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THE RELATIONSHIP BETWEEN CHRONIC SELF-REPORTED STRESS AND DIVIDED ATTENTION PERFORMANCE

by

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B.A. Rollins College, 2002

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Arts
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in the College of Sciences
at the University of Central Florida
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ABSTRACT

While previous research has extensively examined the effect of acute stress on cognitive performance, relatively little research has explored the relationship between chronic stress and cognitive performance. The current study aimed to control for current state anxiety to better isolate more chronic stress, when examining the relationship with performance on divided attention tasks. Fifty-four university undergraduates, who self-reported a wide range of perceived chronic stress (10-item Perceived Stress Scale), completed the Trail-Making Test and a dual (auditory and visual) Continuous Performance Test (CPT). Hierarchical regressions were performed to explore cognitive predictors of chronic perceived stress. After covarying for state anxiety (state portion of State-Trait Anxiety Inventory), the most statistically significant predictor (via stepwise entry) was the auditory omission error change score (dual minus single condition), which showed a medium effect size (r = .36). Results have practical safety implications, as the implementation of an efficient and inexpensive measure of self-reported stress may predict future job-related errors in high-stress professions that require divided attention.

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CHAPTER 1 – INTRODUCTION

Stress has been a central issue in discussions of wellness for over a century, and some researchers posit the issue dates back to the early Greek physicians' discussions on personality (Auerbach & Gramling, 1998). Physical and mental health are linked increasingly to stress due to the biopsychosocial perspective held by many health professionals (Cassidy, 1999). The biopsychosocial perspective posits that biological, social and psychological factors contribute to overall health and susceptibility to illness (Petersen & Spiga, 1982). There are a growing number of studies suggesting that a person's tolerance and predisposition for stress is a significant variable for health in all three factors (Cassidy, 1999). Researchers have long believed the proposition that stress can directly interfere with various aspects of brain function, and contemporary experiments looking at stress effects on task performance began around fifty years ago. More recently, performance of individuals who are experiencing stress, or who have stress induced, has been examined on tasks assessing specific cognitive processes (Lupien & McEwen, 2002; Newcomer et al., 1999).

Researchers have induced stress by using challenging tasks or administering hormones that are known to influence the stress response, such as cortisol. Levels of stress have been measured subjectively, objectively, and physiologically, for example by changes in physiological functioning and through self-report (Cohen, Kessler, & Gordon, 1995). Physiological signs that have been monitored include cardiovascular changes, electrodermal responses, plasma levels of cortisol, and the more commonly used technique for measuring stress hormones - corticosteroid levels present in saliva by radioimmunoassay (Fillenz, 1993). Psychological stress has also been measured subjectively by various self-report questionnaires and observer reports.

Overview of the Construct of Stress

Stress is a term originating from the Latin *stringere* (to draw tight), and variations of the word were used over centuries, but, prior to the 1940's, was rarely used outside of the engineering profession (Cooper & Dewe, 2004). Finding a current definition of the term that a majority of researchers can agree to is almost impossible - with the challenge being that stress is a "composite multidimensional concept" (Ursin & Olff, 1993). Definitions include: the nonspecific response of the body to any demand made upon it (Selye, 1976); a unique interaction between a person and the environment (Lazarus & Folkman, 1984); a single dynamic process that integrates knowledge from the physical environment (input), physiological reactions (adaptation), and psychological resources (output) in a three dimensional matrix with boundaries of adaptational capacity (Hancock and Warm, 1989); an adaptive biological response necessary for homeostasis and survival in a changing environment by mobilizing energy reserves (Levin & Ursin, 1991); and activity in the hypothalamic-pituitary-adrenal system caused by two general types of stressors – physical challenges (i.e., low temperature) and the interpretation of psychological challenges (McNaughton, 1993).

Stress, and the interpretation of stressors, is closed allied to anxiety, which are both, together and separately, implicated in many psychiatric disorders (American Psychiatric Association, 2000; Glue, Nutt, & Coupland, 1993). A source of complication in research comes from the fact that sometimes the terms stress and anxiety are used interchangeably (Bushman, Vagg, & Spielberger, 2005). One description of the differences between the constructs states that if people perceive a stressful situation as threatening they will experience an anxiety reaction, and that overall process is referred to as stress (Spielberger, 1979). This description can be applied to many situations and variables, for example, examinations. The objective stimulus properties of the testing situation, perceived as stressful by most individuals, can be termed *examination stress,* whereas the subjective experience of that stimulus can be termed as *test anxiety* and is relative to the individual differences in anxiety proneness during examinations (Spielberger, Gonzalez, Taylor, Algaze, & Anton, 1978; Bushman, Vagg, & Spielberger, 2005). Stress is usually then, the reaction to a current or ongoing stressor, while anxiety primarily refers to the anticipation of a future stressor, or the outcome of that stressor. Due to the allied nature of the terms, stress levels have often been estimated through the use of anxiety and personality questionnaires that measure both state and trait components. The physiological reactions of the body from stress and anxiety follow similar biological pathways, which further complicates distinguishing their characteristics, as both are implicated in the stress response.

Many advances have been made in the understanding of the biological mechanisms of the stress response. In the late 1960's researchers discovered that peripheral hormones could be recognized by the rodent brain (McEwen, Weiss, & Schwartz, 1968), which subsequently spurred research to replicate the findings in the human brain and map the neurocircuitry of the stress response. The reaction begins with stress perception that is most likely modulated through the fast-acting inhibitory (i.e., gamma-aminobutyric acid; GABA) and excitatory (i.e., glutamate) amino acids (Glue, Nutt & Coupland, 1993). The immediate response to the perception of stress is secretion of catecholamines (i.e., norephinephrine and dopamine) into the blood stream and rapid changes made by sympathetic neurons that increase heart rate, blood pressure, pupil dilation, and respiration (Ursin & Olff, 1993). Parvocellular neurosecretory cells in the periventricular area of the hypothalamus release hypophysiotropic hormones (corticotropin-releasing factor; CRF) into a capillary bed on the floor of the third ventricle, which in turn act on the anterior lobe of the pituitary to release into the bloodstream adrenocorticotropic hormone

(ACTH; Bear, Connors, & Paradiso, 2001). Neuroendocrine CRF acts to mediate the peripheral responses to stress. ACTH acts on the adrenal cortex just above the kidneys to release cortisol, which is part of the slower longer-term neurohormonal response to the stressor (Campbell, Reece, & Mitchell, 1999). Nonendocrine CRF receptors (two known types mineralocorticoids and glucocorticoids; MRs & GRs) are located throughout the limbic system and neocortex, and mediate the central responses of the system and the feedback loop that modulates or arrests the response (Hayden-Hixson & Nemeroff, 1993). Nonendocrine endogenous CRF exerts a neurotransmitter-like action (for a comprehensive overview see Hayden-Hixson & Nemeroff, 1993; and Sutanto & De Kloet, 1993). The stress response has been classified into acute and chronic states, with acute reactions seen as healthy and adaptive responding to the environment, and chronic states being linked to health problems and decreased overall functioning (Lundberg, 2005; Selye, 1973). Physiological arousal and the complex neurological system changes triggered by the stress response have long been implicated in decreased cognitive performance, but research has provided mixed results.

The strongest data supporting cognitive impairments linked to stress come from research involved with aspects of memory. In particular, studies consistently show deficits with declarative memory (conscious recollection of previously learned material) that is postulated to be due to the actions of stress hormones in the hippocampus. A meta-analytic review of sixteen heterogenous memory studies found that cortisol given before recall (induced stress) impairs declarative memory retrieval (Het, Ramlow, & Wolf, 2005). The hippocampus is strongly implicated in the process of declarative memory (Squire, 1992). The memory impairments correlated with stress have been postulated to stem from the high density of corticosteroids receptors within the hippocampus that are activated during the stress response, which, when occupied, inhibit other hippocampal processes (Sauro, Jorgensen, & Pedlow, 2003). Human and animal studies reveal why these effects are posited to be deleterious in stress after chronic exposure to high levels of corticosteroids produce hippocampal dendritic atrophy and suppressive effects on neurogenesis (Lupien, et al., 1998; Shors, et al. 2001). Cognitive impairments have been thought to be also due to the increased levels of firing in the noradrenergic system, which is linked to the exaggerated attentional bias seen in anxiety disorders and the pronounced overcoding of specific stimuli (Glue, Nutt & Coupland, 1993). Norephinephrine neurons in the brain are derived from two groups of noradrenergic neurons. One group is located in the locus coerulus and serves to innervate forebrain regions including the hippocampus and cerebral cortex that are both implicated in memory and attentional systems (Stanford, 1993). Activation of the locus coerulus neurons during the stress response results in an increase of norephinephrine in the structures they innervate, and can ultimately result in a depletion of the neurotransmitter in regions such as the hypothalamus and amgdalya (Fillenz, 1990; Stanford, 1993). This depletion has been linked to an increase for stress vulnerability by depriving the system of an essential coping mechanism (Anisman & Zacharko, 1991).

Over the last hundred years the study of stress mechanisms and governing theories have become increasingly specific due to scientific advances in research. One of the most enduring theoretical viewpoints of stress began with Yerkes and Dodson, from their research with discrimination learning in mice, who proposed that moderate levels of stress were beneficial for performance, and that both high and low levels of stress impede performance (1908). The inverted U-shaped curve they postulated, which became known as the Yerkes-Dodson Law (variously described as task performance efficiency, performance anxiety, or stress arousal), is now used to explain a variety of cognitive and mental processes from the actions of plasma levels of neurotransmitters and hormones and noise level interference to electric shock responses in animal learning (Teigen, 1994). Elevated levels of catecholamines are considered an essential factor in coping with stress, but hyporesponses and hyperesponses both have adverse effect that adds to the assertion that there is an optimal physiological arousal state (Stanford, 1993). The discovery that epinephrine release levels were increased by stress was made by Cannon and de la Paz in 1911, who posited that individual differences in the animals' response to restraint were due to variations in emotional state. This led to the theory that it is essential to examine in an individual both the level of physiological arousal during the stress response (in terms of levels of hormones and neurotransmitters) and their own perception of their emotional state.

Relationship Between Self-Reported Stress and Cognitive Performance

Self-perception of stress can be measured through clinical interview or subjective tests evaluating the level of self-perceived stress an individual is experiencing. The cognitive appraisal of a stressor plays a major role in the interaction of the person and the stressful environment (Lazarus & Launier, 1978). There is a relative paucity of extant research on self-reported stress and cognitive performance, and most have used the related construct of anxiety to measure any effects. A study that measured self-reported anxiety in healthy adult males, using Spielberg's State and Trait Anxiety scales, found no correlation between self-reported anxiety and performance on a neuropsychological battery assessing attention, learning, memory, and perceptuo-motor speed (Waldstein, Ryan, Jenning, Muldoon, & Manuck, 1997). A study that measured self-reported stress levels using the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) during examination stress found that increased self-perceived stress was correlated with reduced performance on a task of attention (Vedhara, Hyde, Gilchrist, Tytherleigh, & Plummer, 2000). Vedhara and colleagues administered the PSS during an exam and non-exam period with sixty university students. The PSS scores indicated significantly higher stress during the exam period. The cognitive assessment measures were given once during each period and differences in performance were examined. Cognitive measures included a free recall task (short term memory; twenty words read aloud that participants were asked to recall immediately) and attention tasks from the Test of Everyday Attention (TEA; Robertson, Ward, Ridgeway, Nimmo-Smith, 1994). The TEA tasks included in the study were the elevator reversal task (auditory verbal working memory; tones indicate the elevator moving up or down and participants report the direction and count the floors), telephone search task (selective attention; two symbols appear next to entries in a telephone directory and participants identify entries where the two symbols are exactly alike), and a telephone search while counting backward (divided attention; the telephone search task with the addition of participants counting backward). During the exam period performance on the short term memory task improved significantly, while significant decreases in performance was found on the tasks of selective and divided attention. No differences were found in the task of auditory verbal working memory.

Overview of the Cognitive Construct of Attention

The construct of attention reflects a state of alertness that excludes certain stimuli while focusing specifically on other stimuli (Shapiro, 1994). Definitions of and research on attention are as varied and as copious as those for stress, but an overview of the processes involved and current theory are essential for clarifying the choice of tasks for this study. Attention is fundamental for a wide range of tasks, and, an argument could be made that all but the most basic functions of life require some form of attention. Researchers have gone as far as positing that there is no conscious perception without attention (Mack & Rock, 1998). Attention has been called one of the three key features of cognitive function: attention, memory formation, and memory consolidation (Mendl, 1999). There is a consensus of agreement that high levels of attention cannot be sustained indefinitely, and that there is a limit to the quantity and complexity of functions that an individual can attend to competently (Eysenck, 1995). This is in part due to physiological limitations of the brain.

The study of attention as a construct incorporates many different aspects of brain function, including the differentiation of external and internal stimuli. External stimuli are classified by the sensory systems, and the attentional systems play an important role in selecting which part of that information is processed by the brain. Therefore visual, auditory and tactile stimuli are all affected by attentional processes. Due to the myriad of processes that attention plays a role in, no specific nuclei are linked as being central to the process. Instead almost all brain regions are implicated in some form of task specific attention, with auditory, visual, spatial, and proprioceptive attention using varying regions and areas, such as the thalamus, the temporal, occipital, parietal and frontal lobes (Kolb & Wishaw, 1996). Attentional processes within each sensory system are classified into further constructs to aide in the study and description of different attention types. Sustained attention, as measured in laboratory tasks, is internally guided and can be thought of as "goal directed persistence" (Barkley, 1998). Selective attention is the act of differentially processing simultaneous sources of information (Bear, Connors, & Paradiso, 2001). Divided attention is closely related to selective attention, but the sources of information are processed simultaneously and not differentially (Matlin, 1994). In divided attention tasks, features are simultaneously monitored and same-different judgments are made to changes in any of the features (Bear, Connors, & Paradiso, 2001).

Early research into attention and stress emphasized visual attention and used different types of stressors (loud noise, heat, sleep deprivation). These studies reported that induced stress was related to decreased performance on sustained attention tasks such as pursuit meter task (tracking the movements of a pointer through poor visibility), and the serial reaction task (touching light bulbs as they illuminate randomly and sequentially)(e.g., Broadbent, 1954; Lazarus, Deese, & Osler, 1952; Rodnick, Rubin & Freeman, 1943; Sarason, 1957). It was postulated that fatiguing effects of stressors (lowered state of alertness) resulted in delayed reaction time that was considered to be due to momentary lapses of attention as well as shifts of attention. Fatigue can also be caused by a process of stimulus overload (i.e., continuous loud noise) that has similar effect on attentional processes (Smith, 1991). Research findings indicate that decisions are made with inadequate information in stressful situations, possibly a result of attention shifting or narrowing. On a multiple-choice analogies test, participants had to choose a word from six choices to complete an analogical phrase. Findings revealed that individuals threatened with a mild electric shock for poor performance provided a response before all alternatives had been considered (Keinan, 1987).

Current Aims & Hypotheses

Recent unpublished laboratory research investigating the link between self-reported stress and performance on neuropsychological tests, in an undergraduate population, revealed a significant correlation between increased self-reported stress (on the PSS) and reduced performance a task that included a divided attention component, as well as psychomotor processing speed and set-shifting demands (Comprehensive Trailmaking Test, Trial 5; Orem & Bedwell, unpublished). The current study aims to replicate this result and expand on it by adding a more demanding divided attention task. The hypothesis for this study is that individuals who report higher levels of self-perceived stress will exhibit greater performance decrements on Trial 5 of the Comprehensive Trailmaking Test (increased time to complete) and the new task of divided attention (increased omission errors). These tasks are described in the Methods section below.

Practical Implications

In today's increasingly technological world, multi-tasking (i.e., divided attention) has become an almost ubiquitous contributor to daily stress. In a variety of challenging professions (i.e., pilots, air-traffic controllers), the need for proficient divided attention skills are paramount for life and death safety issues, and the increased stress levels of these professions is well documented. This study will assess whether an individual's subjective perception of their stress level will correlate with performance on an objective task of divided attention. The results of this research may have practical safety implications for high-stress professions that require divided attention, as implementation of an efficient and inexpensive measure of self-reported stress may predict future job-related errors.

CHAPTER 2 – METHODS

Phase I

Participants for Phase 1

Participants for this study were recruited from a population of undergraduate students enrolled in psychology courses at the University of Central Florida (UCF). A total of 1,266 students participated, 229 of which were excluded due to the following criteria: one or more missing responses on any scale, or failure to met thresholds on two validity measures (see below). This left a total number of 1,037 valid participants. 73.5% of the respondents were female, and 26.5% of the respondents were male. The participants ranged in age from 18 to 48 years of age, with a mean age of 19.85, and a standard deviation of 3.61 years. 69.5% of the respondents identified themselves as Caucasian; 17% as Hispanic; 9.1% as African American; 4.1% as Asian; 0.2% as American Indian; and 0.2% as Pacific Islander. Phase I Perceived Stress Scale scores ranged from 4 – 36, with a mean of 18.82 and a standard deviation of 5.19.

Measures for Phase I

<u>Demographic Information (Appendix A)</u> The demographic section of the questionnaire included contact information, gender, age, race, class status (e.g., Freshman), major, employment situation, a screen for vision problems, and a screen for traumatic experiences.

<u>Perceived Stress Scale (PSS; Appendix B)</u> The version of the PSS that was used is a 10-item questionnaire (Cohen & Williamson, 1988), and is from one of the most common measures of self-perceived stress (Cohen, Kamarck, & Mermelstein, 1983). The Cronbach alpha coefficients reported for this scale ranges from 0.84 to 0.86. The items reflect a person's perception of the intensity of situational stressors they have experienced during the month prior

to completing the questionnaire. The respondent's appraisal of their stress level acted as a pre-selection process for the second phase of this study. Items in the PSS measure the extent that individuals report their lives as unpredictable, uncontrollable, and overloaded (Cohen, Kamarck, & Mermelstein, 1983). The format of the PSS is a Likert Scale with five rating choices, ranging from "never" to "very often" that respondents use to gauge the frequency of feelings they have experienced such as "control of irritations" and "confidence in ability to handle personal problems."

Infrequency Scale (Appendix C) An abbreviated 8-item scale designed from the Infrequency Scale of Personality Research Form was used to assess validity (Calkins, Curtis, Grove, & Iacono, 2004; Jackson, 1984). The scale includes items that almost every individual would endorse in a particular direction (e.g., I cannot remember a single occasion when I have ridden on a bus). Therefore, the scale measures whether participants responded in a random fashion or were attentive to the item content. Participants who endorsed more than one item in the wrong direction were excluded from the study.

The Marlowe-Crowne Social Desirability Scale (MC; Appendix D) An abbreviated 13-item scale (Reynolds, 1982) designed from the 33-itemed Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1960) was used to assess perception of social support and whether participants answered according to what they perceived to be socially appropriate responses. The 13-item form was found to have acceptable internal consistency reliability ($r = .76$) comparable to the standard form and other short forms (Reynolds, 1982). The 13-item version of the Marlowe-Crowne Social Desirability Scale was also found to have strong reliability with the Marlowe-Crowe Standard form ($r = .93$). Items in the MC are answered as true or false, and vary from whether the respondent thinks they are a good listener to whether they believe they are a jealous person. The use of the MC helped with exclusion criteria for phase II, by removing participants who scored high on social desirability (2 standard deviations above the mean) who might not have been reliable reporters of their stress level due to these factors.

Procedure Phase I

Participants completed online a brief questionnaire that included a stress scale, demographic information, and validity scales (see below). The questionnaire was posted on a departmental website, ExperimenTrak, which offers students a choice of different experiments for academic credit in a particular psychology course they are enrolled in. Participation in the study was voluntary, although most participants did receive academic credit. Phase I served as an initial screening phase to create a pool of participants that had sufficient variability and range of stress levels for Phase II.

Participants were directed to an informed consent webpage after they volunteered for the study. The webpage informed the participants about the study and they were asked to read the informed consent carefully before proceeding. Permission was requested from the participants to allow the investigator to contact them directly for future research studies.

After the informed consent, participants completed the online demographic questionnaire followed by questions from the three Phase 1 measures. The questions appeared in a fixed random order and included the 10-items from the Perceived Stress Scale, the 13-items from the Marlow-Crowne Social Desirability Scale, and the 8-item scale modeled after the Infrequency Scale. The total length of the questionnaire (excluding the initial demographic questions) consisted of 31 questions and took approximately 10 minutes to complete. Following the completion of all items on the questionnaire, the participants were given a debriefing form, which also included the opportunity to receive the study results. The debriefing forms included additional information about the purpose of the study as well as researcher contact information.

Phase II

Phase I participants were randomly selected across a broad range of stress levels and were invited to participate in Phase II. An attempt was made to evenly distribute age, gender, and race along the range of PSS scores. In accordance with Cohen's (1992) recommendations for power analysis, it was estimated that a minimum sample size of 41 participants would be needed for sufficient statistical power in Phase II. This estimate was based on an alpha level of .05, an estimated a Pearson's *r* of .41 (coefficient size based on earlier related unpublished data) and power of .80 for a two-tailed test. Participants indicating exposure to a psychological trauma (e.g., rape) were not invited to Phase II because of the potential for Posttraumatic Stress Disorder, which could have confounded the results.

A total of 54 students participated, and each gender was equally represented (27 female, 27 male). The participants ranged in age from 18.04 to 27.66 years of age, with a mean age of 19.79, and a standard deviation of 2.16 years. 70.4% of the respondents identified themselves as Caucasian; 16.7% as Hispanic; 9.3% as African American; and 3.7% as Asian. Age was not correlated with PSS scores ($r = .09$, $p = .50$). Similarly, there was no difference in PSS scores between genders [$t(52) = 0.75$, $p = .45$], or race categories [$F(3,50) = 1.72$, $p = .17$]. The Phase II PSS (paper and pencil) scores at the time cognitive testing ranged 5 – 31, with a mean of 17.57 and a standard deviation of 6.64.

Measures for Phase II

Visual Continuous Performance Test (V-CPT) The V-CPT task was created using Vigil/W v. 1.3.0 software package (ForThought, 1995). Stimuli were presented using a 22-inch

NEC Multisync FP 2141^{SB} monitor and PC computer. Responses were collected using a standard keyboard. The CPT task was modeled after the A-X version (Wohlberg & Kornetsky, 1973), in which a series of random single letters are presented and the participants is asked to press the spacebar after observing a target sequence of two letters. In the present study, the target consisted of the number “1” followed by the number “6,” which occurred 20% of the time. Stimuli were presented in the center of the monitor at a constant rate of 1400 ms, with the target appearing for 50 ms followed by the blank screen appearing for 1350 ms. Each number was approximately 1.5 cm wide and 1.5 cm high. The task began with one 30 second practice block consisting of 30 stimuli and 10 targets. The practice session had no decoys (i.e.; a number other than “1” followed by “6” or “6” followed by a letter other than “1”). White noise on the background was automatically generated by the software package, utilizing a software program setting of stimuli noise at 99 and background noise at 99. During the practice session, participants were given verbal feedback regarding their accuracy. Following the practice session, the full task was administered, consisting of 3 consecutive blocks. Each block contained 24 targets and 12 decoys randomly occurring within 120 total stimuli. Non-target stimuli consisted of random numbers. The total task duration was approximately 7 minutes.

A response was marked as a correct detection when the subject responded to target trials (“1” followed by “6”). Responses to non-targets were marked as a commission error while failure to respond to a target was marked as an omission error.

The developers of the CPT software program used in the present study established construct validity through comparison of a similar degraded version of the CPT with other tests known to measure similar constructs (ForThought, 1995). These tests included the Mesulam Figure Cancellation Tasks and the FAS Test. Results of these tests showed fair correlations with the Vigil CPT Test. Trails A & B, used as a comparison for discriminant validity, showed low correlations with the degraded AX (same as KA only different letters) version of the CPT. Test-retest reliability over a 3 months period for the degraded AX version of the CPT was adequate for errors of omission ($r = 0.67$), and errors of commission ($r = 0.79$).

Auditory Continuous Performance Test (A-CPT) The auditory CPT task was created using Vigil/W v. 1.3.0 software package (ForThought, 1995). Stimuli were presented using a PC computer with stereo speakers. The A-CPT task was modeled after the V-CPT described above, with several modifications. A series of random single letters were presented audibly (recorded male voice on computer) and the participant was asked to respond orally with the word "hit" when a target was heard ("K" followed by "A"). The researcher pressed a keyboard spacebar to indicate the oral response into the computerized accuracy monitoring software. Auditory stimuli were presented at a constant rate of 1400 ms by the computer (85 ms = target, 1315 ms = interstimulus interval. The A-CPT mirrored the same practice and full task protocols as described in the V-CPT section. The primary differences are: 1) the stimuli were letters instead of numbers; 2) stimuli were presented audibly instead of visually; and 3) participant indicated a response orally instead of pressing keyboard button.

Divided Attention Continuous Performance Test (DA-CPT) The DA-CPT consisted of the simultaneous performance of both the V-CPT and the A-CPT. Both the V-CPT and the A-CPT were the exact versions that were used when administered individually. The DA-CPT began with the simultaneous presentations of the practice sessions from the individual V-CPT and A-CPT. Verbal feedback was given prior to the start of the task. Then the full task was administered, which lasted 7 minutes.

The Comprehensive Trail Making Test, Trials 3 and 5 (CTMT) The Comprehensive Trail Making Test (Reynolds, 2002) is an alternate version of the original Trail Making Test (Partington & Leiter, 1949). Both Trials 3 and 5 of this task measure focal attention and psychomotor processing speed. Trial 3 required participants to draw a line to connect the numbers 1-25 (contained in black circles on the page) in order, as quickly as possible, while avoiding distractor circles on the page. Trial 5 was more cognitively demanding, as participants had to draw a line to connect the numbers 1-13 (chronologically) and letters A-L (alphabetically) in alternating order. In addition to measuring psychomotor speed, Trial 5 adds additional requirements of divided attention and set shifting (Reynolds, 2002). Participants were administered abbreviated practice trials prior to completing each scored trial. The performance index for each of the trials was the number of seconds required for successful completion. The divided attention change score for this measure was the number of seconds required to complete Trial 5 minus the number of seconds required to complete Trail 3.

The State Trait Anxiety Inventory (STAI; Appendix E) Only the "state" portion of the State Trait Anxiety Inventory was administered (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) - a 20-item questionnaire that is one of the most common measures of transient current (state) anxiety. The Cronbach alpha coefficient reported for this scale is .87 (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The items in the "state" portion reflect a person's perception of how they feel "right now, at the moment," and not how they generally feel. Items in the STAI are in the format of a Likert Scale with four rating choices, ranging from "not at all" to "very much so" that respondents use to gauge the frequency of feelings they have experienced such as "calm" and "nervous." The STAI will help separate longer, more chronic perceived stress (over the last month), from immediate situational anxiety.

Procedure for Phase II

Research was conducted in the Clinical Cognitive Neuroscience Laboratory (Howard Phillips Hall, Room 409-O) located on campus. The research appointment began with a detailed informed consent procedure with one of the investigators.

Participants were then re-administered the PSS (paper version) to measure their most current level of stress, and asked to complete a state anxiety questionnaire (see measures below). Once the questionnaires were completed (administration time of 5 minutes) participants were administered (in a fixed order) the Comprehensive Trail Making Test Trial 3 & 5 (CTMT; 5 min), the visual CPT (V-CPT; 7 min), the auditory CPT task (A-CPT; 7 min), and the divided attention CPT task (DA-CPT; 7 min). For all CPT tasks participants were oriented towards the computer screen by means of a chin rest positioned 18 cms from the monitor. Following the test administration, students were given a debriefing form, which also gave the opportunity to receive results about the study. The debriefing forms included information about the purpose of the study as well as researcher contact information.

CHAPTER 3 – RESULTS

The results were analyzed using SPSS for Windows version 12.0. All variables were screened for normality, using a Kolmogrov-Smirnov statistic with Lilliefors significance correction. Results of this normality check suggested that the primary CPT performance and Trail Making performance change scores were not normally distributed. However, kurtosis values for these variables did not exceed 1.73, suggesting that the shape of the distribution would not have a significant influence on the regression analyses, which are relatively robust to minor variations in the normality assumption.

A hierarchical regression analysis with $p_{in} = .05$ and $p_{out} = .10$ was used to assess whether, after controlling for the STAI score, total change in commission errors (combined modalities [auditory and visual]; dual minus single condition), total change in omission errors, and the trails difference score (Trail 5 – Trail 3) were significant predictors of scores on the PSS (Appendix F, Table 1). The STAI was entered first in the model and by itself was a significant predictor variable accounting for 57.4% of variance (adjusted R^2) in the PSS score, $F(1, 52) = 72.27$, $p <$ 0.001. In step 2, total change in commission errors, total change in omission errors, and the trails difference score, were added to the model, using the stepwise entry model. Only total change in omission errors accounted for a statistically significant amount of variance to the model, $t(53) =$ 2.23, $p = .03$, $r = .29$, medium effect size.

To further investigate the variance found in model 2 in the combined total omission score, the omission errors for the different modalities, auditory and visual, were investigated separately (Appendix F, Table 2). A hierarchical regression analysis with $p_{in} = .05$ and $p_{out} = .10$ was used and the STAI was entered first in the model. In step 2, the visual omission change score (dual minus single condition) and the auditory omission change score were added to the model using a stepwise entry. Only the auditory omission change score added a statistically significant amount of variance to the model, $t(53) = 2.78$, $p = .008$, $r = .36$, medium effect size (see Figure 1, Appendix G).

The final analysis was used to pinpoint whether the significant variance added to the model by the auditory omission change score was explained by either of the two components that constituted the variable, individual performance on the single and dual CPT auditory task (Appendix F, Table 3). A hierarchical regression analysis with $p_{in} = .05$ and $p_{out} = .10$ was used and the STAI was entered first in the model. In step 2, the single CPT auditory omission error score and the dual CPT auditory omission error score were added to the model using a stepwise entry. Only the dual CPT auditory omission error score added a statistically significant amount of variance to the model, $t(53) = 2.27$ $p = .028$, $r = .30$, medium effect size. The zero-order correlations among all of the variables are shown in Table 4 (Appendix F).

Discussion

The PSS was the main measure for formation of the participant pool for Phase II participants. The use of this instrument enabled the investigation of a wide range of perceived stress in college students. The PSS is designed to be a measure of stress over the previous month, which meant participants' scores did change between the time they took the measure online and in the laboratory (average time between PSS I and II = 18.5 days). However, the range of PSS scores obtained in Phase II spanned from the lowest percentile (<5%) to the highest percentile (>95%) of scores possible. The state portion of the STAI was used in an attempt to account for the participant's acute anxiety during the cognitive testing when attempting to examine chronic stress.

After controlling for the STAI, the cognitive measure that significantly predicted scores on the PSS was the combined omission errors change score on the CPT. This score was obtained by subtracting a participant's baseline single task omission error score within a modality (auditory or visual), from their score on that modality during the dual task condition. The scores from both modalities were then added together to create a total combined omission error change score. To further investigate this finding, the omission error change scores were analyzed separately by modality (visual and auditory), and only the auditory omission error change score significantly predicted scores on the PSS. A final analysis revealed that after separating the single auditory task from the dual auditory task (instead of a change score), only the dual task auditory omission error score was a significant predictor variable of scores on the PSS.

The dual task auditory omission error score was not significantly correlated with the PSS in the zero-order correlation (see Table 4). This may be due to the considerable amount of variance that is shared between chronic stress (PSS) and current anxiety (STAI). When that variance between the PSS and STAI is partialed out, the relationship between the dual task auditory omission error score and the PSS becomes statistically significant. This may indicate that it is the more chronic neurobiological consequences of stress that impair brain networks required in divided attention, while current transient anxiety has little effect (as suggested by the lack of a statistically significant zero-order correlation between dual auditory omission errors and STAI). Notably, when examining the partial correlation between the STAI and dual auditory omission errors (partialing out the PSS), a statistically significant "negative" correlation is found (r = -.27, p = .05). This suggests that acute anxiety may improve divided attention, while chronic stress impairs divided attention.

The difference between the neurobiological consequences of chronic versus acute stress may help elucidate this finding. Chronic cortisol elevation (from chronic stress) has deleterious effects, including hippocampal dendritic atrophy and suppressive effects on neurogenesis (Lupien, et al., 1998; Shors, Miesegaes, Beylin, Zhao, Rydel, & Gould, 2001); while acute stress (acute cortisol spike; top of inverted U function) appears to acutely enhance memory and attention (Diamond, Bennett, Fleshner, & Rose, 1992).

There has been some evidence to show that performance on auditory CPT's is generally poorer than performance on visual CPT's (Borgaro, Pogge, DeLuca, Bilginer, Stokes, & Harvey, 2003), but the emphasis on change scores (within modality) in the current study reduces the impact of this difference on the primary analyses. However, it is possible that a greater range of omission errors on the auditory CPT dual task (0-23), relative to the visual modality (0-14) allowed for more sensitivity to correlate with the PSS.

The cognitive resources that were used in the two CPT tasks can be differentiated into visual with a motor response and auditory with an oral response. Different modality-response type pairings used in future research may clarify how different pairings may influence the relationship to stress. This would clarify whether aspects of chronic self-perceived stress relates to selective attention to visual stimuli at the cost of input from other sensory modalities. However, our data suggests that irrespective of self-reported stress, individuals showed a greater increase in omission errors in the auditory portion of the dual task (mean increase of 4.94, *SD* = 3.70) than the visual portion of the dual task (mean increase of 2.19, *SD* = 2.98). It remains unclear if this is secondary to the response modality (motor vs. oral) or stimuli modality (auditory vs. visual).

Reaction time is often used as a measure of performance in CPT tasks, and has been shown to increase when performing the tasks on days with higher self-reported stress (Sliwinski, Smyth, Hofer, & Stawski, 2006). However, in this protocol, each individual's reaction time was not directly measured in the auditory CPT. Instead, the participant would verbally respond to a target and the researcher would press the space bar to record the response in the computer. Therefore, the reaction times were not analyzed as they were not a true reflection of the participants' times.

Similar to the study that found no correlation between self-reported anxiety, using the STAI, and performance, including Trailmaking A and B (Reitan, 1955) on a neuropsychological battery, (Waldstein, Ryan, Jenning, Muldoon, & Manuck, 1997), this study found no correlations between the STAI and the Trail tasks. The current study did not replicate previous unpublished laboratory research that found a significant correlation between increased self-reported stress (on the PSS) and reduced performance on Comprehensive Trailmaking Test, Trial 5 (Orem & Bedwell, unpublished). This warrants further investigation, as a possible spurious finding of this study was that 24.1% of Phase II participants completed the more complex Trial 5 faster than Trial 3. This is possibly due to a practice effect, as Trial 3 was always administered prior to Trial 5 and both involve visuomotor processing speed and similar task design.

There does not appear to be any literature that has specifically studied the relationship between performance on CPT tasks and self-perceived stress. The CPT has been used however, in a Swedish study that compared performance in female Chronic Burnout (CBO; assumed to be caused by chronic stress) patients to normal controls (NC). Statistically significant performance decrements on the visual and auditory CPT (Riccio, 2001), were found for the CBO patients in both modalities (Sandstrom, Rhodin, Lundberg, Olsson, & Nyberg, 2005).

A study that investigated self-perceived stress and found correlations with reduced performance on a task of attention and were significant predictors of PSS scores (Vedhara, Hyde, Gilchrist, Tytherleigh, & Plummer, 2000). Vedhara and colleagues administered the PSS during an exam and non-exam period, and the PSS scores indicated significantly higher stress during the exam period. Significant decreases in performance were found on tasks of selective and divided attention: the telephone search task (selective attention; two symbols appear next to entries in a telephone directory and participants identify entries where the two symbols are exactly alike), and a telephone search while counting backward (divided attention; the telephone search task with the addition of participants counting backward).

A number of limitations of the current study warrant consideration. The study participants were all college students, and these findings may be exclusive to this population. The participants' age range was restricted (18 - 27 years of age) to that of young adults, and their intelligence was likely to be above that of the average population, as evidenced by their acceptance into an institute of higher education. Also, their stressors are likely to be those experienced habitually and uniquely by this group, and tend to center around academic endeavors and finances. Future research may investigate whether these findings generalize to different populations, in particular working adults employed in high-stress occupations. An additional area of interest would be whether greater divided attention deficits are evidenced by retirees from high-stress occupations.

Another limitation is reliance on the self-report measure of chronic stress. Self-report measures often have inherent problems with construct validity and potential for over- or under-reporting distress. While there was an attempt to control for both underreporting (social desirability scale) and over-reporting (infrequency scale of personality), these scales cannot completely rule out the potential for these confounds within the PSS. The use of repeated cortisol measurements over an extended period of time (e.g., 1-2 months) may provide a more objective measure of biological chronic stress that is theoretically more directly related to changes in cognitive function.

In today's increasingly technological world, multi-tasking (i.e., divided attention) has become an almost ubiquitous contributor to daily stress. In a variety of challenging professions the need for proficient divided attention skills are paramount for life and death safety issues, and the increased stress levels of these professions is well documented. Chronic stress may lead to more human error in employment tasks that have divided attention demands. This study has implications that an individual's subjective perception of their stress level has detrimental effects on auditory stimuli during divided attention tasks. The results of this research may have practical safety implications for high-stress professions that require divided attention, as implementation of an efficient and inexpensive measure of self-reported stress may predict future job-related errors.

APPENDIX A
ONLINE DEMOGRAPHIC QUESTIONNAIRE

Online Demographic Questionnaire

Name:

Contact Information:

Gender: M / F

Date of Birth:

Race:

Which hand do you write with?

Major:

Based on completed credit hours choose your class standing:

Freshman	Sophomore	Junior	Senior

Please choose between: Part-time student (less than 12 credit hours)
Full-time student (12 or more credit hours)

How many hours a week do you work (for pay)?

How many hours a week do you spend volunteering (not paid)?

Do you have significant difficulty reading printed material (i.e., text books), even with the use of corrective lenses?

Have you recently experienced (within the last 12 months) and event that was traumatic (for example, but not limited to: death of a loved one, serious injury in an accident, rape)?
Choose: Yes/No

APPENDIX B
PERCEIVED STRESS SCALE

Perceived Stress Scale

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

Name ________________________________ Date ____________

Age _______ Gender (Circle) M / F

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

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

APPENDIX C
VALIDITY SCALE

VALIDITY SCALE

Note: These are all True/False. Need to make sure you score in appropriate direction for each item as some are reversed (obvious direction from looking at item).

There have been a number of occasions when people I know have said to hello to me.

I cannot remember a single occasion when I have ridden on a bus.

I find that I often walk with a limp which is the result of a skydiving accident.

There have been times when I have dialed a telephone number only to find that the number was busy.

I visited Easter Island last year.

I go at least once every two years to visit either northern Scotland or some parts of Scandinavia.

Sometimes I feel sleepy or tired.

On some occasions I have noticed that some other people are better dressed than myself.

APPENDIX D
ABBREVIATED MARLOWE-CROWNE SOCIAL DESIRABILITY SCALE

MARLOW-CROWNE SOCIAL DESIRABILITY SCALE

<u>Instructions:</u> If the statement is **true** or **mostly true**, as applied to you, click true (T). If a statement is **false** or **not usually true**, as applied to you, click false (F).

True False 1. It is sometimes hard for me to go on with my work if I am not encouraged.

True False 2. I sometimes feel resentful when I don't get my way.

True False 3. On a few occasions, I have given up doing something because I thought too little of my ability.

True False 4. There have been times when I felt like rebelling against people in Authority even though I knew they were right.

True False 5. No matter who I'm talking to, I'm always a good listener.

True False 6. There have been occasions when I took advantage of someone.

True False 7. I'm always willing to admit it when I make a mistake.

True False 8. I sometimes try to get even rather than forgive or forget.

True False 9. I am always courteous, even to people who are disagreeable.

True False 10. I have never been irked when people expressed ideas very different from my own.

True False 11. There have been times when I was quite jealous of the good fortune of others.

True False 12. I am sometimes irritated by people who ask favors of me.

True False 13. I have never deliberately said something that hurt someone's feelings.

APPENDIX E
STATE TRAIT ANXIETY INDEX

STAI Y-1

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

	Not at all	Some-what so	Moder-ately	Very much so
1. I feel calm ………………………………………......	(1)	(2)	(3)	(4)
2. I feel secure…………………………………………….	(1)	(2)	(3)	(4)
3. I feel tense …………………………………………….	(1)	(2)	(3)	(4)
4. I feel strained…………………………………………..	(1)	(2)	(3)	(4)
5. I feel at ease……………………………………………	(1)	(2)	(3)	(4)
6. I feel upset …………………………………………….	(1)	(2)	(3)	(4)
7. I am presently worrying over possible misfortunes……	(1)	(2)	(3)	(4)
8. I feel satisfied………………………………………….	(1)	(2)	(3)	(4)
9. I feel frightened ……………………………………….	(1)	(2)	(3)	(4)
10. I feel comfortable ……………………………………	(1)	(2)	(3)	(4)
11. I feel self-confident…………………………………..	(1)	(2)	(3)	(4)
12. I feel nervous …………………………………………	(1)	(2)	(3)	(4)
13. I feel jittery……………………………………………	(1)	(2)	(3)	(4)
14. I feel indecisive ………………………………………	(1)	(2)	(3)	(4)
15. I feel relaxed …………………………………………	(1)	(2)	(3)	(4)
16. I feel content …………………………………………	(1)	(2)	(3)	(4)
17. I feel worried …………………………………………	(1)	(2)	(3)	(4)
18. I feel confused ………………………………………..	(1)	(2)	(3)	(4)
19. I feel steady……………………………………………	(1)	(2)	(3)	(4)
20. I feel pleasant …………………………………………	(1)	(2)	(3)	(4)

APPENDIX F

TABLES 1-4 - HIERARCHICAL REGRESSION ANALYSES AND INTERCORRELATIONS

Table 1

Summary of Hierarchical Regression Analysis for Combined Change Score Variables Predicting Scores on the Perceived Stress Scale (N=54)

Variable	B	SE B	β
Step 1			
State Trait Anxiety	.439	.052	.763*
Step 2			
State Trait Anxiety	.436	.050	.758
Total change score omission errors	.243	.109	.193*

Note: Adjusted R^2 = .574 for Step 1; Adjusted R^2 = .604

Table 2

Summary of Hierarchical Regression Analysis for Auditory and Visual Omission Change Scores Predicting Scores on the Perceived Stress Scale (N=54)

Variable	B	SE B	β
Step 1			
State Trait Anxiety	.439	.052	.763*
Step 2			
State Trait Anxiety	.456	.049	.793
Auditory omission change score	.425	.153	.237*

Note: Adjusted R^2 = .574 for Step 1; Adjusted R^2 = .622

Table 3

Summary of Hierarchical Regression Analysis for Auditory Omission Variables Predicting Scores on the Perceived Stress Scale (N=54)

Variable	B	SE B	β
Step 1			
State Trait Anxiety	.439	.052	.763*
Step 2			
State Trait Anxiety	.436	.050	.758
Dual Auditory omission error score	.269	.119	.196*

Note: Adjusted R^2 = .574 for Step 1; Adjusted R^2 = .604

Table 4

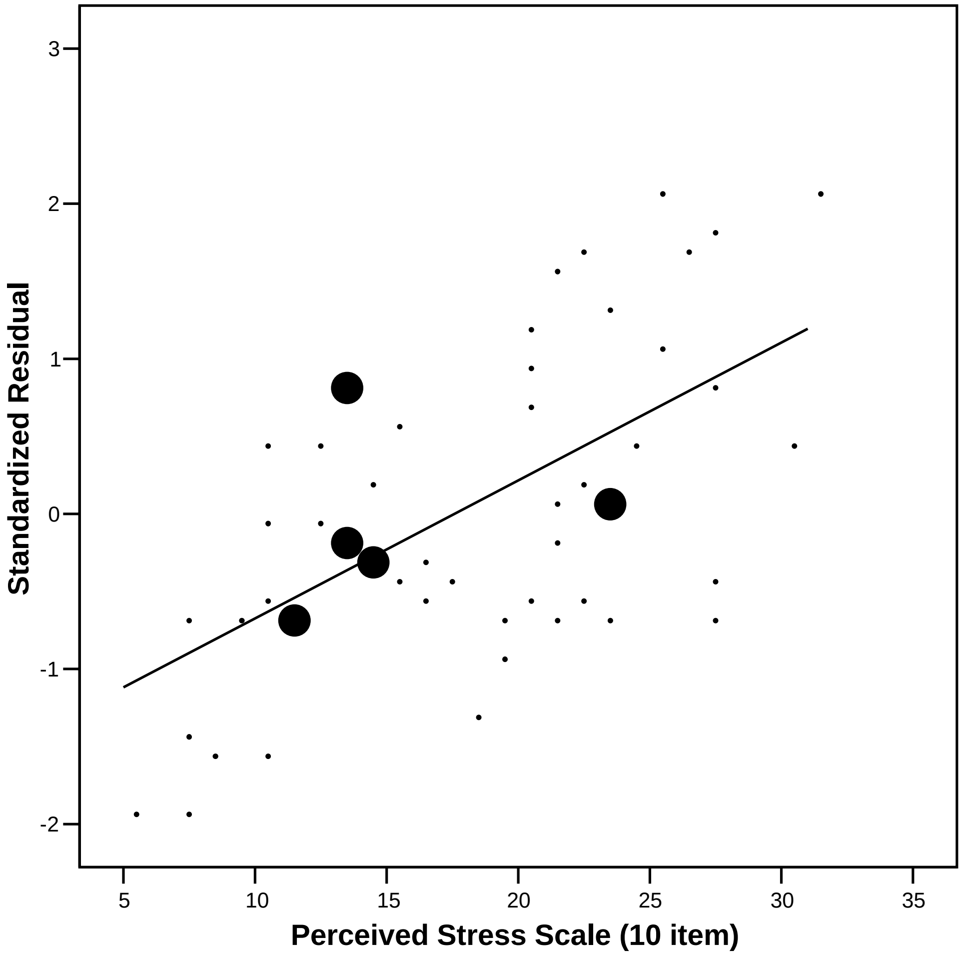
Pearson correlations among Cognitive and Psychological Measures and PSS scores

	PSS	STAI	Tr.3	Tr.5	o-a-s	o-v-s	o-a-d	o-v-d	c-a-s	c-v-s	c-a-d	c-v-d
PSS	--	.76**	.14	.09	.09	.03	.15	.22	.26	.01	.19	-.04
STAI		--	.13	.12	.07	.01	-.06	.20	.10	.01	-.01	-.10
Tr.3			--	.63**	-.01	-.01	-.02	.19	-.03	.09	-.01	.12
Tr. 5				--	.10	.09	.09	.25	-.09	.03	.02	.22
o-a-s					--	.25	.68**	.49**	.74**	-.11	.67**	.08
o-v-s						--	.22	.29*	.29*	.43**	.22	-.05
o-a-d							--	.46**	.53**	.02	.70*	.23
o-v-d								--	.36**	.02	.35**	.20
c-a-s									--	.05	.61**	.11
c-v-s										--	-.14	.09
c-a-d											--	.13
c-v-d												--

Note: * Statistically significant *r* at $p < .05$ (two-tailed); ** Statistically significant *r* at $p < .01$ (two-tailed); PSS = Perceived Stress Scale; STAI = State Trait Inventory; Tr. = The Comprehensive Trail Making Test; o = omission errors; c = commission errors; a = auditory Continuous Performance Test; v = visual Continuous Performance Test; s = single task; d = dual task

APPENDIX G
FIGURE 1 - STANDARDIZED RESIDUAL GRAPH

Figure 1



Standardized residual was derived from a hierarchical regression which first entered the State-Trait Anxiety Inventory (state only) score, followed by the change in ommission errors between the auditory dual and single task conditions.

Note: Larger circles represent a larger number of cases under that value.

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