main window.

Time-Based Prospective Memory Behavioral Task

Stim® 2.0 was used to create the Time-based PM behavioral task completed during EEG recording and was modeled after that of Cona et al. (2012). Within the behavioral task there was an ongoing letter matching task in which participants were asked to identify whether or not the second and fourth letters of a five letter sequence in the center of a black screen are the same (by pressing the "n" key marked "SAME") or different (by pressing the "m" key marked "DIFF"). There were 350 trials in total that lasted 4,000 ms each. Each trial displayed the five-letter sequence for 300 ms or until the participant responded by hitting one of the two keys. A blank black screen was shown after the 300 ms elapsed or an answer was given to bring the combination of letter sequence screen and blank black screen to a combined time of 4,000 ms.

Additionally, there were intention formation trials that occurred in between the letter matching trials which required participants to hit a red colored button ("z" key) on the keyboard in 2/5-minute intervals. The participant could monitor the amount of time elapsed using a digital clock next to the screen. Prior to starting the behavioral task each participant was required to hit the "c" button before starting. Responses that were within ±1 minute of the correct time were considered correct. There were ten intention formation trials within the time-based PM behavioral task – six two-minute delays and four five-minute delay trials. The time-based behavioral task took approximately thirty minutes to complete.

Saliva Sample Collection / Assay

Saliva samples were intended to be assayed using a Cortisol Saliva ELISA Assay Kit from Eagle Biosciences but were not due to the COVID-19 pandemic resulting in Trinity College's Campus closure. Saliva samples were collected using 5 mL centrifuge tubes and frozen at -10 °C immediately after collection.

Questionnaires

Four questionnaires were given prior to participation to rule out the existence of previously standing anxiety markers. The Beck Depression Inventory (BDI) is a brief, criteria-referenced assessment for measuring depression severity (Beck et al., 1988). The Daily Stress Inventory (DSI-II) is an assessment of the sources and individualized impact of relatively minor stressful events (Brantley & Jeffries, 2000). Additionally, the Becks Anxiety Inventory (BAI) is a self-report measure of anxiety symptomology experienced throughout the previous month on a scale of not at all (0) to Severely – it bothered me a lot (3) (Beck et al., 1988). Finally, the Impact of Events Scale-Revised (IES-R) is a 22 item self-report measure that assesses subjective distress caused by traumatic events (Horowitz et al., 1979).

Procedure

Prior to participating individuals were emailed a PDF containing a list of restrictions regarding personal stress levels, required hours of sleep prior to testing, and diet items (water, gum, and acidic foods right before saliva collection) that could potentially interfere with baseline cortisol levels or the integrity of collected saliva samples. Participants were required to read and sign an IRB-approved informed consent form. After completing the questionnaires participants were notified that they had the option to stop participating at any time and receive compensation for the time they had already given. The first saliva sample, which acted as the baseline cortisol level, was then was collected. The participant was asked to enter a different room which contained a different researcher with a clipboard, a camera facing the participant, and a bucket of ice water in front of an empty seat. The Participant was then asked to maintain direct eye contact with the camera while they submerged their hand into the bucket of ice water for an undisclosed amount of time (approximately 3 minutes) – the participant was told that their facial expressions were going to be examined for later behavioral analysis. Additionally, the researcher administering the stressor would avidly observe the participant and pretend to take notes at a rapid pace while the participant submerged their hand. Participants were instructed that hand momentary hand removal from the bucket was allowed, as long as the hand was promptly returned and eye contact with the camera was maintained. Before applying the EEG cap, all participants were required to wipe around their eyes and forehead with an alcohol wipe in order to remove any potential debris between skin and electrode. They were also required to use a sterilized hairbrush to potentially increase impedances during EEG recording. With the assistance of another researcher EEG setup took approximately 10-15 minutes, while clean up took approximately 10 minutes. The second saliva sample, the sample with the highest cortisol content, was collected 15 minutes after completing the stressor. Instructions for the time-based prospective memory behavioral task were given to the participant and then the computer-based paradigm and electrophysiological recording began. After completion of the paradigm the third, and final, salivary sample was collected. Participant confidentiality was maintained by assigning an identification number on all forms of testing. Compensation for participation was offered either in the form of course credit or one $10 Amazon gift card per hour.

Data Analysis

ERP data analysis was conducted within EEGLAB using a permutation-based test. Additionally, the time-based behavioral analysis data was analyzed using a simple T-Test. Finally, the questionnaire results were analyzed using a simple one-way analysis of variance (ANOVA).

Results

Previously Standing Stress Levels Among Stress group and Controls

A one-way ANOVA test revealed no significant differences in pre-existing stress levels between groups (Stress n=10, Nonstress n=2) (Table 1).

Condition	Measure	BAI	BDI	IES-R	DSI-E	DSI-I
Stress	**Mean Score**	8.200	5.000	26.200	20.800	61.400
	Standard Deviation	5.770	3.590	15.718	8.917	33.224
Nonstress	**Mean Score**	7.500	6.500	24.000	10.000	24.500
	Standard Deviation	3.536	4.950	8.485	7.071	17.678
Significance		0.875	0.617	0.855	0.142	0.168

Table 1: One-way ANOVA test showing no significant stress differences in both stress and nonstress groups

Ongoing Task Performance

A two-tailed two-sample equal variance (homoscedastic) T-test revealed no significant differences in accuracy and response time during the ongoing task between groups (p=0.548; p=0.252) (Figure 2 & 3).

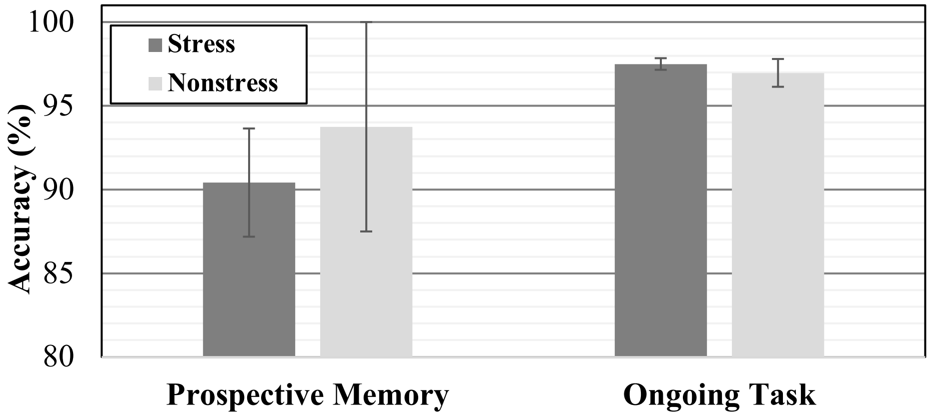

Figure 2. Average Accuracy in performance on both ongoing task and PM task in behavioral task

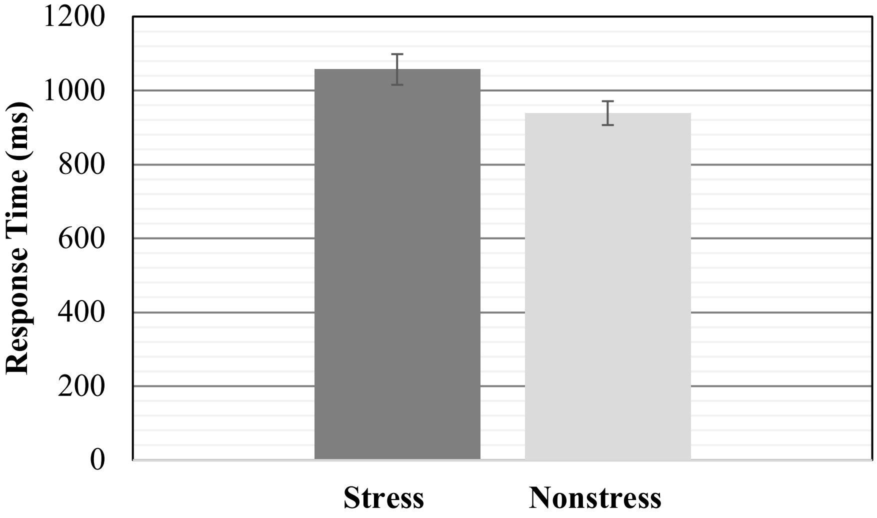

Figure 3. Average response time in ongoing task in stress and nonstress groups

Prospective Memory Performance

A two-tailed two sample equal variance (homoscedastic) T-Test revealed significant differences in the PM response time between groups (**p<0.01) (Figure 4). Students exposed to acute stress had significantly faster PM response times in comparison to the control. Groups did not perform significantly different in the accuracy (p=0.679) (Figure 2).

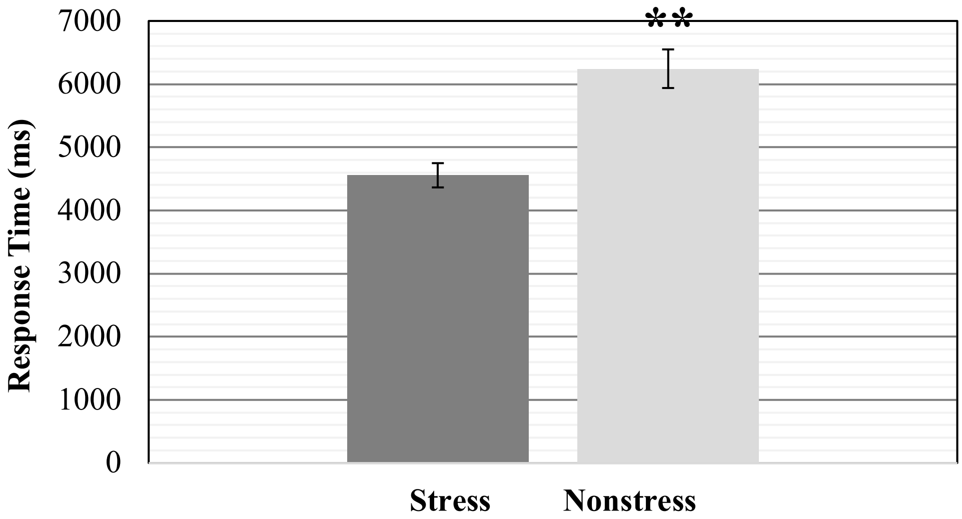

*Figure 4. Average PM response in behavioral tasks in both stress and nonstress groups (**p<0.01)*

Electrophysiological Measures During Behavioral Task

Within EEGLAB, ERPs were averaged and plotted over electrodes FP1, F1, P1, and O2 using the Create A Study Option. Differences between ERPs of both groups were statistically analyzed using permutation ($p<0.05$) and reported below in the form of black lines. It was indicated that the nonstress group had significantly greater activation ($p<0.05$) over electrode FP1 during a visually estimated 120 – 160 ms, 660 ms – 720 ms, and 840 ms post ongoing task response (Figure 5). Additionally, the nonstress group held significantly greater deactivation ($p<0.05$) over electrode FP1 at 400 ms (Figure 5). It was indicated that the nonstress group had significantly greater activation ($p<0.05$) over electrode F1 during a visually estimated 120 – 180 ms, and 820 – 830 ms (Figure 6). Additionally, the nonstress group held significantly greater deactivation ($p<0.05$) over electrode F1 from 350 – 400 ms and 410 – 440 ms (Figure 6).It was indicated that the nonstress group had significantly greater deactivation ($p<0.05$) over electrode P1 during a visually estimated 680 ms (Figure 7). Additionally, the nonstress group held significantly greater activation ($p<0.05$) over electrode F1 at 810 ms (Figure 7). It was indicated that the nonstress group had significantly greater activation ($p<0.05$) over electrode O2 during a visually estimated 0 – 10 ms, 90-110 ms, and 620-630 ms (Figure 8). Additionally, the nonstress group held significantly greater activation ($p<0.05$) over electrode O2 at 150 ms (Figure 8). ERP scalp map projections were created for both stress and nonstress groups within the time frames of 130 – 180 ms, 180 – 300 ms, 400 – 600 ms, and 600 – 800 ms post ongoing task response (Figure 9).

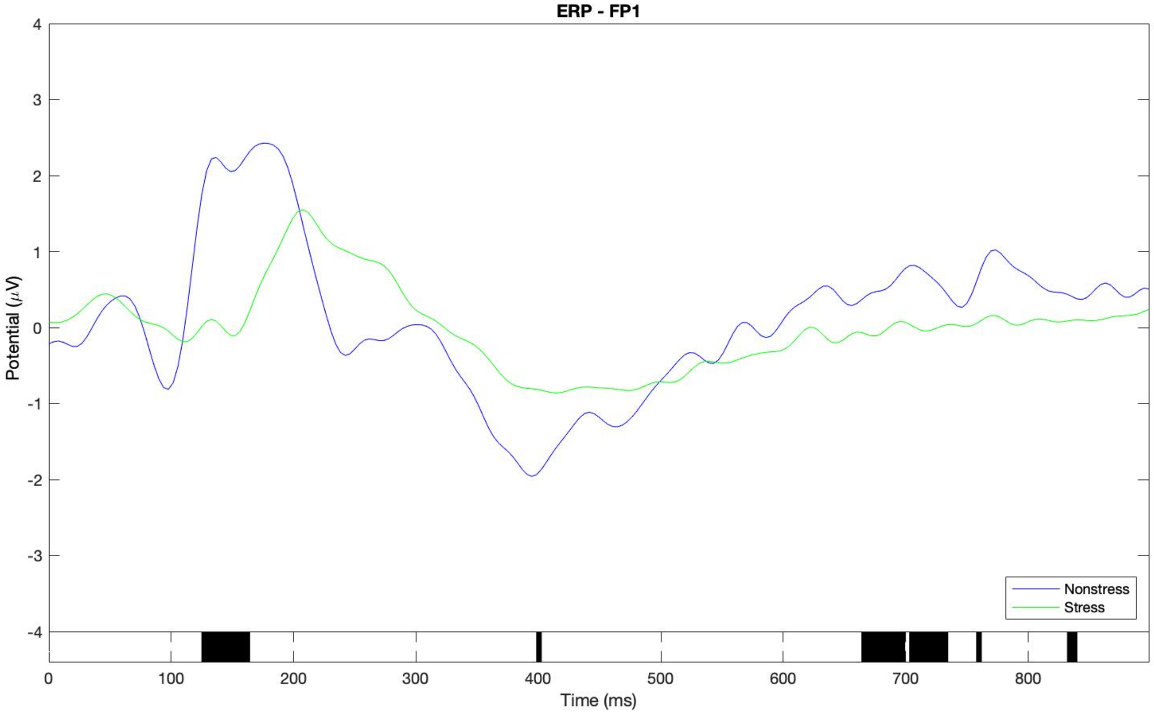

Figure 5. *Grand Average ERP Waveforms calculated in EEGLAB. Recorded from electrode FP1 and epoched 0-900 ms post ongoing task response in stress and nonstress groups*

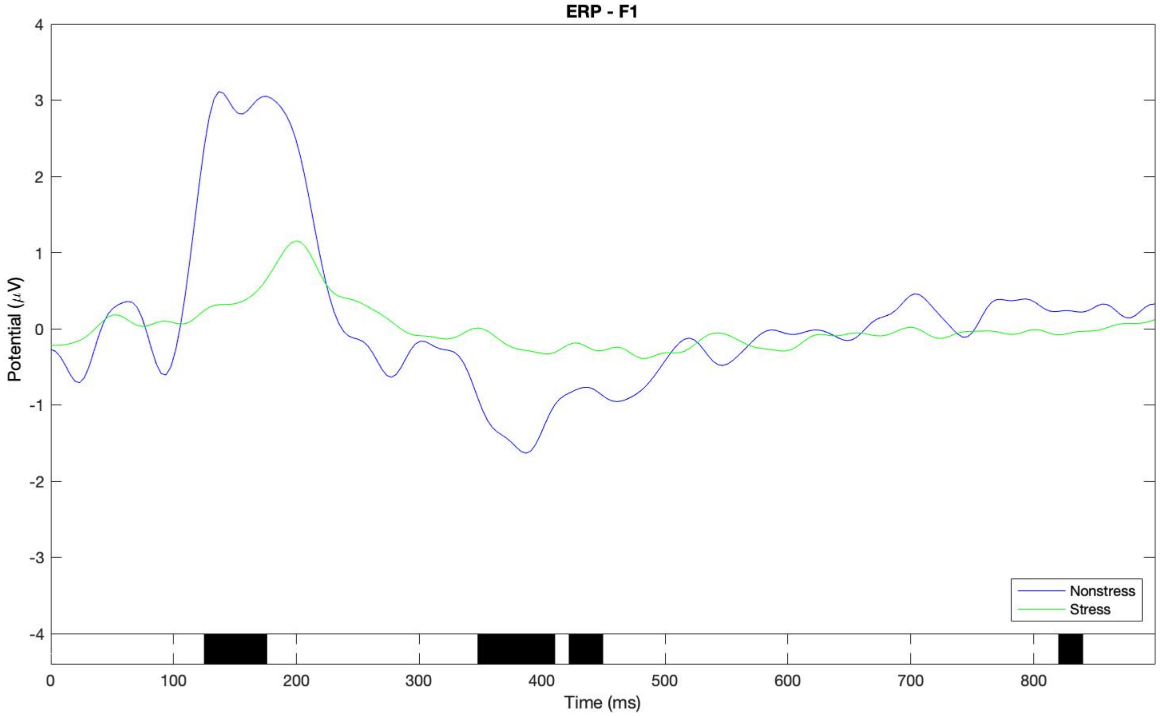

Figure 6. *Grand Average ERP Waveforms calculated in EEGLAB. Recorded from electrode F1 and epoched 0-900 ms post ongoing task response in stress and nonstress groups*

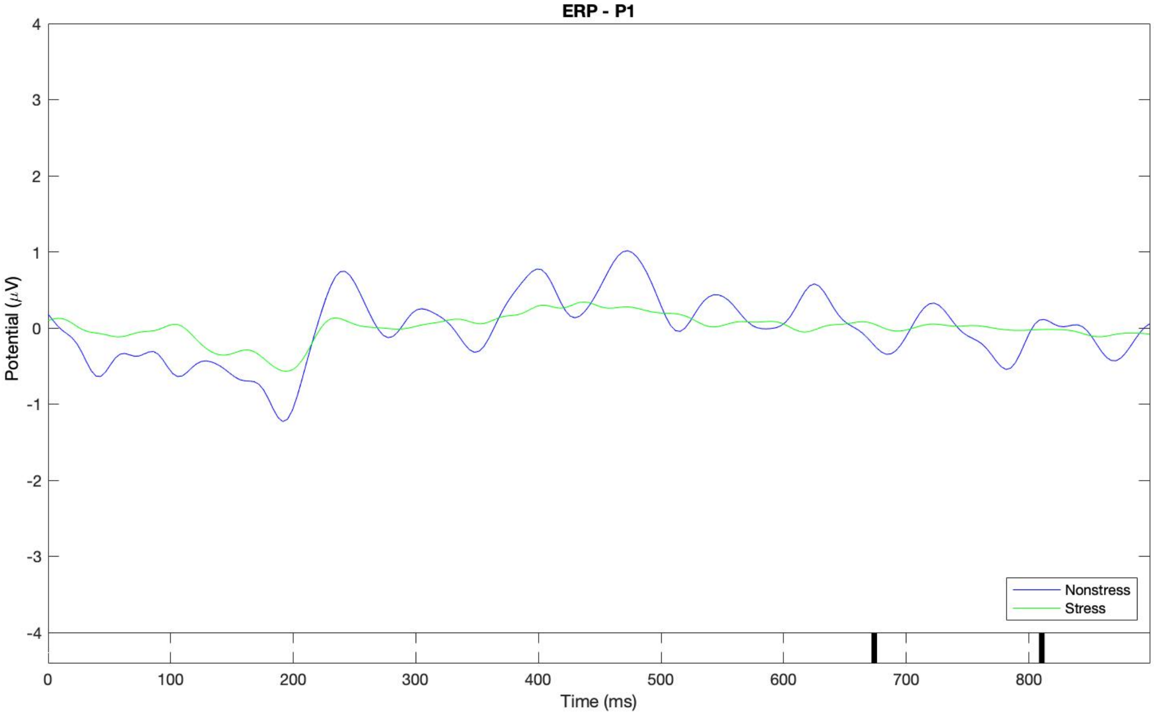

Figure 7. *Grand Average ERP Waveforms calculated in EEGLAB. Recorded from electrode P1 and epoched 0-900 ms post ongoing task response in stress and nonstress groups*

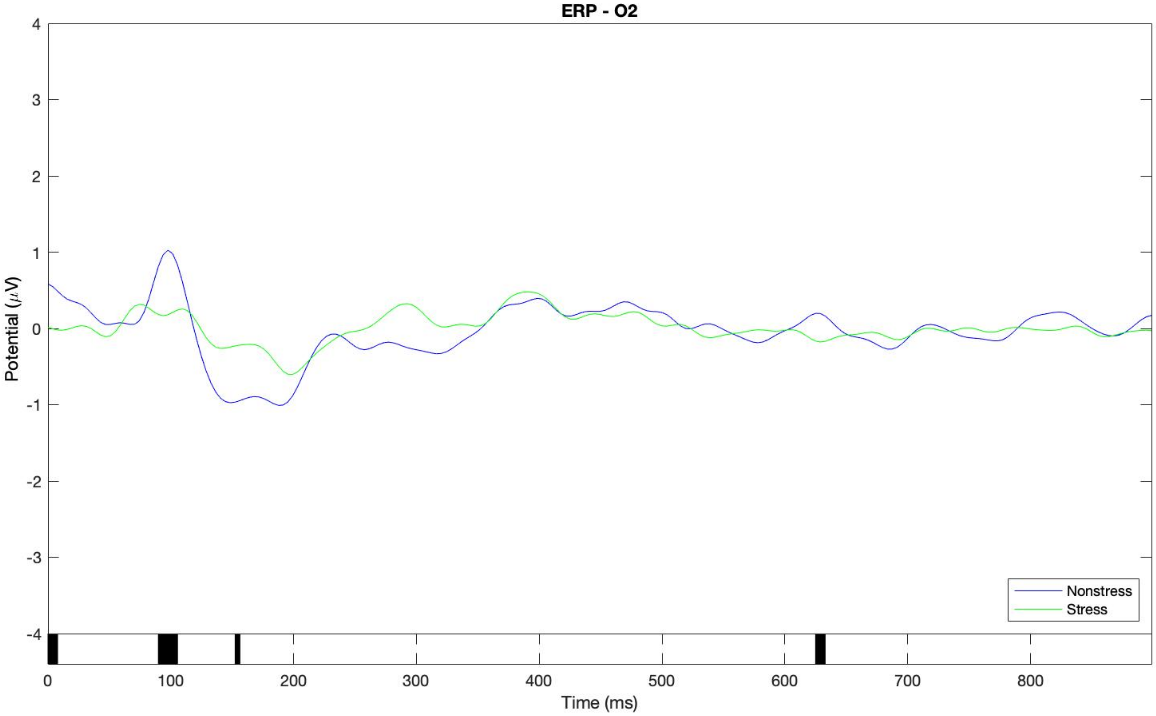

Figure 8. *Grand Average ERP Waveforms calculated in EEGLAB. Recorded from electrode O2 and epoched 0-900 ms post ongoing task response in stress and nonstress groups*

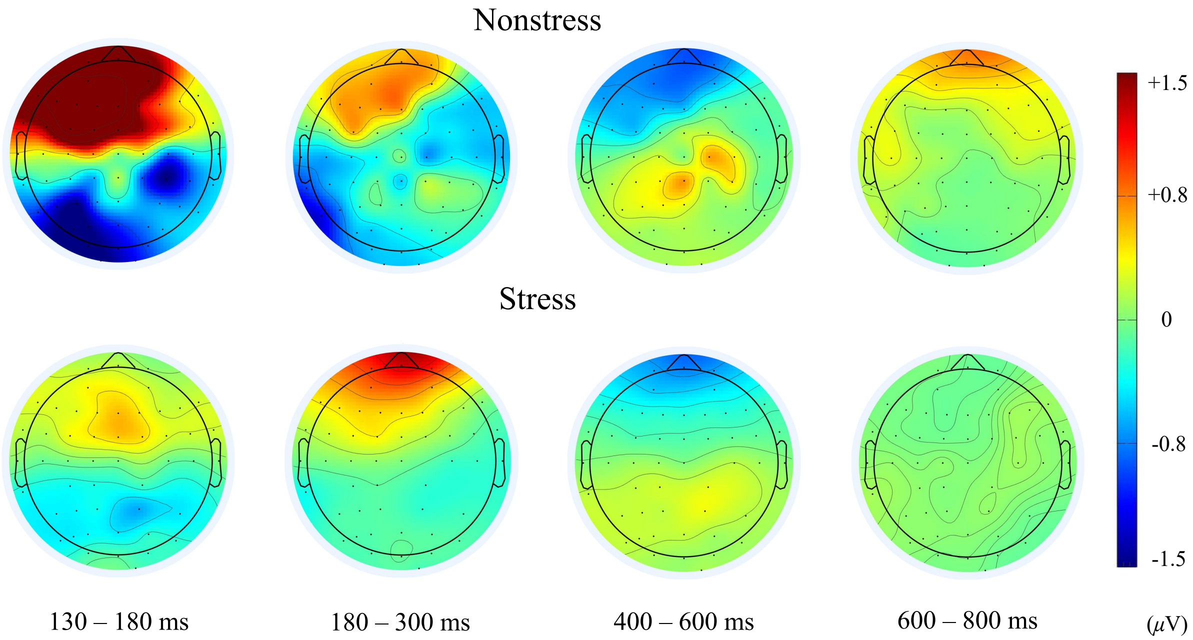

Figure 9. *Grand Average ERPs plotted over a topographical scalp maps during periods 130 – 180 ms, 180 – 300 ms, 400 – 600 ms, 600 – 800 ms post ongoing task response*

Discussion

This study aimed to compare TBPM performance and electrophysiological correlates among college aged individuals exposed to stress and not exposed to stress. Prior research investigating the effects of acute stress on prospective memory have provided varying results. In the present study, the behavioral measure of TBPM showed no significant difference in accuracy of response in the ongoing task and TBPM task, but the stress group gave TBPM answers at a significantly faster rate than the nonstress group. However, there was no significant difference in response time to the ongoing task between stress and nonstress groups.

It was found that acute stress exposure was associated with a faster TBPM response time. This is a novel finding, as changes only in accuracy of TBPM response were expected due to previous literature (Glieke & Piefke, 2016 & Nater et al. 2006). TBPM responses, unlike EBPM, are thought to rely mostly on spontaneous retrieval, defined as reflexive association between the PM cue and the intention stored in PM, due to the high demands of TBPM and cue saliency of TBPM (Cona et al., 2015; McDaniel & Einstein, 2000; Scullin et al., 2013; Piefke & Glieke, 2017). This train of thought posits that there are high cognitive demands placed upon an individual completing a behavioral TBPM task, where one is required to maintain intention while participating in an ongoing task. Previous literature, Plieger et al. (2017), using the same stressor used in this study found performance improvements in stress groups (with significantly raised cortisol levels) on cognitive tasks (FAIR) that were speculated to be caused by improvements in selective attention, which is described as a type of filter that decides whether information is being processed or ignored (i.e. inhibition) (le Blanc et al., 2009). One possible explanation for this result in the behavioral task is that the stress group became less engaged with the ongoing task or more engaged with the TBPM task, or even a combination of the two, which is reflected by the stress group having a non-significantly greater reaction time to the ongoing task in comparison to the nonstress group. However, this explanation is not supported by the accuracy of both ongoing and TBPM tasks as the stress group obtained a non-significantly higher accuracy for the ongoing task and a non-significantly lower accuracy for the TBPM.

On the other hand, there was no significant TBPM accuracy differences between the two groups, a finding that has not been shown in previous literature (Glieke & Piefke, 2016 & Nater et al. 2006). A potential explanation is that the PM task within the behavioral measures only includes six two-minute and four five-minute delay tasks, which is most likely not a large enough measure of PM ability. Additionally, everyday PM tasks are usually on a greater timeline than what is presented to the participants in this study and potentially allow for effective encoding of future intentions (Guynn 2008). Piefke and Glienke (2016) used a “real-life” PM task that included an ‘encoding’ period of about 40 minutes for participants to theoretically move future intentions into their working memory, which could have an enhancing effect for both accuracy and response time of TBPM intentions.

The electrophysiological recordings in juxtaposition with the ongoing task revealed significant differences. The choice of electrodes for ERP analysis was partially based off of Cona et al.’s 2012 study, which indicated that FP1, F1, P1, O2, were over brain regions that were mainly active in TBPM tasks. Interestingly, significant differences were noted over frontal electrodes FP1 and F1 in which the nonstress group had significant positive modulation during the visually estimated timeframe of 120 – 160 ms and 830 ms in addition to significant negative modulation at 400 ms than the stress group ($p<0.05$). Within Cona et al. (2012), it was proposed that greater positive modulation during the time frame of 180 – 300 ms post ongoing task in an identical behavioral task indicated that frontal activity might be mediating TBPM tasks (retrieval mode). Here, similar a positive modulation was observed at an earlier time frame (120-160 ms) in the group that provided PM responses at a slower rate (Figure 5 & 6). In lieu of the selective attention improvements seen in acute stress groups in Plieger et al. (2017), another potential explanation for the faster PM responses from the stress group is that the lower levels of activation seen in frontal cortices of the stress group during this timeframe are reflecting a sort of screen for the ongoing task, a sort of disengagement, which is allowing for the allotment of more cognitive resources toward the prospective memory task. Additionally, the patterns of activity scalp map projections resemble those in Cona et al. (2012). The findings presented could further support the notion that the retrieval mode is mediated by the activity in the frontal cortex.

Conclusion

Results of the present study highlight the need for further research investigating the effect of acute stress on prospective memory and consistency between both stressor and PM measures used. The behavioral measures presented somewhat resembled previous literature, and the electrophysiological data helped create a stronger relationship to previous findings.

Further studies should use the SECPT instead of the TSST due to its shorter nature, smaller number of required researchers, and more reliable cortisol and salivary alpha amylase level elevations. Future studies should have control and experimental groups that are more well balanced than those in the present study (n=12, stress=10, nonstress=2). This study had only two- and five-minute delays, which does not accurately represent the reality of TBPM tasks encountered on a daily basis – PM tasks should occur over the span of hours or even days if possible. Future studies using TBPM paradigms should implement an encoding phase with some sort of distractor to mimic the reality of everyday life. Future studies should implement eye tracking to investigate the difference in target checking between stress and nonstress groups.

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