Fall 12-14-2011

The Relationship between Stress, Cortisol Reactivity and Memory Performance in Younger and Older Adults

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ABSTRACT

The purpose of this study was to examine age differences in cortisol reactivity and memory performance in younger and older adults exposed to cognitive stressors. The current study utilized data from the Anxiety, Memory, and Control study (ACME) conducted at Brandeis University. Stress was measured using a subjective assessment of anxiety and cortisol was measured using a saliva sample. Memory performance was measured using both declarative and working memory tasks. The final sample consisted of 28 younger adults (*M* = 19.8 years, *SD* = 1.5) and 29 older adults (*M* = 71.2 years, *SD* = 6.6). There were significant age differences in cortisol reactivity with older adults showing increases in cortisol and younger adults showing decreases. Cortisol reactivity was not significantly related to memory performance for either age group. Cortisol reactivity did not differentially affect declarative or working memory. The results suggest age and task anxiety are significantly related to memory performance but cortisol reactivity is not.

INDEX WORDS: Thesis, Aging, Gerontology, Psychology, Georgia State University

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by

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Masters of Arts

in the College of Arts and Sciences

Georgia State University

2011

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December 2011

DEDICATION

This thesis is dedicated to my Mom whose love and support has taught me to believe in myself and never give up. Her sacrifices and strength have made me who am I today and have given me the chance to find a career I love. I would not be where I am today or half the person I am today without her guidance and advice. Thank you and I love you!

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

Stress presents itself in many forms and can produce both beneficial and harmful effects on the body. While there may be temporary positive effects of minimal amounts of stress (motivation for learning), most current researchers want to understand the effects of stress because of the known negative consequences on the human body and mind (Aldwin, 2004). There is also increasing interests in how people change as they age and whether there is a difference in how older adults are affected and deal with stress when compared with younger adults. The stress hormone cortisol is a glucocorticoid that is produced in the adrenal gland in response to a stressor and affects how many cells in the body work (McCormick, Matthews, Thomas & Waters, 2010). There have been several studies examining stress and cortisol (De Rooij & Roseboom, 2010; Hay & Diehl, 2010; Neupert, Miller, & Lachman, 2006; Preville, Zarit, Susman, Boulenger, & Lehoux 2008; Stawski, Sliwinski, Almeida & Smyth, 2008), as well as other studies that specifically examine the relationship between stress and memory (Neupert, Almeida & Charles, 2007; Oei, Everaerd, Elzinga, Well & Bermond, 2006; Smeets, 2010).

At this point there have been few studies examining if stress and cortisol reactivity interact to cause problems with memory as people age. The purpose of this study was to examine age differences in stress, cortisol reactivity, and their effects on memory. More specifically, I focused on whether cortisol reactivity was related to cognitive stressors (memory testing) and specific types of memory (declarative or working memory) in younger and older adults. Declarative memory involves facts and learned information whereas working memory is the temporary storage and management of new information.

This study is important because there have been few studies examining both younger and older adults performing the same cognitive tasks for the purpose of measuring cortisol reactivity and how that reactivity affects memory performance. Discovering how younger and older adults perceive cognitive tasks and how that perception affects cortisol and memory performance can lead to a better understanding of age differences in memory performance.

CHAPTER 2

LITERATURE REVIEW

Stress

Stress can present itself in a number of ways. The most popular definition used by the general public is the pressure felt when one has too much to do and not enough time (Lupien, Maheu, Tu, Fiocco & Schramek, 2007, 209). In medical terms physical stress on the body can include extreme heat or cold, an injury, an infection or pain. Intense exercise and even loud sounds are also considered physical stressors (Shier, 2007). Some of the greatest stressors in life are psychological in nature and may include feelings of danger or loss, uncomfortable social situations and worry. Daily hassles and significant life changes such as the death of a loved one, marriage, divorce and the loss of a job are significant life changes that can cause heightened stress levels (Myers, 2004). Some researchers believe it is an individual's interpretation of a stressful situation that determines its effects. For instance, a stressful social situation may be terrifying for one individual and may have little or no effect on another individual (Lupien et al., 2007). Psychological stress does not always have to be negative and can also be caused by pleasant situations such as intense joy or happiness (Shier, 2007).

Stress is not just a reaction, it is a process where the body understands and tries to cope with an environmental challenge (Myers, 2004). If a stressor is seen as threatening the body physically reacts by producing cortisol, increasing heart rate and respiration as well as tensing muscles and perspiring (Comer, 2005). Blood flow is drawn away from digestion and directed toward the skeletal muscles to prepare them for action (Comer, 2005). There has also been evidence that stress may lead to a decrease in the effectiveness of the immune system in protecting the body against bacteria or viruses (Myers, 2004).

While it is unknown how stress exactly influences the health of older adults there have been some ideas to what may occur. Stress can indirectly affect a person by causing them to engage in unhealthy behaviors such as poor sleep habits, lack of exercise as well as an inappropriate diet (Preville, et al., 2008). A direct effect of stress could be the disruption of the "physiological homestasis" or balance the body needs to maintain to be considered healthy (Preville et al., 2008, p. 249). Both of these factors could play into the physical wellness of an older adult.

Stawski and colleagues (2006) suggest that stress causes cognitive interference by interrupting attention. Using a sample of 111 older adults (mean age = 80 years) the researchers measured several items including cognitive interference, working memory, and stress. They found that stress-induced cognitive interference was associated with lower working memory in older adults. The results also suggested that cognitive interference may have an effect on processing speed and episodic memory. This study also suggests there may be different ways stress can affect memory processing by distracting someone or disrupting their focus and concentration.

Cortisol Reactivity

The hypothalamic-pituitary-adrenal (HPA) axis is an important endocrine system that is activated when a person experiences stress. There are two different types of stress hormones, glucorticoids (cortisol) and catecholamines (adrenaline and noradrenaline) (Lupien et al., 2007). Cortisol is the primary hormone released when the body experiences a stressor, either physical or mental. Cortisol is produced in the adrenal gland (found in the kidney) and affects the way glucose is metabolized by the body (Shier, 2007). Cortisol also affects how many cells in the body function, (McCormick et al., 2010) and is utilized when the body attempts to maintain homeostasis following a stressful event (Sauro, Jorgensen & Pedlow, 2003). A negative feedback mechanism regulates how cortisol is released in the body. The hypothalamus, pituitary gland and adrenal cortex work together keeping the amount of cortisol in the blood at its necessary level (Shier, 2007).

There has been some debate in the literature over whether or not cortisol secretion cycles change with age. Preville and colleagues (2008) reported the presence of hypercortisolemia (high amounts of cortisol circulating in the blood) in some older adults. Hypercortisolemia could be caused by an overreaction to stressful situations and there have been some findings that indicate it could speed up the aging process and possibly reduce the immune functionality (Preville et al., 2008).

A study performed by Neupert and colleagues (2006) used data from the Boston oversample of the Midlife in the United States to explore cognitive stress and cortisol response in a total of 74 individuals ranging from 25 to 74 years of age. The individuals in the study performed cognitive tasks while having their salivary cortisol measured. The results showed that older adults were more reactive to stress (higher increases in salivary measures of cortisol) than younger adults while performing the memory tasks (Neupert et al., 2006). They also found that older adults secreted more cortisol as the study continued and they also took longer to recover from the stressors (experience a decrease in cortisol in the salivary measures) and return to baseline (Neupert et al., 2006). This study suggests that while older adults may not have higher resting levels of cortisol, they do appear to have higher reactivity, especially to cognitive tasks.

Memory

There is some evidence that cortisol may have a direct impact on cognition. One line of support for this argument comes from clinical literature examining individuals with Cushing syndrome, Alzheimer’s disease, depression and schizophrenia. Most patients with these disorders have both some degree of cognitive impairment as well as high amounts of cortisol secreted and circulating in their blood (Belanoff, Gross, Yager & Schatzberg, 2001). It has been hypothesized that the higher levels of cortisol may cause the cognitive impairment. In addition, Lupien and colleagues (1994, 2005) have consistently found that both heightened levels and heightened reactivity of cortisol have a long-term impact on memory and cognition.

Different types of memory may be affected differently by stress and cortisol. Working memory is temporary storage for new information where the brain can process and manipulate this information for complex tasks such as reasoning and comprehension. Working memory is thought to be particularly sensitive to stress-related cortisol secretion (e.g. Oei, Everaerd, Elzinga, Van Well, & Bermond, 2006). Declarative memory is used to learn new things and remember facts and events (Lupien et al., 2007). Smeets (2010) and de Quervain and colleagues (2000) found that the ability to recall words (declarative memory) can be very affected by increases in cortisol.

Stress, Cortisol Reactivity and Memory

There is evidence that declarative memory is more vulnerable to stress than non-declarative memory (memory used to perform tasks or processes). It is thought that these effects are due to cortisol effects on the hippocampus which is involved in learning and memory and is also a site where there are a very high volume of glucocorticoid receptors in the brain. Therefore, the theory implies that high amount of stress lead to more secretion of cortisol which in turn causes an overactivation of the glucocorticoid receptors in the brain and then it can lead to problems with memory and learning (Lupien et al., 2007).

Smeets (2010) examined how heightened levels of cortisol induced by stress affected declarative memory in younger adults ages 18-25. A total of 76 participants were placed either in the stress situation (submerging their hand in very cold water for 3 minutes while being watched or videotaped) or the control/no stress group (submerging their hand in lukewarm water without being watched or videotaped). The participants had their salivary cortisol measured and then had to perform a word learning task. The stress-induced cortisol reactivity group had more trouble recalling the words they had learned when compared to the no stress group. This confirms the theory that cortisol reactivity caused by stress will impair an individual's ability to recall words (Smeets, 2010). Sauro and colleagues (2003) performed a computer based literature review and found additional evidence that stress specifically impairs declarative memory function in humans.

In 2006, Oei and colleagues examined the effects of stress-induced cortisol secretion on twenty young men with an average age of 21.86. Participants performed declarative and working memory tasks and were given 10 minutes to prepare for a 5 minute speech and 5 minute arithmetic tasks in front of an audience in order to produce a stress response. The researchers found that working memory is affected by cortisol secretion brought on by cognitive stressors but declarative memory in their study was not.

Another method of testing the cortisol/memory connection is examining the effects of the direct administration of cortisol. One such experiment was performed by de Quervain, Roozendaal, Nitsch, McGaugh & Hock (2000) and included 36 male and female volunteers (ages 20-40). An hour after they received either a dose of cortisone (a synthetic form of cortisol) or a placebo, participants had their salivary cortisol levels tested and were given a word list recall task and word recognition task on day one. After a period of 2 weeks the same participants were given another set of words but this time they received the opposite treatment than they had before (i.e. placebo group now received cortisone and vice versa). The researchers found the group receiving the cortisone (either time period) had a significantly impaired ability to recall the words.

Working memory is also thought to be particularly sensitive to cortisol secretion. Young Sahakian, Robbins and Cowen (1999) performed an experiment examining the effects of glucocorticoids (cortisol) on the brain. Twenty healthy, male volunteers (ages 21-44) were recruited for this study and given hydrocortisone or placebo capsules twice a day for ten days. The day before the cognitive testing the men had their urinary cortisol levels tested. Spatial working memory was found to be significantly affected by the increase in cortisol in the body.

Lupien, Gillin and Hauger (1999) performed a similar experiment where 40 men (ages 19 to 28) were infused with either glucocorticoids or a placebo for 100 minutes. During the infusion blood was drawn to test cortisol levels and their declarative memory (word recall) and working memory (item-recognition) were tested. Contrary to the aforementioned findings, the researchers found that declarative memory was not significantly affected where working memory was significantly affected. Clearly, across these studies the effect of cortisol on memory varies by type of memory and type of stressor. In addition, many of these studies have not included an older adult sample.

Summary

The research looking at the effects of stress and cortisol reactivity on cognition with age has been mixed. In addition, some research has shown that older adults tend to be more reactive to cognitive-specific stressors and have a more difficult time recovering from said stressors (Neupert et al., 2006). There have also been studies suggesting there are no age differences in stress reactivity (Hay et al., 2010). What is apparent is that stress impacts cognition, what is less clear is the age differences in this relationship.

CHAPTER 3

PURPOSE OF RESEARCH, RESEARCH DESIGN AND HYPOTHESES

Purpose of Research

The purpose of the current study was to further explore the relationship between stress, cortisol reactivity and memory performance in younger and older adults. More specifically, there was a focus on cortisol reactivity and memory performance in younger and older adults.

Research Design

The data for the study was secondary data from the Anxiety, Memory, and Control study (ACME) conducted at Brandeis University and funded by the National Institute of Aging (R01). Researchers used an extreme age group design (i.e. young and old age groups). Participants completed cognitive memory tasks as well as subjective assessments (which included their opinion or evaluation of how they performed and how stressful the activity was for them). Salivary cortisol measures were also taken over the course of the testing which took approximately two hours.

For this study, the subjective assessments were examined to determine if participants found the cognitive tasks stressful. Cortisol changes were examined during the testing as well as the performance on the cognitive tasks. There was also an emphasis on an exploration of age differences in both cortisol reactivity and memory accuracy for each task.

Hypotheses

Given the previous research, there were two hypotheses for this study. Hypothesis one was that older adults will be more hormonally reactive to cognitive testing by experiencing increases in cortisol. Hypothesis two was that older adults' memory performance accuracy will be more impacted by cortisol reactivity when compared to younger adults.

Exploratory Research:

Because the previous literature on the relationship between cortisol and type of memory was inconclusive, no specific prediction was made about whether cortisol would affect working memory or declarative memory differently. Instead the relationship between age, cortisol, and the types of memory was explored.

CHAPTER 4

METHODS

Participants

A convenience sample of young adults was recruited on-campus at Brandeis University through fliers and classroom announcements. A convenience sample of older adults was recruited through a participant database and local advertisements**.** A total of 30 university undergraduates and 33 community-dwelling older adult volunteers participated. Participants were excluded from the study if they had one or more of the following: a stroke in the last five years, serious head injury, Parkinson's disease, did not have full use of both hands, had less than a high school education, made more than two errors on a modified-for-telephone version of the Short Portable Mental Status Questionnaire (Pfeiffer, 1975), reported being in poor health compared to others their same age, were on prescription stimulants, or were not native English speakers. On this basis, two younger adults and four older adults were omitted from the study leaving a final sample of 28 younger and 29 older adults. The mean age of the young adult sample was 19.8 (SD = 1.5) ranging from 18 to 23 years. The mean age of the older adult sample was 71.2 (SD = 6.6) ranging from 60 to 85 years. Participants were paid $25.

Measures

1. Memory tasks

The two declarative memory tasks included in this study were word list recall and story recall. The word list recall task, developed by Hertzog, Dixon, and Hultsch (1990), consisted of 30 categorizable nouns. Participants studied the list for three minutes during the first trial and one minute during the second trial. For both trials, participants were given as much time as needed to write down as many words as they could remember. The mean score for number of words correctly recalled across the two trials was calculated with a possible range from 0 to 30. Delayed free recall was also measured 20 minutes later with a total possible of 30. Logical memory from the Wechsler Memory Scale – Third Edition (WMS; Wechsler, 1945/1997) was also administered. The interviewers read two short stories and had the participants repeat back as much as they could remember. As is standard protocol, the second story was read twice. The Logical Memory delayed free recall task was also administered after a 30 minute delay. Following the delayed free recall, examiners read the participants 30 yes/no questions about the two stories to test their recognition memory. Scores on immediate recall could range from 0 – 75, scores on delayed recall could range from 0 – 50, and scores on recognition recall could range from 0 – 30.

Digit Span from the WAIS-III (Wechsler, 1997) and the *n*-back task were used as measures of working memory. In the Digit Span task, participants listen to a string of numbers at one digit per second and are then asked to repeat the numbers back to the examiner. In forward digit span, participants repeat the string back as they heard them. In backward digit span, participants have to recall the string in reverse order. The length of the forward string begins at three digits and goes to nine and for the backward span begins at two digits and goes to eight. Participants are given two strings at each length. When the participants respond incorrectly to both strings of a given length, the test is ended. The participants' forward and backward digit span scores were set as the longest string he or she could correctly repeat forwards and backwards. In this study only the backward digit span was used for data analysis because the forward digit span does not provoke enough anxiety to show a difference. The *n*-back, which requires participants to listen to a sequence of numbers and to indicate the number that was presented *n* trials beforehand, is considered a more difficult task. The present study used 1- and 2-back targets. In this study only the 2-back target trial will be used because the 2-back provoke more anxiety and is more difficult than the 1-back. The final score can range from 0 to 30.

2. Subjective assessments

Subjective assessments were used to determine how stressful the participants rated the tasks. Participants rated their anxiety following each task on a scale of 1 (not at all anxious) to 5 (very anxious). A mean subjective anxiety score was calculated with all subjective anxiety assessments.

3. Salivary cortisol measures

The stress hormone of cortisol was assessed using saliva samples. Cortisol was measured before the cognitive tasks (pretest) and 15 minutes after the tests (posttest). The time-resolved immunoassay with fluorescence detection process has been described previously (Dressendörfer, Kirschbaum, Rohde, Stahl, & Strasburger, 1992). Cortisol is reported in nmols/liter.

While there are some issues with change scores, they are the primary way that this literature has addressed cortisol reactivity (de Quervain et al., 2000; Smeets, 2010; Young et al., 1999). The difference score between posttest cortisol and baseline cortisol (average of pretest one and two) was used as the measure of reactivity.

Procedure

Participants were tested individually in a laboratory room at a Brandeis University in Waltham, Massachusetts. Trained research assistants conducted the evaluations. After informed consent was obtained, cortisol was measured. Next, participants filled out a series of demographic questionnaires. Following the questionnaires, participants gave a second pretest saliva sample. After the saliva sample, participants were given the battery of cognitive tests each followed by the subjective assessment of the task. The posttest saliva sample was taken approximately 15 minutes after the cognitive tests were completed.

Preliminary Data Analyses

1. Potential Confounding Variables

Before conducting the main analysis some potential confounding variables were addressed. Because of the known impact of time of day on cortisol levels, time of testing between younger and older adults was examined using a chi-square test [age groups (young/old) by time tested (morning/afternoon).

There are certain medications that may influence cortisol levels. The current research shows that hormones (e.g. estrogen and androgen) and steroids (e.g. prednisone and prednisolone) may have an effect on salivary cortisol levels (Granger, Hibel, Fortunato, Kapelewski, 2009). Therefore, differences between younger and older adults on levels of these medications were examined using a chi-square test [age groups (young/old) by medication usage. Although stimulants are also known to increase cortisol levels, participants reporting stimulant use were excluded from the final sample.

2. Subjective Assessment

To determine whether anxiety was above threshold, a single-sample *t*-test with a test value of 2 (a little anxious) was conducted. Because it is difficult to measure what the different levels of anxiety mean to each person, it was decided that some anxiety (in this case a choice of 2) would be a good threshold for measuring some anxiety about the tasks so that anyone experiencing some anxiety about the tasks would be included.

Analyses

The first hypothesis predicted that older adults will be more hormonally (cortisol) reactive (increase in cortisol) to cognitive testing than younger adults. A repeated measures analysis of variance (RM-ANOVA) was used to investigate cortisol change between groups from baseline to posttest. The group variable was age group. Relevant confounding variables were used as covariates (see Potential Confounding Variables section).

The second hypothesis predicted that older adults' memory performance will be more impacted by cortisol reactivity when compared to younger adults. A linear regression will be conducted to evaluate this hypothesis. Specifically, a mean of the Z-scores of the memory tests will be the outcome variable with age, cortisol reactivity, and task anxiety as the independent variables. In addition, an age by cortisol reactivity interaction was performed to test the actual hypothesis.

In this study the raw memory scores were transformed into z scores for the purpose of comparing all of the memory scores on the same scale. To create a z-score the mean of the distribution (from the sample) is subtracted from the raw score and divided by the standard deviation. The average then becomes zero and the z-score will either fall above or below the mean (which is now zero). This makes it possible to see how far away from the mean each score truly is in comparison to the rest of the data.

For the exploratory analyses correlational analyses were conducted to determine if there were any significant difference in the types of memory affected by stress and cortisol reactivity. To do this exploratory analyses, partial correlations were conducted (with age as a covariate) looking at the six different memory tests (raw scores) with cortisol level and cortisol reactivity.

CHAPTER 5

RESULTS

Potential Confounding Variables

The results of the chi-square test [age groups (young/old) by time tested (morning/afternoon)] to examine effects of time of testing showed there were no age differences in time of testing [$x^2 = 1.22$, $p = 0.27$]. Because there was no significant age differences, time of testing was not used as a covariate in any other analysis.

The results of the chi-square test [age groups (young/old) by medication usage] showed there were significant age differences on medication usage of oral contraceptives between the different age groups [$x^2 = 11.52$, $p < 0.01$]. Because there was age differences (nine young women taking oral contraceptive compared to no one else in the other groups) a *t*-test was used to determine if that medication was related to the outcome variable of cortisol reactivity. The *t*-test was performed with two groups as the independent variable (taking oral contraceptive/not taking oral contraceptives) and cortisol reactivity as the outcome variable. Medication usage (oral contraceptives) was not related to cortisol reactivity [$t(54) = 0.61$, $p = 0.54$] and was not used as a covariate in any other analysis.

Subjective Assessments

Table 1 shows the means and standard deviations for the subjective assessments of each memory test of the participants separated by age group (young/old). The results of the one-sample *t* test showed that most assessments were above the threshold level of 2 for both age groups. The overall cognitive task anxiety for younger adults was $M = 2.19$, $SD = 0.66$ and $M = 2.37$, $SD = 0.81$ for the older adults. More specifically the word list task had a significance level of $p = 0.05$ and the story recall task had a significance level $p < 0.01$. Although, the younger and older adults rated the tasks similarly, the older adults rated on average the declarative memory tasks more than a little anxiety provoking (i.e. word list & story recall). The only significant difference between young and older adults in terms of subjective anxiety was on word lists (t = 2.69, p < .01) with older adults finding the word list task more anxiety provoking.

Table 1: *Subjective anxiety on memory tasks*

	Younger Adults		***Older Adults***	
Tasks	***M***	***SD***	***M***	***SD***
Backward digit span	2.33 [a]	0.83	2.03	1.05
Word list	1.93	0.92	2.62 [a]	1.12
Logical memory	2.33	1.14	2.62 [a]	1.12
N-back (2-back trial)	2.63 [a]	1.18	3.10 [a]	1.35
Delayed tasks (word list & logical memory)	1.93	0.92	2.07	1.00
Cognitive task anxiety (all)	2.19	0.66	2.37 [a]	0.81

Note: Participants rated their anxiety following each task on a scale of 1 (not at all anxious) to 5 (very anxious). It was predetermined that a response of 2 (a little anxious) would represent above-threshold anxiety.

[a] One-sample t-test significant (test value = 2) at p < .05

a. Hypothesis 1

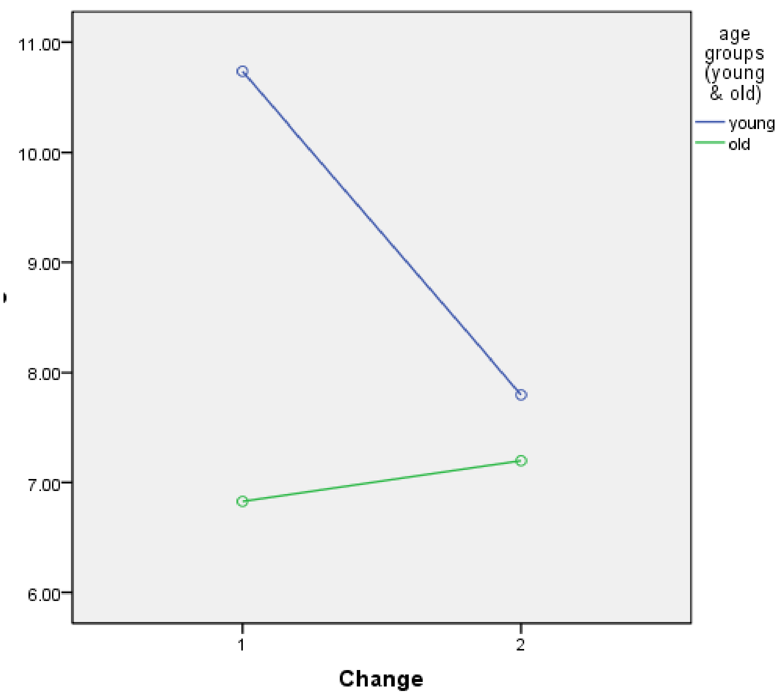
To test the first hypothesis (older adults would experience significant increases in cortisol), a RM-ANOVA was performed which examined the between-subject factor of age with two levels (younger/older). The within-subject variable of cortisol reactivity had two time frames (baseline/posttest). For the two groups (younger/older) there was not a main effect of age group. There was a significant main effect of time, $F(1,54) = 4.54$, p <.05 where cortisol measures significantly changed from baseline to posttest. This means that both groups had a significant change in their cortisol levels from baseline to posttest (with an overall decrease in cortisol). Table 2 shows the means and standard deviations of the cortisol measures and cortisol reactivity separated by age. Younger and older adults differed significantly on their baseline cortisol levels with younger adults having higher baseline and posttest cortisol measures than younger adults. Because there was a significant interaction of age and time the first hypothesis was partially supported. Older adults did increase slightly in cortisol over time (see Cortisol Reactivity in Table 2). However, the younger adults decrease in cortisol over time was much more dramatic.

Table 2: *Salivary cortisol during session*

	Baseline cortisol [a]		**Posttest cortisol**		**Cortisol Reactivity** [a]	
	M	**SD**	**M**	**SD**	**M**	**SD**
Younger adults	10.73	7.67	7.79	3.94	-2.94	5.13
Older adults	6.83	2.38	7.19	4.34	0.37	3.83

Note: Cortisol is measured in nmols/liter.
[a] Age differences significant at p < .05.

Figure 1: *Baseline and Posttest Measures of Cortisol by Age Group*



b. Hypothesis 2

To test hypothesis 2 (cortisol reactivity would significantly affect older adults' memory performance) a simple linear regression was performed with memory performance as the outcome variable. Table 3 shows the means and standard deviations of the z-scores created from the memory task scores separated by age group. The newly formed z-scores will include both age groups and represent each memory task using the full sample.

Results from the linear regression conducted for memory (shown in Table 4) show that age was a significant predictor of memory performance [$\beta = -0.54$, $t = -4.78$, $p < 0.01$]. This regression also showed that cognitive task anxiety was a significant predictor of memory performance [$\beta = -0.26$, $t = -2.38$, $p < 0.02$]. However, cortisol reactivity was not a significant predictor of memory performance [$\beta = -.08$, $t = -0.70$. $p = 0.50$]. These results show that age and cognitive task anxiety are significantly related to memory performance but cortisol reactivity was not.

The age by cortisol reactivity interaction was also tested (Table 4) but was not found to be significant [$\beta = 0.18$, $t = 0.80$, $p = 0.43$]. Therefore, hypothesis 2 was not supported: cortisol reactivity was not significantly related to memory performance in either age group (young/old) in this study.

Table 3: *Memory Performance (z scores)*

	Younger Adults		***Older Adults***	
Memory tests	***M***	***SD***	***M***	***SD***
Backward digit span total	0.16	0.70	-0.15	.90
Word list immediate recall	0.57	0.54	-0.51	0.97
Logical memory immediate recall	0.38	1.08	-0.31	0.82
n-back	0.48	0.27	-0.41	1.20
Word list delayed recall	0.55	0.60	-0.49	1.03
Logical memory delayed recall	0.40	0.96	-0.34	0.92

Table 4: *Linear Regression Coefficients*					
Variable	**t**	***B***	**SE *B***	**β**	***p***
Age in years	-4.78	-0.02	0.004	-0.54	0.001
Reactivity of cortisol (posttest minus pretest)	-0.70	-0.02	0.02	-0.08	0.49
Cognitive task anxiety mean	-2.38	-0.29	0.12	-0.26	0.02
Interaction age x cortisol reactivity	0.80	0.01	< 0.01	0.18	0.43

Exploratory Analysis

The results of the partial correlation that controlled for age (in Table 5) showed that cortisol reactivity did not affect declarative or working memory differently. There was also a partial correlation performed with age included (Table 6). Results show that cortisol reactivity did not affect declarative or working memory differently when the age groups were separated.

Table 5: Partial Correlations of Cortisol Reactivity (Controlled for Age)						
	Declarative Memory				Working Memory	
	Word list immediate recall	**Logical memory immediate recall**	**Word list delayed recall**	**Logical Memory delayed recall**	**Backward Digit Span**	**n-back**
Baseline Cortisol	0.13	0.15	0.11	0.28	-0.19	0.24
Post test Cortisol	0.09	0.04	0.15	0.09	-0.11	-0.01
Cortisol Reactivity	-0.11	-0.20	-0.03	-0.35	0.20	-0.39

Table 6: Partial Correlations of Cortisol Reactivity (Separated by Age)

	Declarative Memory			Working Memory	
	Word list immediate recall	**Logical memory immediate recall**	**Word list & logical memory delayed recall**	**Backward Digit Span**	**n-back**
Younger adults	0.24	0.28	0.33	0.22	0.29
Older adults	-0.13	-0.39	-0.35	-0.10	-0.24

CHAPTER 6

DISCUSSION

Summary of Findings

This study examined the age differences in cortisol reactivity and memory performance in a sample of younger and older adults. The data was also explored to determine if cortisol reactivity affected memory performance in general and then two types of memory (declarative and working memory) specifically. The first hypothesis that older adults would be more reactive (increases in cortisol) to the memory tasks was partially supported with significant results. The second hypothesis (older adults would perform worse on the memory tasks because of the cortisol reactivity) was not supported with the results showing no significant relationship between the cortisol reactivity and memory performance for either age group. The exploratory analysis found that cortisol reactivity did not affect the different types of memory (declarative or working memory) differently. Overall, the results seem to suggest that age and cognitive task anxiety play more of a role in memory performance than cortisol reactivity.

Cortisol Reactivity

In line with previous literature, the first hypothesis which predicted older adults would have more cortisol reactivity was partially supported. While older adults did show a slight increase in cortisol over time, the increase was not large or significant. In addition, the younger adults showed a significant decrease in cortisol over the testing session which appeared to drive most of the significant results. The hypothesis was based on previous literature by Neupert and colleagues (2006) who found that older adults had higher levels of cortisol reactivity than younger adults when performing cognitive tasks.

Preville and colleagues (2008) mentioned the hypothesis that older adults may have higher amounts of cortisol circulating in their blood because of overreaction to stressful situations. While these researchers provide evidence that older adults have more cortisol reactivity when performing cognitive tasks what lacks is a definite reason as to why this happens. In future studies it would be helpful to understand if it is a biological or psychological reason that causes these differences in cortisol reactivity between younger and older adults. When comparing these findings to the present study the opposite was found and it is actually the younger adults who have higher starting measures of cortisol.

An interesting finding was that younger adults' cortisol levels started out very high and then decreased dramatically over the course of the cognitive testing from baseline to posttest. These results are similar to those found by Neupert and colleagues in 2006 where younger and older adults' cortisol secretions were measured while they performed cognitive tasks. One explanation could be the younger adults (who were all college students) may have been anxious about other things before the study began but then relaxed over the course of the testing. Unfortunately, the researchers in this study did not ask about other 'current' stressors that could have contributed to the young adults' high levels of cortisol at baseline. There is also the possibility that because all of the younger adults were students, they may have become accustomed to these types of cognitive tasks and therefore, became more relaxed over the course of the session.

Memory Performance

Not surprisingly, the results of this study found that age was highly related to memory performance. Although older adults did have a small increase in cortisol levels over the course of the testing, their memory performance was not directly related to this increase in cortisol.

This does not follow literature that finds increased effects of cortisol on memory across the lifespan (Belanoff et al., 2001; Lupien et al., 2005). One possible explanation could be that the cognitive tasks included in the current study were not stressful enough to produce raised cortisol that would affect memory. A very low criterion for tasks to be considered stressful was utilized and it is certainly possible that the tasks were actually not anxiety producing enough to raise cortisol.

There also was no difference in the relationship between cortisol on the different types of memory tasks (i.e. declarative vs. working). This was interesting because the past literature on these topics has found fairly consistent evidence supporting the theory that stress and cortisol can influence memory. For instance, de Quervain and colleagues (2000) found exposure to cortisol caused problems with declarative memory in middle aged adults and Sauro and colleagues (2003) found that stress is associated with cortisol reactivity and declarative memory problems in participants of all ages. Smeets (2010) also found that stress impaired declarative memory performance in a sample of younger adults. Additionally, Young and colleagues (1999) found that an increase in cortisol measures impairs working memory. However, given that cortisol reactivity was not related to memory performance as a whole (which was merely a mean of working and declarative memory), it is not surprising that individually they were not related to cortisol reactivity.

Limitations

There are a few limitations of this study including the use of self-reported variables, the way anxiety was measured and the small sample size. One of the most important variables of this study was the subjective assessment of anxiety that was used to determine if the cognitive tasks caused stress to the participants. Because participants may have different opinions of what stress or anxiety means to them there is no way to measure and equate what subjective reports of anxiety mean. That said, most studies of stress include some form of self-report because it is the best way to find out participants' thoughts about the task.

Along the same lines another limitation was that the study did not have a measure of overall stress (both daily and within study) and therefore had to rely on anxiety measurements which may not have been really capturing stress levels. In this study anxiety was measured using an ordinal scale with 1 being 'low anxiety' and 5 being 'high anxiety'. In an ordinal scale the spaces between the numbers are not clearly defined. When a participant chose their anxiety level it could have encompassed more than just cognitive anxiety about the memory tasks.

Another limitation of this study was the small sample size. More participants in both age groups would add more power to detect significant relationships. The sample was not very diverse which limits my ability to make generalizations. In addition, the younger adults were all college students and this may contribute to their ability to handle the stress of a cognitive test better.

Other potential limitations could be that some of the younger adults in this study started with a cortisol level that is well above what is considered 'normal'. That is, 4 of the 27 younger adults had baseline cortisol levels about 23 (which is on the very high end of normal for morning). It is possible that the younger adults did not fully disclose their use of stimulants or caffeine both of which are known to raise cortisol. It may also be the case that the younger adults were just more stressed in general than the older adults which is in line with many findings in the emotional aging literature.

Future Directions

While there were some limitations in this study the results are still important to consider. There are many variables involved when examining memory, especially when comparing younger and older adults.

If a study was performed in the future it could be beneficial to include middle aged adults not necessarily to see when memory performance starts to decline but when people start reacting differently to memory tasks. It would be interesting to see at what age feelings of anxiety about memory performance begin. It would also be helpful if the participants could be a little more educationally diverse and have younger adults who are not in college as well as older adults who have gone back to college.

It would also be interesting to include more potentially stressful tests to see if they can cause more cortisol reactivity with subsequent declines in memory. Because of the very small sample size it was not possible in this study to separate and only look at participants who only scored higher (4 and 5) anxiety levels on the subjective assessments. Therefore if the sample could be increased it would be a great analysis to look only at people who find cognitive tasks extremely anxiety provoking.

CONCLUSIONS

While the hypotheses in this study were not fully supported there were some interesting findings about age, memory and cortisol reactivity. For example, it was found that while younger and older adults rated a task similarly in anxiety it affected the older adults more when it came to memory performance. In the same situation where the age groups rated the tasks similarly, the older adults experienced an increase in cortisol where the younger adults experienced a decrease in cortisol. While the results of the current study may not be significant it does show the need for more research in this area. It would be helpful to have more studies in the future with a larger diverse group of younger and older adults. It would also be interesting to see the results if different levels of anxiety were induced among these different age groups.

REFERENCES

Aldwin, C., Gilmer, D. (2004). Health, illness, and optimal aging: Biological and psychosocial perspectives. Thousand Oaks, CA: Sage Publications.

Belanoff, J., Gross, K., Yager, A., Schatzberg, A. (2001). Corticosteriods and cognition. *Journal of Psychiatric Research, 35*, 127-145.

Birren, J., Schaie, K. (2006). Handbook of the psychology of aging (6th ed.). Burlington, MA: Elsevier Academic Press.

Comer, R. (2005). Fundamentals of abnormal psychology (4th ed.). New York, NY: Worth Publishers.

de Quervain, D., Roozendaal., B., Nitsch, R., McGaugh, J., Hock, C. (2000). Acute cortisone administration impairs retrieval of long-term declarative memory in humans. *Nature Neuroscience, 3*, 313-314.

De Rooij, S., Roseboom, T. (2010). Further evidence for an association between self-reported health and cardiovascular as well as cortisol reactions to acute psychological stress. *Psychophysiology*, *47*, 1172-1175.

Granger, D., Hibel, L., Fortunato, C., Kapelewski, C. (2009). Medication effects on salivary cortisol: Tactics and strategy to minimize impact in behavioral and developmental science. *Psychoneuroendocrinology, 34*, 1437-1448.

Hay, E., Diehl, M. (2010). Reactivity to daily stressors in adulthood: The importance of stressor type in characterizing risk factors. *Psychology and Aging, 25*, 118-131.

Lupien, S., Gillin, C., Hauger, R. (1999). Working memory is more sensitive than declarative memory to the acute effects of corticosteroids: A dose-response study in humans. *Behavioral Neuroscience, 113*, 420-430.

Lupien, S., Maheu, F., Tu, M., Fiocco, A., Schramek, T. (2007). The effects of stress and stress hormones on human cognition: Implications for the field of brain and cognition. Brain *and Cognition, 65*, 209-236.

McCormick, C., Mathews, I., Thomas, C., Waters, P. (2010). Investigations of HPA function and the enduring consequences of stressors in adolescence in animal models. *Brain and Cognition*, *72*, 73-85.

Myers, D. (2004). Psychology (7th ed.). New York, NY: Worth Publishers.

Neupert, S., Miller, L., Lachman, M. (2006). Physiological reactivity to cognitive stressors: Variations by age and socioeconomic status. *International Journal of Aging and Human Development, 62*, 221-235.

Neupert, S., Almeida, D., Charles, S. (2007). Age differences in reactivity to daily stressors: The role of perceived control. *Journal of Gerontology*, *62B*, 216-225.

Oei, N., Everaerd, W., Elzinga, B., Well, S., Bermond, B. (2006). Psychological stress impairs working memory at high loads: An association with cortisol levels and memory retrieval. *Stress, 9*, 133-141.

Preville, M., Zarit, S., Susman, E., Boulenger, P., Lehoux, R. (2008). Response variability of salivary cortisol among older adults under psychological stress. *Aging and Mental Health*, *12,* 249-257.

Sauro, M., Jorgensen, R., Pedlow, C. (2003). Stress, glucocorticoids, and memory: A meta-analytic review. *Stress, 6,* 235-245.

Shier, D., Butler, J., Lewis, R. (2007). Hole's human anatomy & physiology (11th ed.). New York, NY: McGraw-Hill.

Smeets, T. (2010). Acute stress impairs memory retrieval independent of time of day. *Psychoneuroendocrinology*, 1-7.

Stawski, R., Sliwinski, M., Smyth, J. (2006). Stress-related cognitive interference predicts cognitive function in old age. *Psychology and Aging, 21*, 535-544.

Stawski, R., Sliwinski, M., Almeida, D., Smyth, J. (2008) Reported exposure and emotional reactivity to daily stressors: The roles of adult age and global perceived stress. *Psychology and Aging*, *23*, 52-61.

Young, A., Sahakian, B., Robbins, T., Cowen, P. (1999). The effects of chronic administration of hydrocortisone on cognitive function in normal male volunteers. *Psychopharmocology, 145*, 260-266.