CORTISOL AND SELF-REPORT MEASURES OF ANXIETY AS PREDICTORS OF NEUROPSYCHOLOGICAL PERFORMANCE

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ABSTRACT

CORTISOL AND SELF-REPORT MEASURES OF ANXIETY AS PREDICTORS OF NEUROPSYCHOLOGICAL PERFORMANCE

by Shelley L. Leininger

Although literature demonstrates that increased anxiety and cortisol levels can disrupt neural activity and negatively impact cognition, little research has employed neuropsychological instruments to measure cognitive functioning. The current study investigated the relationship between salivary cortisol activity and self-report measures of anxiety on memory and executive functioning measures. Fifty-eight male participants were randomly assigned to either a control (no stress induction) or experimental (stress induction) condition. Self-report state anxiety measures and saliva samples were jointly collected on three occasions. Participants in the experimental group generally performed more poorly than controls on the memory test and more cognitively demanding executive functioning tests. Despite self-report anxiety relating to more impaired neuropsychological performance, contrary to hypotheses, initial elevations of cortisol at session arrival were associated with facilitative memory effects. Cortisol and self-report anxiety appeared to independently influence cognition. It is possible that increased arousal and motivation could in part explain these unexpected effects.

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CHAPTER I

INTRODUCTION

A vast literature supports the deleterious effects of stress and increased hypothalamus-pituitary adrenal (HPA) axis activity on psychological processes. Associations have been demonstrated between cognitive impairment and cortisol, a glucocorticoid stress hormone released by the HPA axis. There is general consensus that cortisol fluctuations impact declarative memory, as the hippocampal region contains the greatest proliferation of corticosteroid receptors (Lupien & McEwen, 1997; Newcomer et al., 1994). Increasing evidence also suggests glucocorticoids can modulate executive functioning (McCormick, Lewis, Somley, & Kahan, 2007). Nonetheless, heterogeneity exists within the literature regarding the relationship between cortisol and neuropsychological performance, partly due to significant differences in methodology across studies.

Cortisol is triggered by stress and is regulated by the HPA axis (Takai et al., 2004). Cortisol release varies by the extent and level of stressor, and prolonged cortisol secretion has been associated with destruction of hippocampal neurons resulting in concentration and memory deficits (McEwen & Sapolsky, 1995). Elevated glucocorticoids in the short-term can alter synapses and dendrites, as well as inhibit neuronal metabolism and glucose transport (McEwen & Magarinos, 1997). The hippocampus is a major site for glucocorticoids (McEwen et al., 1986) and glucocorticoid activation has been shown to impair hippocampal-dependent forms of memory (declarative memory), whereas nonhippocampal types of memory (nondeclarative memory) are left unimpaired (Kirschbaum et al., 1996; Lupien et al., 1997). In addition,

large numbers of corticosteroid receptors also are present in the prefrontal cortex (McAllister-Williams & Rugg, 2002) and cortisol reactivity has been associated with impaired executive functioning (Lupien, Gillin, & Hauger, 1999; McCormick et al., 2007); however, executive functioning measures have infrequently been incorporated in cortisol research (McCormick et al., 2007). Tasks emphasizing cortical areas associated with sparse numbers of glucocorticoid receptors, such as visuospatial functioning and the parietal lobe, are generally unaffected by elevated stress or cortisol levels (e.g., Driscoll, Hamilton, Yeo, Brooks, & Sutherland, 2005; McCormick et al., 2007; McCormick & Teillon, 2001; Zacks, Vettel, & Michelon, 2003).

The relationship between cortisol and neuropsychological functioning is not entirely understood, particularly with regard to the specific conditions that cortisol modulates cognition and memory. Andreano and Cahill (2006) demonstrated a U-shaped relationship between cortisol activity and memory, and Zorawski et al., (2005) revealed low cortisol levels enhance memory acquisition, although this is not a dominant finding in the literature. Cortisol has also been found to differentially impact the memory processes of encoding, consolidation, and retrieval (Het, Ramlow, & Wolf, 2005). Also, various psychological stressors do not uniformly trigger cortisol reactivity, and this inconsistency can stem from variations in participant factors, level of stress, and nature of the task, among other factors (Het, Ramlow, & Wolf, 2005; Kudielka, Hellhammer, & Wust, 2009; Starcke, Wolf, Markowitsch, & Brand, 2008). For example, Egeland et al. (2005) found high levels of cortisol were associated with post-encoding memory weaknesses in retrieval and storage, in addition to executive dysfunction, although cortisol elevations did not correlate with memory acquisition or processing speed. The

authors noted weaknesses with experimental control, as factors known to impact cognition and cortisol (e.g., mood disorders, medications, etc.) were not controlled. These methodological short-comings are common in much of the literature, which in part contributes to the unclear association between glucocorticoids and cognition.

One of the goals of a neuropsychological evaluation is to gather valid and reliable test results, and it is crucial to parse apart the impact of anxiety on cognition, whether through self-report or physiological measures. Although anxiety is known to influence neuropsychological evaluations, investigations targeting the effects of state anxiety during neuropsychological assessments are sparse (Nagra, Skeel, & Penix-Sbraga, 2007). Also, much of the existing research employing stress induction procedures contains weaknesses, particularly speech social stressors that can yield inconsistent cortisol magnitudes over the course of the testing battery. For example, although Lupien et al. (1997) revealed declarative memory impairments following a speech stress induction procedure, cortisol peaks suggested initial anticipation of the speech may be more anxiety provoking than the actual stressor. Also, in a study by Domes et al. (2002), the speech stress induction procedure demonstrated weak cortisol reactivity, which may partially account for the lack of memory findings. In essence, the wide variation of cortisol levels between experiments may in part be due to the conceptual disconnect between the stressors and cognitive measures.

These stress inducing procedures do not simulate a clinical testing situation, which may involve more realistic concerns, such as performance on cognitive measures and/or discovery of testing results. Stress induction procedures targeting cognitive performance would not only reflect a real-life clinical environment, but may also result in

more consistent stress levels over time. Although the social stress paradigms have contained weaknesses in terms of the "speech" stress targets, Nagra, Skeel, and Penix-Sbraga (2007) are an exception. Investigating the effects of stress induction and examiner ethnicity on neuropsychological performance, participants were told the tests were highly predictive of life success and future employment, and these stress-inducing instructions had the greatest negative impact on cognition. State anxiety was also more detrimental for difficult rather than easier tasks, and had a greater influence on performance than trait anxiety.

The current study aimed to clarify the link between cortisol reactivity and self-reported state anxiety as predictors of neuropsychological performance. There is a paucity of literature that has examined the impact of state anxiety and cortisol levels on a broad range of neuropsychological measures. The majority of studies have tended to use social stressors unrelated to the cognitive tasks themselves, which is inconsistent with a clinical setting. Thus, in an effort to induce and maintain elevated anxiety levels throughout the testing battery, the current study employed a stress-induction procedure relating to actual test performance. Three state anxiety self-report measures and saliva samples were gathered concurrently; the first measure reflected baseline levels and subsequent gatherings measured stress reactivity of two points during testing.

Cortisol levels were predicted to increase in the stress induction condition, consequently being linked with elevated state anxiety ratings and impaired neuropsychological performance. Compared to controls, participants in the stress-induction condition were hypothesized to display larger magnitudes of cortisol reactivity between baseline collection and times 2 and 3, following the stress induction procedure.

Participants in the stress induction procedure were also expected to display higher self-report anxiety ratings. It was hypothesized self-report anxiety ratings would correlate with cortisol increases. Participants in the experimental condition were predicted to display specific deficits with tests of declarative memory and executive functioning, but not spatial rotation. Disparities were hypothesized to be most evident among the cognitively demanding measures.

CHAPTER II

LITERATURE REVIEW

Physiology of Cortisol

Glucocorticoids are hormones produced in the adrenal cortex in mammalian species (Funder, 1987), and the most common is cortisol, which is termed corticosterone in rodent species. Secreted cortisol is regulated and used as a peripheral measure of the hypothalamic-pituitary-adrenal (HPA) axis (Takai et al., 2004). The HPA axis is a network connecting the central nervous and endocrine systems that is triggered by stress (Kudielka & Kirschbaum, 2005). Early views by Selye (1936) indicated that HPA axis activity is triggered unspecifically as a response to internal and external stimuli. Reactivity to threatening or novel stimuli results in the quick release of cortisol into both saliva and blood. The HPA axis releases corticotrophin-releasing hormone (CRH) from the hypothalamus and this promotes secretion of adrenocorticotrophic hormone located in the posterior pituitary. Consequently, this activity aids in the release of cortisol from the adrenal cortex.

The endocrine system releases hormones, such as cortisol, into the blood from ductless glands, which supports the nervous system in regulating bodily functions (Taylor, 1999). The endocrine system includes the adrenal glands that consist of two small glands found above the kidneys. The adrenal glands include an adrenal medulla, which secretes the catecholamines epinephrine and norepinephrine. These regulate heart rate, blood pressure, blood flow to muscles, and breathing. The adrenal glands also include an adrenal cortex, which is activated by the adrenocorticotropic hormone (ACTH). ACTH is activated from the anterior pituitary lobe and releases corticosteroids

that facilitate regulatory functions involving proteins, fats, and energy. Corticosteriods include cortisol, androgens, and estrogens. Stressors both physical and psychological in nature prompt the release of the catecholamines epinephrine and norepinephrine through the sympathetic nervous system, along with glucocorticoids from the adrenal gland. Although the ratios of the release vary by the extent and level of the stressor, in general there is a consistent pattern of catecholamine and glucocorticoid activation from stressors (McEwen & Sapolsky, 1995).

There are two different types of glucocorticoid receptors. Type I are known as mineralocorticoid receptors and Type II are termed glucocorticoid receptors. High-affinity Type I receptors are generally activated by basal levels of adrenal steroids during the diurnal cycle, and stress range glucocorticoid activation raises occupation of lower-affinity Type II receptors. Consequently, circulating adrenal steroids can have various effects on the brain depending on basal and stressful periods. Type II receptors also mediate glucose transport and have suppressant effects on neuronal excitability (Joëls & de Kloet, 1994). The hippocampus is one of the few brain regions with high concentrations of both Type I and II receptors (McEwen, de Kloet, & Rostene, 1986), which will later be discussed in more detail.

Function of Glucocorticoids in Allostasis

Catecholamines and glucocorticoids are released in the body in order to maintain allostasis, or the process of keeping organisms functioning and alive by facilitating stability through change (McEwen, 1998). For example, catecholamine and glucocorticoid increases occur during exercise and restore energy needed for both the brain and body during challenging events. Allostasis in this case creates adaptations that

are needed for stable body temperature and metabolism. Allostasis also takes place during dangerous situations, as acute stress-induced release of both catecholamines and glucocorticoids aids in the transport of immune cells to body regions, which are needed to fight infection or different immune activity (McEwen, 2000). As another protective factor, studies with rats have found that stress hormones can facilitate long-term memory consolidation (Roozendaal, 2000). Specifically, these hormones work together to aid in memory of situations that could be unsafe, potentially helping to stave off danger. However, there are also negative consequences to stress hormones. Although glucocorticoids may replenish energy in the short-term when individuals are faced with threats, through increasing appetite, locomotor activity, and foraging behavior, this could be harmful during periods of inactivity. Furthermore, inactivity can create chronically high levels of glucocorticoids stemming from long-term stress, insufficient sleep, or heavy diets preventing insulin from facilitating glucose uptake. Physically, together increases in glucocorticoids and insulin result in elevated fat deposits and atherosclerotic plaques throughout arteries of the heart (Brindley & Rolland, 1989). Research has also demonstrated that cortisol can have immunosuppressive effects relating to suppressed lymphocyte responsivity (Chrousos, 1995). In addition, there is increasing evidence that HPA axis dysregulation, as reflected through cortisol levels, can negatively impact cognition and psychopathology. Specifically, elevated cortisol levels have been correlated with depression (Campbell, Marriott, Nahmias, & MacQueen, 2004), Alzheimer's disease (O'Brien et al., 1996), and Cushing syndrome (Starkman et al., 1992).

Triggered glucocorticoids can have deleterious effects on the nervous system. Excessive discharge of epinephrine and norepinephrine is believed to lead to a suppression of cellular immune functions and to produce neurochemical imbalances potentially contributing to onset of psychiatric disorders (e.g., Charmandari, Tsigos, & Chrousos, 2005; Habib et al., 2001). Prolonged HPA activation and cortisol secretion have been associated with destruction of neurons in the hippocampus that result in concentration and memory deficits, which may be characteristic of psychiatric diagnoses such as anxiety and depression (Taylor, 1999). Specifically, high levels of catecholamines and glucose can disrupt memory (McGaugh, 1989). This results in the inverted U-shaped effects of catecholamines and glucose on memory functioning. Within the hippocampus, psychological stress and stress-induced release of glucocorticoids can interfere with LTP and/or the related primed burst potentiation (Diamond, Fleshner, & Rose, 1994). The adrenal steroids, specifically glucocorticoids, have a biphasic effect on both long term potentiation (LTP) and primed burst potentiation (PBP) (Diamond, Bennet, Fleshner, & Rose, 1992). Although stress released glucocorticoid levels inhibit LTP, lower hormonal levels that occur naturally during the diurnal rise improve plasticity (Diamond, Bennett, Engstrom, Fleshner, & Rose, 1989; Diamond et al. 1992; Pavlides, Kimura, Magarinos, & McEwen, 1994).

Cortisol, Self-Reported Distress, and Personality Traits

Although changes in the HPA axis have been associated with mood disorders like anxiety and depression (Holsboer, 2000; Young, Abelson, & Cameron, 2004), and hypercortisolism has been commonly found within psychiatric patients (Holsboer & Barden, 1996; Linkowski, 2003; Young et al., 2000), there is great debate regarding the

equivocal relationship between self-reported distress and cortisol (Vedhara et al., 2003). Although numerous studies have demonstrated an association between elevated cortisol levels and increased self-reported distress (Melamed et al., 1999), many have found little to no relationship (Marshall et al., 1998; Kirschbaum et al., 1995). The literature is also equivocal concerning a link between personality traits and glucocorticoid stress (Pruessner et al., 1997). Personality variables such as sensation seeking (Kirschbaum, Bartussek, & Strasburger, 1992), anxiety (Jezova, Makatsori, Duncko, Moncek, & Jakubek, 2004; van Eck, Nicolson, Berkhof, & Sulon, 1996), and neuroticism (LeBlanc & Ducharme, 2005; Phillips, Carroll, Burns, & Drayson, 2005) have been studied in association with cortisol, and results have been variable.

Vedhara et al. (2003) investigated the relationship between cortisol changes and self-reported anxiety and depression. Participants included women who were instructed to gather five saliva samples over the course of one day in their natural environment, while avoiding caffeine and meals within 60 min. of each sample and caffeine during the day. Emotional distress was reflected through a global measure of perceived stress scale and a hospital anxiety and depression scale. There were no significant relationships between absolute cortisol levels and self-reported distress, but there was an association between cortisol change and measurements of distress. Furthermore, there was a non-linear association between cortisol levels and time of day, although the magnitude of non-linearity depended on anxiety and stress, rather than depression. This particular study had many limitations, however, in that there was no control group, no control for confounders, and no evaluation of how variability in the measurement of distress may have influenced associations.

Young et al. (2000) examined cortisol levels and history of major depression in monozygotic twins. Past studies have found increased basal cortisol levels in patients with major depression, although this finding has been inconsistent. Also, other studies have demonstrated nonsuppression of cortisol to a 1-mg dexamethasone challenge, which appeared to be state-dependent since it resolved with treatment for depression (Ribeiro et al., 1993). These studies were confounded, however, in that patients were on antidepressant medications, which regulate HPA axis activity through increasing glucocorticoid receptors (Holsboer & Barden, 1996). Thus, Young et al. used women twin pairs no longer on medication and for 14 days collected salivary samples within 45-minutes of waking, along with evening samples collected before sleeping. There was stability in cortisol levels, as morning and evening values were significantly correlated with both individuals and twin pairs. Twins with a history of major depression also had high cortisol levels. Approximately 40-45% of total salivary cortisol variance was shared by the twin pairs. This still leaves unanswered questions of whether increased baseline cortisol for some "in episode" depressed patients is a state or trait marker, along with if the increase is a result of, or risk factor for, depression.

Impulsivity has been studied in relation to cortisol and heart measures during casino gambling. Krueger, Schedlowski, and Meyer (2005) recruited blackjack players for their study. The experimental group played a 90-minute session of blackjack with their own money in a casino, whereas the control condition played cards for accumulation of points. Baseline data were gathered 20 minutes prior to gambling with heart rate recorded in a resting position. Heart rate continued to be monitored throughout the entire experiment. Thirty minutes prior to playing blackjack, an intravenous cannula was

inserted for repeated blood sampling. A baseline blood sample was gathered 15 minutes before gambling, a sample was obtained during the session, and a follow-up sample was obtained 20 minutes following the end of the game. Then, participants completed German versions of the Eysenck Impulsivity Questionnaire and South Oaks Gambling Screen (SOGS). Impulsivity scores were divided into a median split with low and high impulsivity subgroups. Consistent with past studies, there was a significant increase in heart rate with the onset of casino play. The high impulsivity group displayed higher heart rate levels throughout play in the casino compared to the low impulsivity group. Impulsivity scores correlated with SOGS scores, as pathological gamblers were higher in impulsivity. Cortisol levels increased substantially with the onset of gambling, but decreased at the end of play compared to the control condition. This reflected a moderate stress response to the gambling. However, cortisol levels did not differ significantly between low and high impulsivity participants, although those higher in impulsivity had more elevated sympathetic activity. There were several limitations in this study, as only 29 participants completed the entire experiment. In addition, past research has suggested that sensation seeking can moderate impulsivity and gambling behavior, but the current study did not investigate this. The authors stated that future studies should include additional self-report measures.

Oswald et al. (2006) investigated the relationship between cortisol response to personality and stress in 68 healthy adults. Participants began the study at 1200 h and were asked to fast since 1000 h and refrain from alcohol, illicit drugs, or medications for 48 h prior to the study. An intravenous catheter was used for blood sampling. Participants then underwent a modified psychosocial stressor, the Trier Social Stress Test

(TSST; Kirschbaum et al., 1993), which has been an effective paradigm for studying individual differences in HPA axis reactivity. The original TSST has participants prepare a 5 min. timed mock job interview/public speaking task in front of 2–3 confederates and then a 5 min. timed arithmetic task is completed (i.e., counting backwards from 2083 in increments of 13) with confederate feedback. In the Kirschbaum et al. (1993) study, approximately one week prior to the TSST, participants completed the Revised NEO Personality Inventory, the Brief Symptom Inventory, and the State-Trait Anxiety Inventory. Results showed that peak cortisol levels were significantly higher than baseline levels. Only scores on the NEO Openness factor displayed significant effect sizes and were associated with lower cortisol responses from the TSST ($z = 1.96$; $p = .050$). Also, cortisol responses varied with gender, as blunted cortisol responses were found in women with higher Neuroticism and in men with lower Extraversion. Study weaknesses involved a number of analyses without correction for multiple comparisons. Also, the authors stated that the association between cortisol and personality is still exploratory, and that the study was unable to reveal why gender affected linkages between cortisol and personality.

Since research has been inconsistent in clarifying the association between cortisol stress responses and personality traits, Pruessner et al. (1997) attempted to examine this relationship by aggregating cortisol stress responses. Using 20 nonsmoking, male university participants, the experiment occurred over the course of five days. Every day, participants were exposed to the TSST 10 minutes after arrival, and six saliva samples were gathered at 10-min. intervals. The aim of the study was to investigate differences in self-concept, locus of control, self-esteem, and cortisol stress responses. The authors

stated that since novelty is a random situational factor that can hide individual differences in stress response, the areas under the response curve (AUC), or index of daily cortisol stress responses, were combined only for days two through five. Day one was not included because it produced a significantly higher stress response. Following repeated exposures, cortisol responses and personality variable correlations were inconsistent and scattered for each separate day. However, after aggregation of cortisol responses for days two through five, consistent patterns emerged for some variables, such as social dominance. This may have led to identification of a trait factor of the state "stress response," particularly relating to one's ability to cope with subsequent stress exposures. Nonetheless, data aggregation did not generally change the number of correlations that were statistically significant.

Physiological Effects of Glucocorticoids on the Hippocampus

Although glucocorticoids are essential for life, excessive levels can be pathogenic. McEwen et al. (1986) demonstrated that the hippocampus is a major target for glucocorticoids, as there are high numbers of receptors within this brain region. The hippocampus has more Type I receptors than any other area in the brain, and as many Type II receptors as are present in other brain regions. Selective activation of Type I hippocampal receptors elevates long term potentiation (LTP) (Pavlides, Kimua, Magarinos, & McEwen, 1994), as lower levels of corticosterone increase primed burst potentiation (Diamond et al., 1992); however, activation of Type II receptors by high concentrations of endogenous glucocorticoids inhibits LTP and primed burst potentiation (PBP) (Pavlides, Watanabe, & McEwen, 1993). Furthermore, Type II receptor stimulation has been found to result in a long-term synaptic depotentiation, and stress

levels have been long documented to decrease hippocampal activity (Joëls & de Kloet, 1992; Zeise, Teschemacher, Arriagada, & Zieglgansberger, 1992). It is thought that glucocorticoids contribute to after-hyperpolarizations, or enhance calcium currents, which increase the refractory period of inactive neurons in the hippocampus. Thus, the biphasic effects of glucocorticoids result in inhibitory effects during stress levels of the hormone and excitatory effects during basal levels (Hesen & Joëls, 1993).

Cushing's syndrome is characterized by excessive amounts of cortisol caused by either iatrogenic, pituitary adenoma, adrenal adenoma/carcinoma, or ectopic production of adrenocorticotrophic hormone (Salway, 2006). This patient group has made a powerful model for examining the link between hypercortisolemia, brain structures, and cognition. Patients have been found to display decreased hippocampal formation volume (HFV), as shown through magnetic resonance imaging (MRI). A number of studies have found that patients with Cushing's disease perform poorly on neuropsychological measures, and with treatment aiming to lower cortisol levels, performance appears to improve (Whelan et al., 1980).

Starkman et al. (1999) evaluated whether decreases in cortisol can reverse hippocampal atrophy following treatment of Cushing's disease. Results indicated that human hippocampal formation was able to increase in volume after treatment reducing cortisol levels. Following remission of Cushing's disease, the HFV increased up to 10% in patients, which correlated significantly with the magnitude of change in urinary free cortisol levels. However, the investigators did not have brain imaging of patients before the onset of the disease.

Although literature has demonstrated that emotion often affects memory in an inverted-U-shaped manner, incidental effects of stress are more complex with memory (Preston, Buchanan, Stansfield, & Bechara, 2007). Corticosteriods like cortisol and prolonged HPA activation have been linked to deterioration of hippocampal neurons, resulting in memory and attentional problems. Countless studies have investigated cortisol and memory ability, particularly declarative memory. Studies have commonly shown that because the hippocampus contains Type I and Type II corticosteroid receptors (McEwen et al., 1986), chronic elevations of corticosteroids impair hippocampal-dependent forms of memory (declarative memory), whereas nonhippocampal types of memory (nondeclarative memory) are left unimpaired (Lupien et al., 1997, 1999).

The Impact of State Anxiety on Cognition

The effects of stress on cognition, whether facilitative or interfering, have important implications within a clinical assessment setting. One of the goals of a neuropsychological evaluation is to gather valid and reliable test results that are essential for accurate diagnoses, along with formulation of recommendations that may ameliorate presenting problems. Inaccurate diagnoses may precipitate unforeseen negative consequences and undue stress for the patient and family. Research is sparse regarding investigations targeting the effects of state anxiety during neuropsychological assessments (Nagra, Skeel, & Penix-Sbraga, 2007). Thus, there is a call for research clarifying the role between stress and neuropsychological performance.

The vast majority of research examining the effects of state anxiety on cognition contains weaknesses with regard to stress induction procedures. Specifically, the stress induction paradigms generally involve a social stress test, such as the TSST, which is

unrelated to the cognitive measures themselves. The TSST instructs participants that they will be giving a speech regarding a fictitious job at the conclusion of the testing battery. These social stress tests evoke inconsistent magnitudes of stress and cortisol over time, since participant cortisol levels peak as testing time elapses and the speech nears. These stress inducing procedures do not simulate a clinical testing situation, which may involve more realistic concerns, such as performance on cognitive measures and/or discovery of testing results. Stress induction procedures targeting cognitive performance would not only reflect a real-life clinical environment, but it may also result in more consistent stress elevations over time. Although the social stress paradigms have contained inherent flaws in terms of the "speech" stress targets, an exception is described below.

Nagra, Skeel, and Penix-Sbraga (2007) investigated the effects of stress and examiner ethnicity on neuropsychological performance. Participants included Asian-Indian males living in the United States, who had been born and raised in India. They were assigned to conditions involving high or neutral stress, along with having either an examiner of the same ethnicity or different ethnicity. The stress-inducing instructions informed participants that the tests were highly predictive of life success and were predictive of future employment, while the neutral instructions stated the measures were new and being tested, and performance did not matter. Following these instructions, a neuropsychological battery was administered that included the Paced Auditory Serial Addition Task (PASAT), Digit Span, Digit-Symbol-Coding, Spatial Span, Trails A and B, Fingering Tapping, along with the State-Trait Anxiety Scale as a self-report measure. Results indicated that high self-reported anxiety and examiners of a different ethnicity

negatively influenced neuropsychological results. The stress-inducing instructions had a larger impact on performance than examiner ethnicity. Also, state anxiety was more detrimental for difficult rather than easier tasks, and state anxiety had a greater influence on performance than trait anxiety.

Effects of Stress and Cortisol Levels on Neuropsychological Performance

A number of conflicting views in the literature exist regarding the association between stress, cortisol levels, and neuropsychological measures. Specifically, studies have examined the relationship between stress and memory and executive functioning performance, which appear to be inconsistent depending on participant variables, the level of stress, the nature of the task, etc. (Starcke, Wolf, Markowitsch, & Brand, 2008). For example, although increased cortisol levels are generally found to have a negative impact on declarative memory, elevated levels have also been found to improve (Domes et al., 2002), or have no effect on declarative memory. In addition, some researchers have stated there has been too narrow of a focus on hippocampal-related tasks, rather than broadening examination to prefrontal cortex (PFC) related tests, especially since a large number of corticosteroid receptors exist in the PFC (McAllister-Williams & Rugg, 2002). Research has supported that the PFC is involved in "hippocampal" declarative memory activity such as encoding, retrieval of episodic memories, and working memory (Lee, Robbins, & Owen, 2000). Administration of cortisol has also been found to negatively influence working memory without changing declarative memory (Lupien, Gillin, & Hauger, 1999), though another study by Monk and Nelson (2002) demonstrated that cortisol levels did not differentially influence working memory. Thus, the research investigating the relationship between cortisol levels and cognition has been equivocal.

Furthermore, there has been little research examining the role between stress, cortisol, and various prefrontal cortex activities (McCormick et al., 2007). The few studies that have are described below.

Memory

Wolf et al. (2001b) investigated the association between stress induced cortisol levels and memory between males and females. None of the women in the study were using oral contraceptives and all women were tested in the late luteal phase (days 21-25) of their menstrual cycle, which they indicated on self-report. This phase was chosen because stress-induced free cortisol levels are generally equivalent between men and women during that phase (Kirschbaum et al., 1999). Experimental participants were exposed to a psychosocial stressor, the TSST before memory testing, while the controls were exposed to the stressor one hour following memory testing. Saliva samples were obtained before and 10 minutes following the stressor, in order to determine free cortisol. The memory test consisted of a word list of 25 words, in which participants were instructed to read the words aloud from a piece of paper at a speed of one word per three seconds. Following the learning phase, a 25 second distractor task was used that consisted of reading aloud color words from a piece of paper. Then, free recall of the word list was tested. Cortisol levels doubled in response to the TSST, but overall, the experimental participants did not display impaired recall of the word-list when compared to controls. However, cortisol elevations in response to the stress test were negatively correlated with memory performance (r = -.43). In addition, the high correlation was mainly a result of the strong association with male participants (r = -.82), while no correlation was found with women (r = -.05). Thus, this suggests that gender may

modulate the link between cortisol levels and memory. The authors posited that higher magnitudes of stress-induced cortisol may be required in order to detect group differences between stressed and non-stressed participants. In addition, use of only one memory test restricted the ability to evaluate the effects of learning versus recall.

Lund et al. (2005) investigated the role of cortisol in predicting executive and memory function in depression, with patients who were part of a larger study on depression and schizophrenia. In the study, saliva samples were gathered at 8 a.m. for baseline measurement, and participants completed the Wisconsin Card Sorting Task, Stroop Color and Word Test, reaction time subtests from the California Computerized Assessment Package (CalCAP), and the California Verbal Learning Test (CVLT). High levels of cortisol were associated with post-encoding memory weaknesses in retrieval and storage, along with executive dysfunction. However, cortisol levels did not correlate with memory acquisition or processing speed.

The MacArthur studies of successful aging (Seeman et al., 1997) investigated the relationship between cortisol and memory. Individuals were in their 70's at the time of enrollment and the study took place over a period of three years. Participants completed one overnight urine collection, both in the first and third year, in order to minimize potential effects related to physical activity, and to estimate more intrinsic individual differences in basal cortisol levels. Measures of cognition included the Boston Naming Test, delayed story recall, delayed spatial recognition, abstraction, and spatial ability. Results revealed that increased levels of HPA axis activity, indicated through urinary free cortisol excretion, were associated with memory declines only in females. Women with higher baseline cortisol levels showed worse delayed recall at baseline, and

longitudinally, increasing cortisol levels were linked with declined memory performance. In contrast, women who exhibited declined cortisol levels longitudinally had improved memory performance in the third year. One study limitation pertains to the narrow collection of overnight urine cortisol excretion, which minimizes individual differences and potentially attenuates associations with memory performance. Future studies should also exert greater control over factors known to impact cognition and cortisol, such as mood disorders, medications, etc.

Lupien et al. (1997) also investigated cognitive tasks and cortisol levels with stress induction in an elderly sample of participants. Testing began at 1:30 p.m. and participants aged 62-83 gave informed consent to a "speech evaluation." In actuality, participants were exposed to nonstressful and stress-induced conditions with memory tests administered before each condition. The nonstressful condition was described as a practice task, and involved a predetermined target to be searched on a computer (Sharti & Czaja, 1994). The stressful condition involved the TSST. Cortisol saliva samples were obtained before and after memory testing, as well as before and following the nonstressful and stressful conditions. The stressful condition decreased declarative memory performance significantly, and the nonstressful condition resulted in normal performance. In addition, the stressor had no effect on nondeclarative memory. For analyses, participants were divided into cortisol responders and nonresponders, due to variability. Cortisol levels increased drastically around 62 min. prior to the actual stressor for "responders" and 25 min. for the nonresponders; thus, the anticipation of the stress may have had more of an effect on memory than the actual stressor. However, mental tasks themselves can result in elevated cortisol levels (Brandenberger et al., 1980;

Wittersheim, Brandenberger, & Follenius, 1985). Therefore, the early cortisol increase in the responder group could have been influenced by the first memory test. In addition, there was wide variation in cortisol levels across the entire experiment, which may have been in part due to the disconnect between the TSST and the cognitive measures.

Wolf et al. (2001a) studied the differential age effects of cortisol on memory between young and elderly men. The design was a placebo-controlled, double-blind, crossover and in the first testing session either an intravenous injection of 0.5 mg/kg cortisol or placebo was administered. The second session occurred 7 to 14 days later and the injection not given in the first session was administered. The cognitive domains of attention, working memory, and declarative memory were used for cognitive testing. Different versions of cognitive tests were administered twice during each session, which were pre- and post-injection. During each session, a word list was first learned before cortisol administration. The effects of cortisol were analyzed with recall of the task. The second list was learned one hour after drug injection in order to evaluate of the effects of cortisol on learning. Additionally, a series of neuropsychological tests, such as the Stroop Color and Word Test, were also administered, with several blood samples gathered throughout the testing period. Results revealed that cortisol impaired recall of word lists before any drugs were administered during task learning. However, after the cortisol was administered, there appeared to be no effects on learning of word lists or paragraphs in both young and elderly. Also, Digit Span performance was decreased in the younger participants but not the elderly, and none of the age groups were negatively affected with respect to attention and response inhibition. Weaknesses of the design included difficulty determining if observable effects were mediated by cortisol affecting

memory consolidation. A ceiling effect could have also occurred with the list of 10 words learned to a criterion, which was defended by the authors stating that they attempted to reduce task difficulty and resulting stress.

Using middle-aged women, Domes et al. (2002) assigned participants to either a stress or control condition. The stress condition employed a modified TSST (Kirschbaum et al., 1993), while in the control condition participants wrote a letter of application and completed paper-and-pencil math with no evaluation of their performance. Over a 90-minute period, 8 saliva samples were gathered with Salivette collection devices. In addition, cognitive tasks were employed following either the stress test or control condition. Results demonstrated that the psychosocial stressor did not influence declarative memory, which does not align with the majority of previous research. Peak cortisol levels following the stressor were lower than those found in past studies. The authors speculated that the stress induction procedure may have been insufficient for elevating cortisol levels or impacting memory. They also stated that the memory task itself may have been inappropriate, as it contained an intermediate delay of 5 minutes and it most likely tapped into memory that was neither generally mediated by the PFC nor usually hippocampus dependent. Lastly, the sample size and power were quite low, and the screening procedures were weak for excluding individuals with psychological symptoms and chronic stress.

Executive Functioning

Lee et al. (2007) investigated the effects of cortisol on executive functioning with participants 50 to 70 years of age. Basal cortisol levels can be useful for measuring steady-state HPA axis functioning, but evaluating responses to stressors can be utilized as

an indicator of possible HPA axis dysregulation. The authors stated that although psychosocial challenges have been used extensively in past studies, not only can these challenges influence cognition (Lupien et al., 1997), but results may have been an artifact of testing anxiety or acute cortisol effects (Lupien & McEwen, 1997). Thus, four saliva samples were obtained in one study visit that were before, during, and after cognitive testing, along with at visit completion. In addition, the authors stated that the Trier Social Stress Test is time-consuming and cannot be implemented along with cognitive testing, as it can create unwanted acute effects on performance scores. Consequently, the cognitive battery was utilized as a mild psychosocial stressor, although the technician avoided saying the tests were being used for measuring individual ability. Participants completed 20 tests categorized into 7 cognitive domains: language, processing speed, eye-hand coordination, executive functioning, verbal memory and learning, visual memory, and visuoconstruction. Magnitudes of relationships were large and comparable to cognitive performance age related effects. Language processing speed, eye-hand coordination, and executive functioning were significantly related to at least 2 of 3 cortisol metrics (i.e., pretest, mean, and area under the curve with respect to zero. Higher cortisol levels were related to poorer performance. Also, adjusting for self-reported subjective stress at sampling did not weaken the relationship of the metrics with the test scores; thus, relationships were more likely to have occurred from long-term cortisol elevations. However, there were limitations that included gathering cortisol samples during all times of the day, without controlling for diurnal variation. There may have been potential confound associated with the lack of participant screening, as individuals

were not excluded based on medication and mood disorders. Lastly, the cross-sectional design restricts the ability to evaluate short-term versus long-term cortisol exposure.

Using both men and women, McCormick et al. (2007) examined the relationship between cortisol levels and executive functioning. Cortisol samples were gathered four times over the 35-minute testing session. Since the general mode of cortisol activity is at intracellular glucocorticoid receptors, the authors posited that a time lag would occur with the association between cognitive performance and the circulating cortisol levels. Therefore, they hypothesized the link between cognition and cortisol levels would be most strong for samples gathered at arrival to testing, which was before the cognitive tests. Associations would be weakest for the later samples gathered following the cognitive tests. The authors also predicted that testing performance and cortisol levels would be most strongly related with tests involving the PFC (e.g., Wisconsin Card Sorting Task perseverative errors), but weakest for tests not relating to the PFC (e.g., Primary Mental Abilities-Spatial Relations (PMA-SR); Thurstone & Thurstone, 1962). Testing occurred between the hours of 2:00 and 4:15 to minimize time of day effects on cortisol levels. Results revealed that although women displayed higher salivary cortisol levels compared to men at arrival, over time women's levels declined and were more similar to the men. Cortisol levels did not differ with the men over time. Also, consistent with hypotheses, cortisol levels were correlated with executive functioning performance on the WCST, but not on the test of mental rotation (PMA-SR). In addition, cortisol levels at arrival were related to more perseverative errors for women, but fewer errors for the men on the WCST. However, the authors note that they did not screen stringently for inclusion, as they did not take into account menstrual cycle phase, oral contraceptive use,

or time since last meal, which have been found to affect cortisol levels (Smyth et al., 1997).

Starcke, Wolf, Markowitsch, and Brand (2008) have also found that anticipatory stress can negatively influence decision making under explicit risk conditions. Like the majority of studies gathering cortisol samples in reaction to stress, participants were tested between 2 and 5 p.m. to decrease endocrine variations. The experimental group was told they would have to deliver a speech with the topic, "how I evaluate my cognitive abilities," in front of two psychologists following completion of several neuropsychological tests. The control group was instructed to think about their last holiday during the time in which stress was induced for the experimental group. The State Anxiety subscale of the State-Trait Anxiety Inventory was used to evaluate anxiety and the Positive and Negative Affect Schedule (PANAS) was used to determine changes in positive and negative affect. These questionnaires were administered before and following the stress induction period of time. Salivary cortisol and alpha-amylase samples were obtained before and during the course of performance. Neuropsychological instruments included a German intelligence battery, a modified Wisconsin Card Sorting Test to measure concept formation and set shifting, and the Trail Making Test Parts A and B to measure psychomotor speed and mental flexibility. The Word-Color Interference Test, a German version of the Stroop test, was employed to evaluate interference susceptibility. These tests were used to compare performance between experimental and control groups, along with serving the purpose of the cover story in the experimental group. The Game of Dice (GDT) (Brand et al., 2005) was also used to analyze decision-making under risk. The GDT is a computerized task similar to the IGT,

in that fictitious money is won through throwing die with numbers associated with safe or risky decisions. In the current study, participants played the game once with feedback and another time without feedback. Results showed that the experimental condition performed more poorly on the GDT than controls. Also, GDT performance was negatively correlated with the increase of cortisol, although reaction pattern to the "stressor" did not differ significantly between groups. Contrary to some studies, but consistent with others, those under stress performed normally on all executive tasks. Stress related emotions, such as anxiety and fear, can impair decision-making through release of stress hormones with receptors in the orbitofrontal cortex and amygdala (Roozendaal, McReynolds, & McGaugh, 2004; Sapolsky, 1992). There were several strengths and limitations associated with this study. First, the social stressor was an improvement from the general TSST, in that the focus was on cognitive abilities rather than an extraneous topic. Additionally, the authors did not thoroughly address why differences may not have occurred with executive functioning tasks, such as the WCST.

Working memory is the ability to focus attention and complete required operations on a specific task while inhibiting irrelevant information (Kane & Engle, 2002), and research has demonstrated that it can be negatively impacted by stress. Beilock and Carr (2005) examined the link between "choking under pressure" in solving arithmetic problems and individual differences in working memory. Participants performed math problems under both low-pressure and high-pressure conditions, and the problems were either high or low in working memory demands. The low-pressure test was explained as more of a practice test, whereas the high-pressure test contained scenarios involving real world pressure like monetary incentives, peer pressure, and

social evaluation. For data analysis, participants were divided into either a low working memory group or high working memory group using a median split of their average scores on both working memory tests. Poorer performance only occurred with problems of highest working memory demand. Surprisingly, only participants high in working memory capacity displayed decrements. However, those lower in working memory capacity did more poorly on the high-demand problems without any pressure, although when pressure scenarios were added, this group was not disadvantaged because their performance did not decline under pressure. Although this study did not evaluate cortisol levels, it nonetheless contributes to the literature examining the differential effects of various stress levels, or in this case working memory loads, on executive functioning. Future research could incorporate this experimental model with physiological indicators like glucocorticoids.

Visuospatial Ability

Research generally supports that visuospatial ability is not as heavily influenced by stress and elevated cortisol levels, in comparison to other cognitive domains. This is due to glucocorticoids impacting declarative and executive functioning tasks more heavily than procedural tasks, as relatively fewer glucocorticoids are located in posterior brain regions (McEwen & Sapolsky, 1995). Spatial rotation measures, such as the *Primary Mental Abilities-Spatial Relations (PMA-SR*; Thurstone & Thurstone, 1962*),* are commonly used as "control" tasks when investigating the effects of stress on cognition. Several studies have found that unlike other neuropsychological domains, spatial rotation measures were not influenced by altered stress or cortisol levels (e.g., Driscoll, Hamilton, Yeo, Brooks, & Sutherland, 2005; McCormick et al., 2007; McCormick & Teillon,

2001). There have been few exceptions to this finding and many contradictory studies have employed poor methodology. For example, McCormick and Teillon (2001) studied gender differences on the PMA-SR, with respect to variations in female cortisol levels over the course of menstrual cycles. Although the authors demonstrated a large effect of gender and menstrual cycle on the PMA, these findings did not relate to differences in cortisol levels, as female cortisol levels were generally consistent across cycles. The authors reported that past research finding spatial ability differences across menstrual cycles may have stemmed from inconsistent visuospatial measures employed, and performance may be unrelated to differing cortisol levels.

Current Study

The current study sought to clarify the link between cortisol levels and self-reported state anxiety as predictors of neuropsychological performance. Research has investigated the effects of both basal cortisol levels and reactivity to stressors fairly extensively. However, there is a paucity of literature that has examined the impact of state anxiety and cortisol levels on a broad range of neuropsychological measures. The majority of studies have tended to use social stressors unrelated to the cognitive tasks themselves. These studies generally demonstrate that cortisol levels peak as the social stressor nears in time, which could unevenly influence cognitive performance. In addition, the literature is mixed in terms of the effects of state anxiety on specific cognitive domains, such as executive functioning. Thus, the current study aimed to elucidate the associations between state anxiety measures, cortisol levels, and neuropsychological performance, using a stress-induction procedure relating to actual test performance.

CHAPTER III

METHODS

Participants

Due to cortisol variability during the menstrual cycle (Kirschbaum et al., 1993, 1999), women were excluded from the study in order to reduce potential confounding variables. Participants were screened for extraneous factors that have been found to alter cortisol levels, which are discussed below. Six participants were excluded from analyses, as they either acknowledged deviation from the instruction protocol (n = 1), were experiencing abnormally high stressors prior to the study (n = 2), did not meet eligibility criteria (n = 2), or had a cortisol measurement suggesting measurement error (> 3SD above the mean). The final sample consisted of 58 male, college students recruited through a mid-sized Midwestern University. Participants were randomly assigned to a stress induction condition (n = 31) or a control condition (n = 27). Ages ranged from 18 to 39, with an average age of 20.49 (SD = 3.44) and an average education of 14.02 (SD = 1.15). Ninety-two percent (n = 54) of the sample was Caucasian, 3% (n = 2) African-American, 3% (n = 2) Asian, and the remaining 2% indicated "other".

Procedure

Participants were randomly assigned in a between group design to either a control (no stress induction) or experimental (stress induction) condition. After signing up, individuals were instructed they were to refrain from the following activities for the two hours prior to testing: ingesting a large meal, chewing gum, brushing teeth, exercising, smoking, or drinking punch, lemonade, or caffeinated beverages.

Participants were screened for eligibility at the onset of the experimental session. Those who had not followed the aforementioned protocol were excluded from participation. Participants reporting a significant past or present psychiatric illness were deemed ineligible, since mood disorders can alter cortisol levels (Holsboer, 2000; Young, Abelson, & Cameron, 2004). Exclusionary criteria also included participants taking anabolic steroids, prescription medications, supplements known to alter cortisol levels (e.g., hydrocortisone creams, DHEA supplements, use of inhalers), those experiencing abnormally high levels of life stress, and individuals who were physically unhealthy at testing time. Lastly, due to cortisol levels being elevated and more variable in the morning (Susman, Dorn, Inoff-Germain, & Chrousaos, 1997), scheduling of participants occurred in the afternoon hours between 12:00 and 5:00 p.m.

Testing was completed in one session lasting 90 minutes. A baseline saliva sample was initially collected and participants completed the *State-Trait Anxiety Inventory* (*STAI*; Spielberger, Gorsuch & Lushene, 1972) state portion as a baseline measure of self-report anxiety. A background demographic questionnaire was also completed before receiving either a stress-inducing or a neutral oral script describing the study. Participants were read the following script in the experimental condition:

> Time efficiency is important during neuropsychological evaluations to decrease patient fatigue and such, and the current study is testing a new method for increasing time efficiency. Your performance will dictate which sets of tests will be administered. The tests are constructed so that you will receive fewer problems if you are performing well in order to stream-line the evaluation process; however, if you have difficulty you will receive additional problems to

identify specific deficits. Since I can't score the tests as I am administering them, there will be a Ph.D. level neuropsychologist and two graduate level clinical psychology students behind this one-way mirror who will be scoring the tests and evaluating your performance as we go along. Towards the end of the session, they will tell me how you have been performing, which will determine whether you receive more tests. Before we begin, I have to now leave and bring the neuropsychologist and graduate students to the room next door, so they can observe your performance. We wanted to wait so they won't have any judgmental biases of you as an individual, which could affect their scoring.

The control condition received the following neutral instructions used in Nagra, Skeel, and Penix-Sbraga (2007):

This study involves performing several tasks, such as solving some math problems, examining some pictures, repeating some digits and doing some motor tasks. We are testing some new tests to see how well they work. Therefore we are not concerned about your performance; so do not worry about whether you are doing well or not. Just relax, try to do your best and follow the instructions provided to you.

Following the experimental script, the examiner exited the room to escort the fictitious judges behind the one-way mirror and returned after a few minutes to begin the neuropsychological battery. The first portion of the neuropsychological battery protocol order was as follows: Letter-Number Sequencing; Mental Rotations Test (MRT); STAI-State #2 and saliva sample #2 (approximately 20-minutes following time #1 collection), California Verbal Learning Test - Second Edition (CVLT-II) (trials 1-5, list B, recall);

and the Paced Auditory Serial Addition Task (PASAT). The second sample was gathered approximately 20-minutes following the baseline due to peak cortisol levels generally occurring 20-40 minutes following onset of acute stressors in healthy individuals (Dickerson & Kemeny, 2004).

Following the PASAT, examiners informed participants in the experimental condition they were to now consult with the judges next door regarding their performance, to determine whether more tests would be administered. The examiner then left the room for a few minutes and returned saying, "Your test scores indicate you had difficulty on the tasks, so we are going to administer more tests to identify specific deficits." In the control condition, following the PASAT, examiners informed participants they just realized a test that was to be later administered had been left in another room. This fictitious story was created to retain time consistency between conditions, and the examiner left the room for a few minutes and returned telling the participant the missing materials were obtained.

Participants in both conditions then received identical instructions and procedures for the remainder of the study. The following tests were subsequently administered: CVLT-II recall and recognition, D-KEFS Color Word Interference, Trails A and B, and STAI state #3 and saliva sample #3 (approximately 60-minutes following time #2 stress collection). Next, a debriefing questionnaire was administered, measuring on a scale from 1-10, the extent to which participants believed the explained purpose of the study. Participants were then verbally questioned what they believed the study was evaluating. They were then debriefed regarding the true nature of the study and the rationale for the

use of deception, and were given a list of psychological services in the event they felt distressed. Finally, the STAI-Trait measure was administered.

Materials

Cortisol Assay

Salivary cortisol is considered a reliable and valid measure of unbound or free cortisol levels in plasma. Although resting cortisol provides a general index of HPA activation, changes to cortisol production from stressors may be a more accurate measurement of stress reactivity (O'Leary et al., 2007). Swabs and salivettes were purchased through Salimetrics and samples were stored in a lab freezer. Samples were mailed to Salimetrics Corporation located in University Park, PA, where they were assayed for salivary cortisol using a highly sensitive enzyme immunoassay. Duplicate assays were conducted for reliability and results contain the averaged values. The intra- and interassay coefficients of variance were less than 10% and 15%, respectively.

California Verbal Learning Test - Second Edition (CVLT-II; Delis et al. 2000)

The CVLT is typically used to assess immediate and delayed verbal memory. It measures recall and recognition of lists containing related words across several trials. Standardized scores include memory for a word list repeated over five trials, learning slope over the five trials, memory for an interference list, immediate and long-delayed free and cued recall, along with recognition of words from the original list. Test-retest performance has been found to range between .80-.84 (Woods et al., 2006).

Color-Word Interference Test from the Delis-Kaplan Executive Function System (Delis et al. 2001; D-KEFS)

The Color-Word Interference Test assesses cognitive flexibility by requiring the inhibition of reading words denoting colors, while naming the color of ink the word is printed in. It measures components of executive functioning, such as attention, flexibility, and inhibition. The Color-Word Interference Test also demonstrates adequate reliability (.62 to .86), considering executive functioning can be impacted by a variety of factors (Delis et al., 2001).

Debriefing Questionnaire

All participants were administered a debriefing questionnaire measuring on a scale from 1-10 (1=Not at all, 10=Very much), the extent to which they believed the explained purpose of the study.

Letter-Number Sequencing from the WAIS-IV (Wechsler, 2008)

Letter-Number Sequencing is a measure of working memory. It requires individuals to repeat a list of numbers and letters by first placing the numbers in numerical order and then the letters in alphabetical order. It demonstrates good reliability with an average split-half of .82 and average test-retest reliability of .74.

Mental Rotations Test (MRT-A; Peters et al., 1995.

This is a spatial rotation task and the object is to select two matrix figures among a series of four options, which reflect a rotated target figure. The test is divided into two timed portions of three minutes each, and the two test portions contain 12 questions. For every item, a large "X" is to be drawn through two figures reflecting a rotated target. The

MRT-A has adequate internal consistency (Peters et al, 1995). Norms from Peters et al. (1995) were used in the current study for determining z-score calculations.

Paced Auditory Serial Addition Task (PASAT; Gronwall & Sampson, 1974)

The PASAT is a measure of sustained and divided attention, working memory, and speed of information processing. The current study employed the "PASAT-200," a 200 item version adapted by Levin, Benton, and Grossman (1982). This modification uses four series of 50 digits (numbers 1 to 9) that are presented in random order to the participant via an audiotape. The numbers are presented at an increasing speed (2.4, 2.0, 1.6, and 1.2 seconds per digit), and the participant is instructed to add the first number to the second, verbalize it aloud, then add the second number to the third, and so on until the conclusion of the test. Test-retest reliability ranges from .93 to .97 (McCaffrey et al., 1995). Norms from Wiens, Fuller, and Crossen (1997) were used to determine z-scores in the current study.

State-Trait Anxiety Inventory (*STAI; Spielberger, Gorsuch & Lushene, 1972)*

The STAI includes separate self-report scales for measuring state and trait anxiety. The S-anxiety scale (STAI Form Y-1) consists of twenty statements that evaluate how the respondent feels "*right now*, at this moment." The T-anxiety scale (STAI Form Y-2) includes twenty statements that assess how one "*generally* feels." The S-anxiety scale is a sensitive indicator of changes in transitory states of anxiety experienced by individuals. The test-retest reliability of the T-anxiety scale ranged from .73 to .86, with a median reliability coefficient of .77.

Trail Making Test (Reitan & Wolfson, 1985)

The Trail Making Test consists of Part A, in which the participant is asked to draw lines connecting consecutively numbered circles. Part B consists of connecting the same number of consecutively numbered and lettered circles while alternating between the two sequences (Lezak, 1995). This measure assesses focused attention, motor speed, and complex visual scanning (Lezak, 1995; Spreen & Strauss, 1998). Goldstein and Watson (1989) reported test-retest reliabilities ranging from .69 to .94 for Part A and from .66 to .86 for Part B.

Statistical Analyses

In comparing the cognitive tests, raw scores were converted to standard scores for the Letter-Number Sequencing subtest and D-KEFS Color-Word Interference test. Z-scores were computed for the Mental Rotations Test and the total of the PASAT. Raw scores were compared for the PASAT trials 1 through 4. T-scores were used for the CVLT-II. Group differences in STAI self-report and cortisol secretion were tested with ANOVA. Correlations between STAI self-report and cortisol levels were examined. ANOVA was used to test relationships between neuropsychological performance and state anxiety, through self-report measures and cortisol activity. In past studies examining repeated measures salivary cortisol, there is no methodological consensus of data summary metric (Lee et al., 2007). Also, literature demonstrates inter-individual differences in cortisol reactivity to given stressors can lead to response pattern variability (Smyth et al., 1997). Thus, post hoc median splits were employed separating participants in each condition with high and low cortisol reactivity between collections 1 and 2.

CHAPTER IV

RESULTS

State Anxiety Self-Report Measures

Descriptive statistics are displayed in Table 1.

Table 1. State and Trait Self-Report Descriptive Statistics

Measures	Control Condition *Mean* (*SD*)	Experimental Condition *Mean* (*SD*)
State Self-Report Time 1	30.33 (7.07)	30.55 (6.15)
State Self-Report Time 2	33.07 (9.12)	37.65 (8.11)
State Self-Report Time 3	35.89 (10.52)	39.23 (11.48)
Trait Self-Report	33.70 (7.87)	35.58 (8.88)

Note. Control $n = 27$, Experimental $n = 31$

Over time the experimental condition generally endorsed higher self-report anxiety levels compared to controls. Split-plot ANOVA revealed a STAI-State x condition interaction, as the experimental condition displayed greater self-report anxiety over the three time gatherings, $F(2, 112) = 3.22$, $p = .04$, $\eta^2 = .054$. There was not a between group main effect of self-report anxiety across the three STAI-State gatherings, $F(1, 56) = 1.85$, $p = .18$, $\eta^2 = .032$. Repeated measures within subjects revealed STAI-State generally increased over time, $F(2, 112) = 29.27$, $p = .00$, $\eta^2 = .34$. The experimental condition (*Mean* = 37.65, *SD* = 8.11) reported higher self-report anxiety after the stress induction procedure at time 2 compared to controls (*Mean* = 33.07, *SD* = 9.12), $F(1, 56) = 4.79$, $p = .03$, $\eta^2 = .079$. There were no time 3 STAI-State or Trait differences between conditions. In addition, there were no differences in the debriefing questionnaire (scale of 1-10) between the control (*Mean* = 7.26, *SD* = 2.01) and experimental (*Mean* = 6.97, *SD* = 1.87) groups, in which participants rated 1 being "not

at all" and 10 being "very much," the extent that they believed the explained purpose of the study; $F(1, 56) = .33$, $p = .57$, $\eta^2 = .01$.

Cortisol Levels between Conditions

Between time 1 and time 2, mean cortisol levels in the control condition decreased from .20 ± .04 (SE) μg/dL to .18 ± .13 (SE) μg/dL and rose in the experimental condition from .17 ± .03 (SE) μg/dL to .23 ± .18 (SE) μg/dL (See Table 2). However, there were no interactions between conditions across the three cortisol samples, $F(2, 94) = 2.42$, $p = .10$. There were also no main effects of cortisol over time, $F(1, 47) = .27$, $p = .61$. Between groups, post-hoc tests showed similar baseline cortisol levels at time 1. However, post-hoc tests revealed that in comparison to baseline measures, cortisol reactivity at time 2 was greater in the experimental condition compared to controls, $F(1, 48) = 4.59$, $p = .04$, $\eta^2 = .087$. There were no other cortisol differences between groups, either in each time sampling or in reactivity between collections. Means are displayed in Table 2.

Table 2. Cortisol Assay (μg/dL) Descriptive Statistics

Measures	Control Condition *Mean* (*SD*)	Experimental Condition *Mean* (*SD*)
Cortisol Time 1	.20 (.17)	.17 (.14)
Cortisol Time 2*	.18 (.13)*	.23 (.18)*
Cortisol Time 3	.16 (.12)	.19 (.13)
Time 2-1 Difference	-.02 (.13)	.07 (.15)
Time 3-2 Difference	-.02 (.13)	-.04 (.16)
Time 3-1 Difference	-.05 (.18)	.02 (.19)

Note. Control Group: Time 1 ($n = 22$), Time 2 ($n = 25$), Time 3 ($n = 23$); Experimental Group: Time 1 ($n = 29$), Time 2 ($n = 29$), Time 3 ($n = 31$). * = significant at the .05 level

Self-Report Anxiety and Cortisol Correlations

As shown in Table 3, correlations between the self-report anxiety measures revealed strong relationships between all self-report anxiety measures across time, and state anxiety was highly related to trait anxiety. Cortisol itself was not related to state anxiety across time, although cortisol levels at time 1 and 2, along with time 2 and 3 were highly related.

Table 3. Correlations between Self-Report Anxiety and Cortisol Assays

	Trait	STAI #1	STAI #2	STAI #3	Cortisol #1	Cortisol #2
STAI #1	.61*					
STAI #2	.42*	.65*				
STAI #3	.49*	.72*	.75*			
Cortisol #1	-.06	.11	.04	.09		
Cortisol #2	.08	.23	.20	.19	.55**	
Cortisol #3	-.10	-.02	-.03	-.07	.10	.50**

Note. STAI #1 = State-Trait Anxiety Inventory Time #1 (N = 58), STAI #2 = State-Trait Anxiety Inventory Time #2 (N = 58), STAI #3 = State-Trait Anxiety Inventory Time #3 (N = 58), Trait = STAI Trait (N = 58), Cortisol #1 = Cortisol Assay (μg/dL) Time #1 (N = 51), Cortisol #2 = Cortisol Assay (μg/dL) Time #2 (N = 54), Cortisol #3 = Cortisol Assay (μg/dL)Time #3 (N = 54), * = significant at the .05 level, ** = significant at the .01 level.

Neuropsychological Performance between Conditions

Overall, hypotheses were partially supported, as individuals in the stress induction condition performed more poorly on a number of executive functioning and memory measures compared to controls (Table 4).

Table 4. Neuropsychological Battery Descriptive Statistics

	Condition				
	Control Mean(SD)	Experimental Mean(SD)	*F*	*p*	η^2
Letter-Number Sequencing	00 (.66)	-.47 (.65)	7.55	**.01**	.119
MRT	-.67 (.83)	-.74 (1.04)	.07	.80	.001
PASAT					
Trial 1	-.39 (1.32)	-.95 (1.70)	1.89	.17	.033
Trial 2	-.02 (.81)	-.25 (1.12)	.77	.38	.014
Trial 3	.13 (.94)	-.48 (1.18)	4.59	**.04**	.076
Trial 4	.47 (1.21)	-.17 (1.14)	4.31	**.04**	.071
total	.99 (.79)	.55 (1.03)	3.28	.08	.055
CW Trial 1	.27 (.70)	.06 (.65)	1.35	.25	.024
CW Trial 2	.53 (.70)	.46 (.63)	.15	.70	.003
CW Trial 3	.49 (.55)	.33 (.87)	.68	.41	.012
Trails A	.27 (.95)	.14 (1.72)	.13	.72	.002
Trails B	.21 (.67)	-.22 (1.29)	2.47	.12	.042
CVLT					
Trials 1-5	.60 (.78)	.05 (.11)	4.64	**.04**	.077
Trial B	-.22 (.84)	-.47 (.10)	1.01	.32	.018
Short Delay Free Recall	.15 (1.16)	-.11 (1.30)	.65	.43	.011
Short Delay Cued Recall	.15 (.91)	-.47 (1.32)	4.18	**.05**	.069
Long Delay Free Recall	.20 (.96)	-.53 (1.38)	5.40	**.02**	.088
Long Delay Cued Recall	.02 (.88)	-.63 (1.35)	4.54	**.04**	.075
Total Learning Slope: Trials 1-5	-.17 (.78)	-.16 (.88)	.00	.98	.000
Long vs. Short Delay Free Recall	.06 (.70)	-.42 (1.02)	4.17	**.05**	.069
Delayed Yes/No Recog. Hits	-.06 (1.07)	-.51 (1.45)	1.84	.18	.032
Yes/No False Positives	-.06 (.51)	.39 (1.00)	4.28	**.04**	.071
Yes/No Total Recog. (d')	.22 (.90)	-.24 (1.20)	2.72	.11	.046

Note. Control *n* = 27, Experimental *n* = 31, Means = z-scores, Yes/No Total Recog. (d') = Total Recognition Discriminability (d') (Hits vs. Total False Positives), CW=D-KEFS Color Word Interference Test.

It was hypothesized that score discrepancies between conditions would be most evident on cognitively demanding tasks tapping into executive functioning and memory. Results indicated the experimental group performed significantly worse than controls on the Letter-Number Sequencing test. Although groups did not differ on the first two trials of the PASAT, the experimental group had significantly lower scores on the more

challenging third and fourth PASAT trials. Also, Trails B approached significance between conditions. As predicted, performance on the MRT, a spatial rotation control task, was generally unaffected by the stress induction.

Overall on the CVLT-2, individuals receiving the stress inducing instructions demonstrated weaker memory performance compared to controls. In sum, the experimental condition freely recalled significantly fewer words over the five trials of word list repetition. Although there were no differences in short delay free recall, the experimental condition recalled fewer words when given semantic cues for categorization. Long delay free recall of the repeated word list was significantly poorer among the experimental condition. Compared to controls, experimental participants also did not benefit from semantic cues during free recall.

Neuropsychological Performance and Self-Report Anxiety

Pearson product moment correlations using the combined groups were used to evaluate the relationship between neuropsychological performance and self-report anxiety (Table 5).

Table 5. Correlations between STAI-State and Neuropsychological Measures

Measures	Time 1 STAI	Time 2 STAI	Time 3 STAI
Letter-Number	-.11	-.29*	-.29*
MRT	-.05	-.23	-.10
PASAT			
Trial 1	-.09	-.08	-.18
Trial 2	.05	-.04	-.07
Trial 3	-.03	-.14	-.11
Trial 4	-.06	-.13	-.17
total	-.03	-.11	-.15
CW Trial 1	-.25	-.15	-.31*
CW Trial 2	-.25	-.17	-.19
CW Trial 3	-.02	-.13	-.17
Trails A	.13	-.07	.02
Trails B	.21	-.20	-.01
CVLT			
Trials 1-5	-.10	-.18	-.11
Trial B	-.10	-.18	-.14
Short Delay Free Recall	-.27*	-.30*	-.25
Short Delay Cued Recall	.00	-.14	-.12
Long Delay Free Recall	-.03	-.16	-.19
Long Delay Cued Recall	-.02	-.10	-.12
Total Learning Slope: Trials 1-5	-.23	-.26*	-.24
Long vs. Short Delay Free Recall	.34**	.18	.08
Delayed Yes/No Recog. Hits	-.16	-.16	-.24
Yes/No False Positives	-.13	.03	.02
Yes/No Total Recog. (d')	-.02	-.07	-.12

Note. MRT=Mental Rotation Test, PASAT=Paced Auditory Serial Addition Test. Yes/No Total Recog. (d') = Total Recognition Discriminability (d') (Hits vs. Total False Positives), *$p < .05$, **$p < .01$

Time 2 (r = -.29, $p < .05$) and 3 (r = -.29, $p < .05$) STAI-State ratings were negatively related to on the Letter-Number Sequencing test performance. Elevated time 3 self-report anxiety ratings were related to slower naming of colors during Trial 1 of the Color-Word Interference test (r = -.31, $p < .05$). Elevated time 1 (r = -.27, $p < .05$) and 2 (r = -.31, $p < .05$) STAI-State was negatively related to CVLT-2 short delay free call.

Those endorsing higher self-report anxiety levels at time 2 learned more slowly over the course of trials 1 through 5 during the CVLT-2 (r = -.26, p < .05).

Controlling for trait anxiety, correlation patterns between STAI-Anxiety and performance were largely similar and became stronger in many respects. The D-KEFS Color-Word Interference Trial 3 (inhibition) was negatively related to state anxiety at Time 1 (r = -.28, p < .05), Time 2 (r = -.27, p < .05), and Time 3 (r = -.35, p < .05). Word reading speed during Color-Word Trial 1 was negatively related to state anxiety at Time 1 (r = -.28, p < .05) and Time 3 (r = -.33, p < .05). Partialling out trait anxiety, Trails B speed was negatively associated with anxiety at Time 2 (r = -.37, p < .05). Time 2 and 3 Letter-Number Sequencing and STAI-Anxiety relationships continued to be significant (r = -.26, p < .05). Time 2 STAI-Anxiety was inversely related to CVLT-II learning slope through trials 1 through 5 (r = -.23, p < .05), as well as short delay free recall performance (r =-.27, p < .05). Time 3 STAI-Anxiety was negatively associated with CVLT-II long delay free recall (r = -.23, p < .05). Inverse relationships between PASAT performance and anxiety increased when controlling for trait anxiety. PASAT trial 3 was negatively related STAI-Anxiety time 2 (r = -.20, p < .05) and 3 (r = -.18, p < .05). PASAT trial 4 and state anxiety ratings were also stronger at Time 2 (r = -.18, p < .05) and Time 3 (r = -.23, p < .05). Total PASAT performance was subsequently stronger with STAI-Anxiety at Time 2 (r = -.17, p < .05) and Time 3 (r = -.23, p < .05). Controlling for trait anxiety, MRT performance was negatively associated with Time 2 (r = -.34, p < .05) and Time 3 (r = -.21, p < .05) STAI-State.

Correlations using the combined groups were also examined between the STAI-State over time and neuropsychological performance. Results were largely similar with a

few exceptions. Increases in self-report anxiety between time 1 and 2 were significantly related to poor performance on Trails B (r = -.47, p < .05).

Neuropsychological Performance Predicted by Cortisol Levels

There was generally little relationship between the executive functioning measures and cortisol levels (Table 6). There was a positive relationship between time 2 cortisol and number of errors on the third Stroop trial of the Color-Word Interference test (r = .28, p < .05).

Time 1 baseline cortisol elevations were generally associated with improved memory performance (Table 6).

Table 6. Correlations between Cortisol and Neuropsychological Measures

Measures	Time 1 Cortisol	Time 2 Cortisol	Time 3 Cortisol
Letter-Number	.28*	.07	-.04
MRT	-.11	-.16	-.07
PASAT			
Trial 1	.03	-.10	-.05
Trial 2	.10	-.06	-.07
Trial 3	.07	-.08	-.10
Trial 4	.09	-.12	.01
total	.08	-.10	-.06
CW Trial 1	.13	-.08	.12
CW Trial 2	.14	-.06	.10
CW Trial 3	-.09	-.16	.08
Trails A	.10	.06	-.03
Trails B	.06	.08	.17
CVLT-II			
Trials 1-5	.26	.07	.03
Trial B	-.01	.14	-.01
Short Delay Free Recall	.16	.01	.18
Short Delay Cued Recall	.16	.00	.02
Long Delay Free Recall	.15	.03	.12
Long Delay Cued Recall	.17	.01	.09
Total Learning Slope: Trials 1-5	.34*	.05	.08
Long vs. Short Delay Free Recall	.00	.04	-.09
Total Intrusions	-.17	-.17	-.30*
Delayed Yes/No Recog. Hits	.02	.08	.26
Yes/No False Positives	-.39**	-.29*	-.22
Yes/No Total Recog. (d')	.29*	.26	.31*

Note. Note. Time 1 (n = 51), Time 2 (n = 54), Time 3 (n = 54). MRT=Mental Rotation Test, PASAT=Paced Auditory Serial Addition Test, CW=Color Word ; Yes/No Total Recog. (d') = Total Recognition Discriminability (d') (Hits vs. Total False Positives), *p < .05, **p < .01.

Higher baseline cortisol magnitudes were associated with improved learning, reflected through total learning slope over CVLT-2 trials 1-5 (r = -.34, p < .05), along with improved ability to discriminate between words that were and were not on the list during a recognition format (r = .29, p < .05). Time 1 cortisol and number of words

freely recalled on trials one through five were positively related and approached significance (r = .26, p = .06). Individuals with higher time 3 cortisol levels were more likely to make intrusions, or name words not from the original word list, during free and cued recall (r = -.30, p < .05).

Analyses were also run between performance and cortisol difference scores across time. Results were largely similar with a few exceptions. Increases in saliva reactivity between the baseline and time 3 measurement were associated with poorer performance on the Letter-Number Sequencing test (r = -.31, p < 05). Cortisol elevation between baseline and time 2 was associated with slower reading time on the second trial of the Color-Word Interference test (r = -.28, p < .05).

Additional CVLT-2 correlation analyses using cortisol difference scores revealed similar results, except cortisol reactivity between time 1 and 2 was related to poorer total learning slopes across the trials (r = -.31, p < .05).

Additional Analyses

Additional analyses were conducted using STAI-State and cortisol difference scores between time gatherings, as previously mentioned. Individuals were also collectively compared, separating those displaying elevated versus decreased cortisol over time. These analyses revealed results similar to those previously discussed. Correlational analyses between the anxiety and neuropsychological measures were also conducted within each of the control and experimental conditions. Results which differ from the combined groups correlations will be discussed.

Within the experimental condition, STAI-State and cortisol time 1were highly correlated (r = .43, p < .05). In the control condition, as shown through difference scores,

elevations between cortisol time 1 and 2 were related to elevated STAI-State time 2 (r = .47, p < .05), and approached significance in positively relating to STAI-State time 3 (r = .40, p = .06). Also, in the control condition, elevated baseline STAI-State was associated with decreased cortisol between times 1 and 3 cortisol (r = -.36, p = .06).

Regarding correlations between anxiety and neuropsychological performance within each condition, in the experimental condition, time 2 cortisol (r = .37, p < .05) was positively related to List B recall, although cortisol decreases between times 2 and 3 (r = -.41, p < .05) were related to poorer performance on List B. This may be consistent with initial elevated cortisol levels typically decreasing over time. Elevated time 3 cortisol was related to more intrusions (r = -.38, p < .05) of non-list words during both free and cued recall over the test. However, in the control condition, elevated cortisol time 1 was associated with improved learning slope over the five trials (r = .48, p < .05).

In the experimental condition, STAI-State baseline elevations were related to better performance on Trails B (r = .37, p < .05), although after controlling for STAI baseline time 1, STAI-State time 2 was negatively related to Trails B performance (r = -.52, p < .05). In the control condition, STAI-State elevations between times 1 and 3 were negatively related to Color-Word Interference test performance on color naming trial 1 (r = -.41, p < .05), along with Stroop trial 3 (r = -.52, p < .05). Speed to complete Trails A was negatively related to increased self-report anxiety between times 1 and 3 (r = -.43, p < .05).

CHAPTER IV

DISCUSSION

The current study demonstrated that self-report anxiety and cortisol assayed from saliva samples independently impacted memory and executive functioning performance. Although there were no relationships between self-report anxiety and cortisol over the course of three time gatherings, both self-reported anxiety and cortisol levels were associated with cognitive performance. Paradoxically, initial baseline cortisol elevations were generally associated with improved memory performance over time; however, following the stress induction procedure, higher magnitudes of self-report anxiety were associated with poorer executive functioning and reduced memory performance.

Baseline levels of cortisol were highly predictive of cognitive performance across conditions. Contrary to hypotheses, baseline cortisol elevations appeared to have a facilitating effect on neuropsychological performance. Higher cortisol baseline levels were associated with greater number of words freely recalled over trials 1-5 and a steeper learning slope. Initial cortisol elevations also facilitated discrimination between words that were previously presented during a recognition format. Although literature has demonstrated that emotion often affects memory in an inverted-U-shaped manner, incidental effects of stress are more complex with memory (Preston, Buchanan, Stansfield, & Bechara, 2007). For example, glucocorticoid injections immediately following memory post-training have been found to improve memory consolidation (Roozendaal, 2002). Albeit uncommon, but in line with current findings, cortisol elevations have been shown to at times enhance declarative memory (Domes et al., 2002; Zorawski et al., 2005) and memory formation (Shors, Weiss, & Thompson, 1992). More

recent studies have shown U-shaped relationships between cortisol and memory, with moderate cortisol levels having facilitating effects on memory, and extreme low and high magnitudes being associated with suboptimal performance (Andreano & Cahill, 2006). Despite some research demonstrating a link between prolonged HPA activation and deterioration of hippocampal neurons (Joëls & de Kloet, 1992), in the current study cortisol elevations may have been too brief to lead to neuronal deterioration. It is also possible that individuals with initial cortisol elevations were more invested in the tasks and motivation may have enhanced attention and consequential memory. Physiological arousal during learning may have improved memory consolidation, which has been demonstrated with emotional stimuli in humans (Buchanan & Lovallo, 2001).

In line with hypotheses of self-report anxiety, the stress induction appeared to be successful, as participants in the experimental condition endorsed higher levels of state anxiety compared to controls over time. Those receiving the stress inducing instructions performed worse on more cognitively demanding executive functioning and memory tasks, which is consistent with previous research (e.g., Kirschbaum et al., 1996; Lee et al., 2007; Lupien et al., 1997; Lupien, Gillin, & Hauger, 1999; McCormick et al., 2007). Differences between groups were especially pronounced on the Letter-Number Sequencing test, as this cognitive test reflects working memory and immediately followed the initial stress induction. Although there was little difference on the first two PASAT trials, controls displayed higher scores on the more challenging third and fourth trials. There was a small effect between conditions during Trails B, as the stress condition performed more poorly. Also, aligning with predictions, there were no differences in spatial rotation task performance between groups, which is typically

demonstrated (Driscoll et al., 2005; McCormick et al., 2007). Despite the lack of evidence that cortisol magnitudes may specifically be associated with cognitive interference, as prefrontal cortex regions contain a large number of glucocorticoid receptors (McAllister-Williams & Rugg, 2002), self-report anxiety appears to nonetheless disrupt working memory abilities.

In support of hypotheses, regardless of experimental groups, self-report anxiety was predictive of cognitive performance, with the overall tendency for negative relationships to appear between elevated anxiety ratings and cognitive performance. Few studies have investigated the effects of both self-report anxiety and cortisol on neuropsychological performance. STAI-State discriminated between experimental conditions over time, as participants in the experimental group endorsed higher stress levels. In general, higher self-report anxiety was associated with worse Letter-Numbering Sequencing performance, poorer short delay memory free recall, and slower learning over the list memory repetition. State anxiety likely disrupted attention and working-memory processes, particularly with the more cognitively demanding tasks.

Controls also generally performed better on the memory trials of the CVLT-2, in which they learned more words over the five repetition trials. A wide variety of literature commonly supports memory disruption with elevated stress (Kirschbaum et al., 1996; Lupien et al., 1997). Consistent with hypotheses, the experimental group displayed worse long delay memory than controls during the free and cued recall portions. In addition, the experimental condition retained fewer words during the long delay when compared to their short delay performance. This variation between memory in the short versus long-term could be in part due to the second stress induction procedure occurring

immediately before the long-delay recall trial. At that time, the experimental group was informed that they had been performing poorly and would receive additional tests. Despite the disconnect between the cortisol and self-report anxiety ratings, state psychological stress appeared to have a negative effect on cognition.

The stress induction appeared to have weak effects on physiological cortisol reactivity, as there was little difference between groups. This cortisol inconsistency in reactivity appears to be common in the literature. Psychological stressors differ in cortisol release, particularly since there is a great deal of individual variability (Het, Ramlow, & Wolf, 2005). The current study attempted to control for extraneous factors known to influence cortisol levels, as the study took place during afternoon hours and excluded women and participants that a few hours prior to the study ate a heavy meal, engaged in strenuous exercise, drank caffeine, and such. Past studies have employed fairly lenient guidelines for participant inclusion, since many have used both males and females, and did not control for menstrual cycle or medications known to alter cortisol levels. Thus, it is possible the lack of control in past studies may in part explain varying strength in cortisol reactivity. In addition, the current study may not have employed a stress induction that was sufficiently anxiety-provoking. Past studies have attributed weak relationships between cortisol and cognitive performance to insufficient stress inductions (e.g., Domes et al., 2002). If this was the case in the current study, then one would assume that self-report anxiety ratings would be similar between conditions and differences in cognitive performance would not be evident between groups. However, the stress induction did indeed evince an effect between conditions, as the experimental

group displayed higher self-report anxiety over time, and performed more poorly than controls on cognitively demanding tasks.

The results of this study support that state anxiety may interfere with attentional and cognitive processes apart from physiological cortisol magnitudes. Despite literature supporting the effects of acute stressors in prompting cortisol reactivity, the action of cortisol on neural processes is delayed and peak levels are generally observed 20-40 minutes following the onset of a stressor (Dickerson & Kemeny, 2004). Albeit unexpected, the initial cortisol magnitudes may have lingered and facilitated neural processes, separate from the self-report measures. These findings continue to reflect the complicated relationship between cortisol, self-report anxiety, and neuropsychological performance. There were several weaknesses in the current study. Only three cortisol and STAI-State measures were gathered during the experiment, and future research should obtain more frequent measurements over time. Exact cortisol activity was unknown in conjunction with the majority of tests. Also, analyzing cortisol reactivity during each of the memory phases would be beneficial in understanding the possibly facilitative effects during some memory stages. There is limited research on the utility of both self-report and physiological anxiety measures concurrently predicting cognition. Future studies should consider more frequently employing self-report measures in differentiating the effects of state psychological stress from glucocorticoids over time. Elucidating these relationships would have important implications in an applied neuropsychological setting, particularly the utility of state self-report measures in parsing apart the impact of anxiety on cognition.

APPENDICES

APPENDIX A

CONTROL CONDITION CONSENT FORM

CMU
CENTRAL MICHIGAN UNIVERSITY

Adult Consent Form

Study Title: Cortisol, Acute Stress, and Self-Report Measures of Anxiety as Predictors of Neuropsychological Performance

Research Investigators' Names and Departments: Shelley Leininger, Psychology Graduate Student; Reid Skeel, Ph.D., Advisor

Contact information for researcher (and Advisor, if researcher is a student): 136 Sloan Hall, Mt. Pleasant, MI 48859 – (989) 774-6485, e-mail: leini1sl@cmich.edu or reid.skeel@cmich.edu.

Introductory Statement: You are invited to participate in a research study that will be used to investigate new neuropsychological measures. The researcher is available to answer any questions you might have about the study or your participation. This research project is in fulfillment of a Doctoral dissertation project.

What is the purpose of this study? The purpose of this research study is to analyze new neuropsychological measures to see how well they work.

What will I do in this study? You will be administered a variety of new neuropsychological measures, in which you will be asked questions pertaining to memory and concentration. You will also be asked to fill-out some questionnaires and give saliva swab samples, in order to rule out extraneous variables. During this procedure, you will be putting a cotton swab under your tongue and letting it soak with saliva.

How long will it take me to do this? The study will take approximately 90 minutes.

Are there any risks of participating in the study? In the current study, there are no foreseeable risks; however, if you feel distressed at any time, the Central Michigan University Counseling Center is available to help and contact information is provided below. All identifying information will be coded according to a random numbering system.

Central Michigan University Counseling Center (989) 774-3381 www.counsel.cmich.edu

What are the benefits of participating in the study? Participants in the study will receive 3 extra credit points in participating classes. As an alternative to participating in the study, you may also earn 3 extra credit points by reading and summarizing an article provided by the experimenter. You have the right to withdraw from the study at any time.

Will anyone know what I do or say in this study (Confidentiality)? The results of your participation will be confidential and will not be released in an individually identifiable form

without your prior consent unless required by law. Your responses will remain strictly confidential initially. Data will be entered into a database in a non-identifying manner.

Will I receive any compensation for participation? Participants in the study will receive extra credit in participating classes.

Is there a different way for me to receive this compensation or the benefits of this study? As an alternative to participating in the study, you may also earn extra credit by reading and summarizing an article provided by the experimenter.

Who can I contact for information about this study? If you have any questions or concerns at this time, please do not hesitate to ask. If any additional questions or concerns occur please feel free to contact Dr. Reid Skeel (989-774-6485).

You are free to refuse to participate in this research project or to withdraw your consent and discontinue participation in the project at any time without penalty or loss of benefits to which you are otherwise entitled. Your participation will not affect your relationship with the institution(s) involved in this research project.

If you are not satisfied with the manner in which this study is being conducted, you may report (anonymously if you so choose) any complaints to the Institutional Review Board by calling 989-774-6777, or addressing a letter to the Institutional Review Board, 251 Foust Hall Central Michigan University, Mt. Pleasant, MI 48859.

My signature below indicates that all my questions have been answered. I agree to participate in the project as described above.

_____ _____

Signature of Subject Date Signed

A copy of this form has been given to me. _____ Subject's Initials

For the Research Investigator—I have discussed with this subject the procedure(s) described above and the risks involved; I believe he/she understands the contents of the consent document and is competent to give legally effective and informed consent.

_____ _____

Signature of Responsible Investigator Date Signed

PLEASE SIGN BOTH COPIES. KEEP ONE AND RETURN THE OTHER TO THE INVESTIGATOR. THANK YOU

APPENDIX B

EXPERIMENTAL CONDITION CONSENT FORM

CMU
CENTRAL MICHIGAN UNIVERSITY

Adult Consent Form

Study Title: Cortisol, Acute Stress, and Self-Report Measures of Anxiety as Predictors of Neuropsychological Performance

Research Investigators' Names and Departments: Shelley Leininger, Psychology Graduate Student; Reid Skeel, Ph.D., Advisor

Contact information for researcher (and Advisor, if researcher is a student): 136 Sloan Hall, Mt. Pleasant, MI 48859 – (989) 774-6485, e-mail: leini1sl@cmich.edu or reid.skeel@cmich.edu.

Introductory Statement: You are invited to participate in a research study that will be used to investigate neuropsychological measures and procedures. The researcher is available to answer any questions you might have about the study or your participation. This research project is in fulfillment of a Doctoral dissertation project.

What is the purpose of this study? The purpose of this research study is to analyze various neuropsychological measures and procedures.

What will I do in this study? You will be administered a variety of neuropsychological measures, in which you will be asked questions pertaining to memory and concentration. We are interested in methods for increasing administration time efficiency. Thus, a panel of judges will be evaluating your performance behind a one-way mirror, which will dictate which sets of tests will be administered. You will also be asked to fill-out some questionnaires and give saliva swab samples, in order to rule out extraneous variables. During this procedure, you will be putting a cotton swab under your tongue and letting it soak with saliva.

How long will it take me to do this? The study will take approximately 90 minutes.

Are there any risks of participating in the study? In the current study, there are no foreseeable risks; however, if you feel distressed at any time, the Central Michigan University Counseling Center is available to help and contact information is provided below. All identifying information will be coded according to a random numbering system.

Central Michigan University Counseling Center (989) 774-3381 www.counsel.cmich.edu

What are the benefits of participating in the study? Participants in the study will receive 3 extra credit points in participating classes. As an alternative to participating in the study, you may also earn 3 extra credit points by reading and summarizing an article provided by the experimenter. You have the right to withdraw from the study at any time.

Will anyone know what I do or say in this study (Confidentiality)? The results of your participation will be confidential and will not be released in an individually identifiable form without your prior consent unless required by law. Your responses will remain strictly confidential initially. Data will be entered into a database in a non-identifying manner.

Will I receive any compensation for participation? Participants in the study will receive extra credit in participating classes.

Is there a different way for me to receive this compensation or the benefits of this study? As an alternative to participating in the study, you may also earn extra credit by reading and summarizing an article provided by the experimenter.

Who can I contact for information about this study? If you have any questions or concerns at this time, please do not hesitate to ask. If any additional questions or concerns occur please feel free to contact Dr. Reid Skeel (989-774-6485).

You are free to refuse to participate in this research project or to withdraw your consent and discontinue participation in the project at any time without penalty or loss of benefits to which you are otherwise entitled. Your participation will not affect your relationship with the institution(s) involved in this research project.

If you are not satisfied with the manner in which this study is being conducted, you may report (anonymously if you so choose) any complaints to the Institutional Review Board by calling 989-774-6777, or addressing a letter to the Institutional Review Board, 251 Foust Hall Central Michigan University, Mt. Pleasant, MI 48859.

My signature below indicates that all my questions have been answered. I agree to participate in the project as described above.

_____ _____

Signature of Subject Date Signed

A copy of this form has been given to me. _____ Subject's Initials

For the Research Investigator—I have discussed with this subject the procedure(s) described above and the risks involved; I believe he/she understands the contents of the consent document and is competent to give legally effective and informed consent.

_____ _____

Signature of Responsible Investigator Date Signed

PLEASE SIGN BOTH COPIES. KEEP ONE AND RETURN THE OTHER TO THE INVESTIGATOR. THANK YOU

APPENDIX C

BACKGROUND QUESTIONNAIRE

- Age: _____
- Education (indicate your highest/current level of education attainment, for example 3rd year college education): _____
- Race: _____
- Do you smoke? (check one): Yes _____ No_____
- If you smoke, indicate how many cigarettes you typically smoke per day: _____
- Indicate the number of drinks you typically have in a week (one drink = 12 oz. beer, one glass of wine, 1 oz. (shot) of alcohol): _____
- How many alcoholic drinks did you have the night before and today: _____
- How many caffeinated beverages did you consume today: _____
- Are you taking any prescription or over-the-counter medications (check one): Yes___ No___
- If taking medications, please indicate the name and dosage: _____ _____ _____
- Have you ever been hit in the head hard enough to lose consciousness for more than 20 minutes? If so, please describe. _____ _____
- How many days per week do you exercise? _____

APPENDIX D

DEBRIEFING FORM

How much did you believe the explained purpose of the study?

1	2	3	4	5	6	7	8	9	10
Not at All				Moderately					Very Much

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