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Academic Stress and Working Memory in Elementary School Students

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UNIVERSITY OF NORTHERN COLORADO
Greeley, Colorado
The Graduate School

ACADEMIC STRESS AND WORKING MEMORY
IN ELEMENTARY SCHOOL STUDENTS

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy

Maile Maria Blashill

College of Education and Behavioral Sciences
Department of School Psychology
School Psychology

July 2016
This Dissertation by: Maile Maria Blashill

Entitled: *Academic Stress and Working Memory in Elementary School Students*

has been approved as meeting the requirement for the Degree of Doctor of Philosophy in College of Education and Behavioral Sciences in School of School Psychology, Program of School Psychology

Accepted by the Doctoral Committee

________________________________________
Michelle Athanasiou, Ph.D., Research Advisor

________________________________________
Robyn Hess, Ph.D., Committee Member

________________________________________
Thomas Dunn, Ph.D., Committee Member

________________________________________
Marilyn Welsh, Ph.D., Faculty Representative

Date of Dissertation Defense ________________________________

Accepted by the Graduate School

________________________________________
Linda L. Black, Ed.D.
Associate Provost and Dean
Graduate School and International Admissions
ABSTRACT


Although it is sometimes believed that children do not suffer from stress and its negative consequences as adults do, children are equally affected by the harmful potential of excess stress. Because childhood is a period of rapid neurological growth, the effects of unnecessary stress may be more pronounced and enduring throughout the individual’s life. Past investigations suggest that individuals who experience excessive levels of psychological stress associated with anxiety show reduced executive functioning, especially within the area of working memory ability. Further, poor working memory has been shown to affect educational achievement across many different academic subjects. The purpose of this study was to investigate the nature of the relationships among academic stress, working memory, and academic achievement in elementary school students. This study represents a unique contribution to current research in this area by utilizing elementary-age participants and considering specific academic related stressors. Results of the multiple linear regression analyses utilized in the current study suggest that academic stress was a significant predictor of both verbal and visual-spatial working memory. Further, both verbal and visual-spatial working memory abilities were found to be significant mediators of the relationship between achievement and academic stress in these models.
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CHAPTER I

INTRODUCTION

Background

Stress can be defined as a physical or psychological force that causes bodily or emotional tension. The Hungarian endocrinologist Hans Selye (1936) was the first individual outside of the discipline of physics to popularize the term stress to describe a series of reactions experienced by his animal subjects when suffering significant stressors. Selye’s work on General Adaptation Syndrome examined the role and consequences of stress in relation to the body’s tendency toward homeostasis. When homeostasis is disturbed, an organism experiences stress in the form of an immediate sympathetic nervous response, which then forces the organism to compensate for changes its environment (e.g., see danger, feel stress, run) (Cannon, 1915). The physiological changes that occur during this survival response, such as the release of adrenaline, create the phenomenon of stress. The sympathetic nervous response and subsequent experience of stress can be highly adaptive in life-threatening situations; however, humans have developed a propensity to generalize the survival response to nonlife-threatening circumstances (e.g., feeling stress in anticipation of an exam, in reaction to traffic). In these situations of acute stress, there is no outlet for the increased strength and energy produced by the sympathetic nervous response. As the body returns to homeostasis, the breakdown of hormones and other physical remnants of this stress become maladaptive and negatively impact the human body and mind.
People may experience the phenomenon of psychological stress throughout their lifetimes. Although it is sometimes believed that children do not suffer from stress and its negative consequences as adults do, all types of stress are experienced by adults, as well as by children (Read, Perry, Moskowitz, & Connolly, 2001). While adults may be more aware of the causes and repercussions of stress, children are equally affected by the harmful potential of excess stress (Huber et al., 2006; Omizo, Omizo, & Suzuki, 1988). Because childhood is a period of rapid neurological growth, the effects of unnecessary stress may be more pronounced and enduring throughout the individual’s life (Eiland & Romeo, 2013; Meyers, 2009). Evans and Schamberg (2009) found that the greater the duration of childhood poverty from birth to age 13, the more the individual’s cognitive functioning was impacted, even into early adulthood. It can therefore be inferred that children are susceptible to the same injurious effects of excessive chronic stress that adults incur. Moreover, they may actually be more vulnerable (Band & Weisz, 1988; Read et al., 2001).

As dendritic connections are rapidly forming during childhood, this period of development is particularly susceptible to environmental factors that may contribute to the experience of excess stress. These early connections within the brain contribute to a lifelong predisposition to re-experiencing a stress reaction in novel situations (Read et al., 2001). The perception of stress and its impact on the physical body, emotions, and cognition is the result of a combination of several complex physiological mechanisms. The sympathetic nervous system initiates the sympathetic nervous response when the individual encounters a disturbance in the surrounding environment, with glucocorticoids, epinephrine, and other hormones serving as the catalysts of arousal.
Once the disturbance in the environment has passed, the parasympathetic nervous system brings the body back to the normal level of functioning.

Stress created by this activation and deactivation of the sympathetic nervous response affects several subregions of the prefrontal cortex. McLaughlin, Baran, and Conrad (2009) found that the medial prefrontal cortex in particular is more sensitive to the effects of stress than other forebrain structures and noted that increased levels of chronic stress were associated with fewer dendritic branches and decreased dendritic length. Additionally, different types of stress have been found to affect different subregions of the prefrontal cortex that contribute to cognitive functions such as inhibition, attention shifting, encoding, and temporary storage. In particular, excessive stress that affects the dorsolateral region impairs working memory ability (Arnsten, 2009; Popoli, Yan, McEwen, & Sanacora, 2011).

In childhood, stress reactions may result from a variety of environmental triggers. Miller and Smith (1994) defined three types of stress differentiating each by characteristics, duration, and symptoms. Acute stress is the most common form of stress and occurs in reaction to the daily demands of everyday life. A brief incident of acute stress can be an exhilarating sensation; however, repeated incidents will eventually lead to exhaustion. A child may experience acute stress resulting from the demands and pressures of everyday activities (e.g., meeting a new person, missing a homework assignment). However, the time between each episode of acute stress is interjected by periods of recovery without significant stressors.

Episodic stress is characterized by frequently occurring episodes of acute stress. Episodic stress in childhood may manifest as excessive shyness when encountering
strangers, an aversion to going to school, or becoming anxious when separating from their parents. Because it is a state of perpetual acute stress, individuals who experience episodic stress are easily over aroused, anxious, and tense (Miller & Smith, 1994).

Finally, chronic stress results from the seemingly unrelenting demands and pressures of severely stressful environments for extended periods of time. A characteristic of chronic stress is a sense of hopelessness and learned helplessness resulting from situations such as extreme poverty, abusive home environments, or bullying situations at school. It is distinct from episodic stress in that chronic stress involves long-term exposure to stressors, whereas episodic stress occurs much less frequently. Chronic stress becomes routine and generates a sense that it is inescapable and is often responsible for serious physical and psychological maladies such as decreased immune functions, heart disease, anxiety disorders, and depression (Miller & Smith, 1994).

Of these different types of stress, acute and episodic stress represent the vast majority of external stressors for most individuals. Causes and reactions to acute and episodic stress tend to relate to a child’s level of development. Because of infants’ and toddlers’ physical vulnerabilities, psychological stress experienced in early childhood is most often associated with attachment and separation of a caregiver (Haley & Stansbury, 2003). Stress may manifest as crying, frantic flailing of limbs, or withdrawal at this stage in development, as these expressions are limited to the physical capabilities of the individuals experiencing the stress. During the preschool years, stress tends to be associated with changes in daily routine or interruptions in expected patterns and can often be observed during the transition from a home setting into formal schooling.
Reactions to stress at this age may appear as crying, irritability, anxiety, trembling, sleeping problems, and eating problems.

During the elementary school years, the experience of stress becomes more complex and is often related to social relationships with peers, parents, and other adults such as teachers, as well as the occupational demands of multiple roles (e.g., student, athlete, artist) (Hart, Hodgkinson, Belcher, Hyman, & Cooley-Strickland, 2013). Stress at this stage of development may manifest itself in a variety of different behaviors: bullying, conduct problems, social withdrawal, depression, irritability, nightmares, problems with emotional regulation, and changes in academic performance (Compas, Connor-Smith, Saltzman, Thomsen, & Wadsworth, 2001; Gupta & Khan, 1987). Sources of stress at this age tend to be diverse and vary from individual to individual; however, an increased emphasis on the child’s role as a student is a common and pervasive factor among children at this stage of development.

A child within a formal educational setting is met with high expectations for both behavior and learning outcomes. Academic stress is the product of a combination of academic-related demands that exceed the adaptive resources of the individual (Kadapatti & Vijayalaxmi, 2012). It is the mental distress associated with academic failure, apprehension of such failure, or even an awareness of the possibility of failure (Gupta & Khan, 1987). Academic stress may be experienced as acute, episodic, and chronic depending on the external conditions creating the stress and the individual’s perception of the different stressors. When academic demands create short, infrequent increases in sympathetic nervous system arousal (e.g., increased stress on the day of an important exam) that are interjected with periods without significant stressors, the resulting stress
experience can be described as acute stress. If academic demands generate more frequent occurrences of stress (e.g., pop quizzes throughout the school year), the stress experience is episodic. Chronic academic stress results from frequent or constant demands of schoolwork that are a part of the individual’s ongoing routine and are perceived as being inescapable and never-ending. For students with learning challenges, each school day may represent overwhelming demands. Students at any level of education, from early childhood to post-secondary, may experience psychological stress associate with academic demands and are susceptible to the negative repercussions of episodic and chronic stress.

**Statement of the Problem**

It is estimated that U.S. students, ages 6-17 years, spend approximately one-third of their day in formal education settings (Juster, Stafford, & Ono, 2004). The significant amount of time dedicated to school emphasizes the child’s role as a student and the importance of academic performance. As academic stress results from academic-related demands that exceed the individual’s coping resources, a student’s increased awareness of the importance of personal academic success may lead to more frequent and intense experiences of academic stress. Some of the most prominent factors impacting academic stress include: evaluation procedures, homework material and load, attitude towards school, relationships with teachers and parents, expectations of teachers/parents/self, and peer relationships (Kadapatti & Vijayalaxmi, 2012; Verma & Gupta, 1990; Zeidner, 1994). Other factors influencing perceptions of academic stress have been linked to school climate, relationships between teachers and schools, and community resources (Barnett & McCormick, 2004; Jacobs, Samarasekera, Shen, Rajendran, & Hooi, 2013;
The combination of these internal and external factors contributes to students’ experiences of excessive psychological strain related to educational demands.

Excessive academic stress is often accompanied by physical and psychological impairment (Misra & McKean, 2000). When academic stress reaches an unhealthy level, students often experience a decrease in self-esteem and scholastic efficacy (Yusoff, Rahim, & Yaacob, 2010). Enduring stress for extended periods of time fosters a sense of burnout, reducing the students’ motivation to learn and undermining their confidence in abilities to perform. Moreover, excess stress also affects an individual’s physical and emotional wellbeing. If a student is experiencing a high allostatic load and subsequently suffers from poor health, participation in the classroom may therefore be limited (McEwen & Stellar, 1993). Similarly, high levels of stress have been associated with increased symptoms of depression and anxiety (Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005). Emotional problems caused by chronic stress can shape a child’s role as a student as well as social experiences with peers.

Maladaptive academic stress also affects the cognitive functions associated with learning. The pressure to perform in the classroom creates stress, which influences a student’s cognitive abilities and subsequent academic potential (Goleman, 1995). Because stress negatively affects executive functioning ability, working memory in particular, increased academic stress will likely affect working memory in a similar manner (Arnsten, 2009; Coy, O’Brien, Tabaczynski, Northern, & Carels, 2011; Deffenbacher, 1978; Hanson et al., 2010; Sapolsky, 1994; 2003; Popoli, et al, 2011). Within working memory, increased stress negatively affects the central executive and
phonological loop, which directly affect verbal comprehension and retention of verbal information (Moriya & Sugiura, 2012).

It is important to note that working memory is associated such academic skills as reading, writing, and language comprehension, and has been demonstrated as a mediator between academic stress and academic performance (Alloway et al., 2005; Daneman & Carpenter, 1980; Owens, Stevenson, Norgate, & Hadwin, 2008). Therefore, if students are experiencing academic stress, this may be negatively associated with their working memory abilities, and may also be associated with lower academic achievement. Because some students who perceive themselves as lacking academic self-efficacy may experience increased levels of academic stress, these students may also experience decreased academic achievement (mentioned above). Such decreases in achievement are likely to create more academic related stress, which may in turn affect working memory abilities. If working memory does indeed function as a mediator between perceived stress and academic achievement, high levels of academic stress may negatively affect academic achievement, and could create a cycle of increased stress and reduced cognitive functioning and academic achievement (Hilsman & Garber, 1995).

**Purpose of the Study**

Although students at all grade levels experience the phenomenon of academic stress (Leung & He, 2010; Verma & Gupta, 1990), the vast majority of research in this area has focused on adolescents and young adults. Additionally, some preliminary research has explored the relationships among academic stress, working memory, and academic achievement, but further information is required to gain a more thorough understanding of this process. By clarifying the connections among excessive levels of
academic stress, working memory, and academic achievement, efforts may be focused on reducing the levels of stress experienced by students. Students, parents, and educators may benefit from understanding student perceptions of this type of stress, addressing the sources of stress in a school setting, as well as investigating the cognitive and academic implications of excessive academic stress. Because of the need for additional research in this area, the purpose of the present study was to investigate the nature of the relationships among academic stress, working memory, and academic achievement in elementary school students. Based on previous literature, academic stress was conceptualized as affected by multiple factors both internal and external to the individual including: perceived teacher and parent expectations, homework load, perceived peer competition, and attitude toward school. The research questions follow.

**Research Questions**

Q1 To what extent is perceived academic stress associated with verbal working memory in elementary school students?

Q2 To what extent is perceived academic stress associated with visual-spatial working memory in elementary school students?

Q3 To what extent does verbal working memory serve as a mediator between perceived stress and academic achievement?

Q4 To what extent does visual-spatial working memory serve as a mediator between perceived stress and academic achievement?

**Definition of Terms**

*Academic Achievement* – the outcome of education. The extent to which a student has achieved her educational goals as demonstrated by objective measures of academic skills (Zimmerman, 1990).
**Academic Self-Efficacy** – a component of academic stress, students’ belief that they can successfully complete academic tasks (Hilsman & Garber, 1995).

**Academic Stress** – the perception of a discrepancy between environmental demands and one’s capacities to fulfill these demands that creates mental distress with respect to frustration associated with academic failure, apprehension of such failure, or even an awareness of the possibility of failure (Malach-Pines & Keinan, 2007; Topper, 2007; Gupta & Khan, 1987).

**Attentional Control Theory** – a framework for conceptualizing the relationship between stress, cognitive load, and performance. It states that cognitive energy is occupied by worry and diverted away from executive functions. Anxiety characteristically impairs processing efficiency of a task, in the form of both positive and negative attentional control, while increasing the need for on-task effort (Eysenck, Derakshan, Sontos, & Calvo, 2007).

**Attitude Toward School** – a component of academic stress, the perceived value of an educational experience (Kahlon, 1993).

**Expectations of Self** – a component of academic stress, the level of academic performance of which students believe themselves capable (Zeidner, 1994).

**Homework Load** – student perception of the amount of work given to be completed outside of class time (Zeidner, 1994).

**Parent Expectations** – a component of academic stress, the level of academic performance of which a parent or caregiver believes a student is capable (Verma & Gupta, 1990).
Peer Competition – a component of academic stress, the perceived need to vie with others for academic achievement and/or recognition (Clift & Thomas, 1983).

School Climate – a component of academic stress, the perceived atmosphere of student support given by teachers, administration, and other school staff (Shin, Lee, & Kim, 2009).

Stress – a physical or psychological force that causes bodily or emotional tension (Selye, 1936).

Teacher Expectations – a component of academic stress, the level of academic performance and classroom behavior a teacher believes a student is and should be capable of (Verma & Gupta, 1990).

Working Memory – an executive function of the prefrontal cortex with functions dependent on the parietal regions of the brain. The system that actively holds transitory information and allows for complex mental manipulation such as comprehension, reasoning, and learning of said information. It is comprised of the central executive and its slave systems: the phonological loop and visual-spatial sketchpad, which are mediated by the episodic buffer (Baddeley, 2010).

Summary

Because childhood is a period of rapid neurological growth, the effects of excessive levels of stress may be more pronounced and enduring throughout the individual’s life. Past investigations suggest that individuals who experience excessive levels of stress show reduced executive functioning, especially within the area of working memory. The aim of this study was to investigate the relationships among academic stress, working memory, and academic achievement in elementary school students.
CHAPTER II

LITERATURE REVIEW

Chronic low-level stress is detrimental to several aspects of an individual’s overall wellbeing, as it may be physically harmful and reduce both psychological and cognitive functioning. Past research has focused largely on the effects of acute and chronic stress (from a variety of stressors) on the physical body and on long-term health. However, more recent investigations have also explored the negative repercussions of excess stress from specific environmental stressors (e.g., work-related stress, academic stress) on a range of different functions: physical, psychological, and cognitive. Some such studies have examined the specific relationship between chronic stress and executive functions and have extended the findings to the realm of academic functioning. However, few of these have explored the effects of chronic psychological stress specifically on working memory, and even fewer have linked a particular source of stress (e.g., academic stress) to impairments in working memory and academic functioning.

The following review of the literature is a description of previous work in multiple areas of stress research. The mechanisms of the physiological response to stress as well as the implications of excessive levels of stress, including physical, psychological, and cognitive ramifications are discussed. Moreover, the experience of stress during childhood, as well as the phenomenon of academic-related stress, is examined. This review describes the evolution of Baddeley and Hitch’s 1974 model of working memory throughout the past three decades and the role of this model of working
memory in understanding the relationship among working memory, excessive levels of stress, and educational achievement.

The Negative Consequences of Excessive Stress

In mammals, the experience of stress occurs as a series of multifaceted neuroendocrine responses within two main systems that can be broadly categorized as the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic-adrenal-medullary (SAM) axis (Compas, 2006; Herman & Cullinan, 1997). When an individual encounters a threatening stimulus (physical or psychological) the amygdala sends a distress signal to the hypothalamus, which triggers the activation of both the SAM and HPA axes (Davis & Whalen, 2001). With the activation of the SAM axis, the catecholamines epinephrine and norepinephrine are released, causing increases in heart rate, respiration, blood pressure, and decrease the activity of the digestive system (Habib, Gold, & Chrousos, 2001; Whitnall, 1993). Activation of the HPA axis occurs simultaneously, although at a slower rate, and involves the secretion of corticotropin-releasing hormone and vasopressin from the hypothalamus, which stimulates the production of adrenocorticotropic hormone from the anterior pituitary gland, which in turn stimulates the adrenal gland to release several different stress hormones known as glucocorticoids, especially hydrocortisol, which acts on various tissues throughout the brain and body (Parkes, Rivest, Lee, Rivier, & Vale, 1993; Vale, Spiess, Rivier, & Rivier, 1981).

Together, these two systems increase physiological and emotional arousal and prepare the body for the sympathetic nervous response, or what is commonly known as the “fight or flight” response required to increase an individual’s chances of survival when encountering a stressor including: increased in heart rate and blood pressure,
dilation of pupils, constriction of blood vessels in the skin, increase in blood-glucose, skeletal muscle contraction, relaxation of the diaphragm and smooth muscle, and reduction of activity in nonessential biological systems (e.g., immune system, reproductive system) (Sapolsky, 1990; Sapolsky, Romero, & Munck, 2000). After the initial threat has passed, the process of recovery is triggered by glucocorticoids exerting negative feedback and slowing the release of corticotropin-releasing hormone and adrenocorticotropic hormone, returning the body to homeostasis (Herman & Cullinan, 1997; Sapolsky, 1992).

**Physical Effects**

While the stress response is integral as a survival mechanism, it has evolved to operate in response to acute, short-term stressors (Sapolsky, 1990). Prolonged activation of the SAM and HPA axes has detrimental effects on the components of the stress response systems, other areas of the brain, and the body (McEwen, 1998). McEwen and Stellar (1993) defined allostatic load as the physiological consequences of stress, which can be conceptualized as wear and tear on the body produced by repeated activation of biological stress response systems (e.g., elevated heart rate, increased cortisol levels), which contribute to physical disease and psychological disorders (McEwen, 2003). Within the area of physiological responses, an elevated allostatic load over an extended period of time can lead to a variety of negative physical consequences including: cardiovascular problems, gastrointestinal problems, decreased immune efficiency, as well as several other physical ailments (Chen, Mathews, & Boyce, 2002; Sapolsky, 1990; Sapolsky, 1994).
Although Hans Selye’s original description of stress referred to physical stressors such as pain, sleep deprivation, and restraint, modern research in the area of human stress suggests that psychological stress occurs as a result of conscious appraisal of threat of harm and can trigger the same physiological responses as a physical stressor (Gaab, Rhleder, Nater, & Ehlert, 2005; Sapolsky, 1994). Laboratory research with humans suggests that the HPA axis shows the highest level of activation and requires the longest time to recover in response to stressors that involve motivated performance, present a threat to self-evaluation, and are outside the control of the individual (Dickerson & Kemeny, 2004; Kirschbaum, Wüst, & Hellhammer, 1992).

In a meta-analysis of 10 studies involving Alzheimer’s patients, Russ and colleagues (2012) investigated the relationship between psychological stress and mortality rates. Their results suggest that increased psychological distress was positively associated with mortality from several different causes including cardiovascular disease and cancer (Russ et al., 2012). Moreover, for the past several decades, stress has been indisputably linked to gastrointestinal problems. In a review of past literature with nonhuman subjects (e.g., rodents, nonhuman primates), Caso, Leza, and Menchen (2008) suggested that psychological stress alters gastrointestinal mobility and ion release, and increases intestinal permeability leading to gastrointestinal disease. Similar findings in rodent subjects indicated that excess levels of stress are associated with functional bowel disorders, inflammatory bowel disease, peptic ulcers, and gastrointestinal reflux (Bhatia & Tandon, 2005).

An exploration of the effects of work-related stress on the physical health of adult humans by researchers van Steenbergen and Ellemers (2009) found that high levels of
chronic stress were associated with increased cholesterol levels, body mass index (BMI), and decreased physical stamina. Similarly, in a study of Korean high school students, increased levels of psychological stress, which centered on academic pressures, were associated with an increase in consumption of foods high in sugar (i.e., confectionaries, breads, candies/chocolates; Kim, Yang, Kim, & Lim, 2013). The results of these investigations suggest that increased stress is associated with unhealthy food choice and has a direct relationship with poor physical health in humans as measured by BMI, cholesterol levels, and physical stamina.

Immune system functioning is also impacted by stress. The results of a comparative analysis suggest that psychological stress decreases immune and metabolic functioning in both human and nonhuman subjects (Priyadarshini & Aich, 2012; Stein & Miller, 1993). Further, a meta-analysis of 30 years of research with humans revealed that acute stress resulting from brief, naturalistic stressors (e.g., exams) tend to suppress cellular immunity, while chronic stress suppresses cellular and humoral immunity (Segerstrom & Miller, 2004). Because excessive stress appears to decrease immune functioning, individuals experiencing high levels of stress are therefore more susceptible to attacks on their immune systems and will experience decreased overall health. Additionally, other physical consequences of excessive stress include muscle pain, hyper/hyposomnia, decreased sex drive, and lower rates of physical growth during development (Chen et al., 2002; Nephew & Bridges, 2011).

A significant amount of literature also exists regarding the neurological impact of excessive stress. Research involving nonhuman subjects has revealed a great deal about the mechanisms of the stress response and its effects on brain structures. In a study using
nonhuman primates, Joëls (2011) noted that stress and glucocorticoid elevations lead to a reduction in neuronal excitability, decreasing the efficiency of communication between neurons and their ability to interact with other cells in the body. Similar studies have also found that stress impairs synaptic plasticity and reduces neurogenesis (McEwen, 2012; Schoenfeld & Gould, 2012). Other research involving rodents has revealed sustained levels of stress hormones are associated with regression of synapses and decreased dendritic spines in both hippocampal and prefrontal neurons, both of which are indicated in higher level processing abilities such as attention and memory (Arnsten, 2009; Isgor, Kabbaj, Akil, & Watson, 2004; McEwen, 2012; McLaughlin et al., 2009; Popoli, et al., 2011).

Investigations involving human participants suggest a similar relationship between stress and its effect on brain structures. Specifically, increased cortisol levels are associated with decreased hippocampal and cortical gray matter volume, which may interrupt long-term potentiation (Rao, Leo, Haughton, Aubin-Faubert, & Bernardin, 1989; Sapolsky, 1994; Starkman, Gebarski, Berent, & Schteingart, 1992; Tessner, Walker, Dhruv, Hochman, & Hamann, 2007). It has been hypothesized that psychological stress affects the hippocampus, and thus affects memory, more than other brain structures because of the high concentration of both Type I and Type II glucocorticoid receptors within the structure (McEwen, De Kloet, & Rostene, 1986). Additionally, glucocorticoids have been found to reduce brain-derived neurotrophic factor (BDNF), which is known to promote neuron survival and growth, especially during adolescence (Issa, Wilson, Terry, & Pillai, 2010). The slow-acting glucocorticoids produce long-term changes in dendritic structure and neural atrophy, especially within the
hippocampus, leading to cognitive impairments in declarative memory, whereas the fast-acting catecholamines are believed to affect neurons that comprise the amygdala and may impair more emotionally laden memories (Sapolsky, 1990; Sapolsky, 1994; Starkman et al., 1992). Taken together, these findings suggest that prolonged exposure to psychological stress has a detrimental effect on individual neurons and larger brain structures, and consequently impedes general brain functioning.

**Psychological Effects**

In addition to the physical effects of excessive stress, chronic stress can also have an effect on an individual’s psychological wellbeing, and is specifically associated with internalizing symptoms and disorders such as depression and anxiety disorders (Grant, Compas, Thurm, McMahon, & Gipson, 2004; Mash & Barkley, 2003). Excessive levels of stress have also been known to decrease serotonin levels and are associated with increased levels of aggression, obsessive-compulsive behaviors, and incidence of depression (Duval et al., 2001). Other research has also suggested that environmental factors, such as excessive stress, are strongly implicated in the development of clinically significant depression (Brinker & Dozois, 2009; Heim & Binder, 2012; Morrison & O’Connor, 2005; Robinson & Alloy, 2003; Shively & Willard, 2012). Major depression can be characterized by symptoms including low mood, changes in sleep patterns, eating disturbances, feelings of worthlessness and hopelessness, and suicidal ideation (Grant, Guille, & Sen, 2013). The transactional model of the development of depression states that psychological stress negatively affects self-esteem, which subsequently increases these and other symptoms of depression (Bolton & Oatley, 1987; Roberts & Monroe, 1999). In an attempt to explain this connection between psychological stress and
depressive symptoms, Iwata, Ota, & Duman (2013) hypothesized that the protein complex, known as the inflammasome, acts as a central mediator by which physical and psychological stressors may contribute to the development of depression.

Anxiety, as another internalizing disorder, is also strongly associated with excessive psychological stress (Mash & Barkley, 2003). As the individual encounters a threat, activation of the amygdala triggers a series of automatic responses including emotional arousal, which may manifest as intrusive thoughts, impulsive behaviors, and escape behaviors (Compas et al., 2001). The perception of anxiety can be described as the experience of external stressors that evoke a series of unpleasant emotional reactions such as fear, nervousness, and tension (Wang et al., 2007). Unsurprisingly, excessive amounts of psychological stress have been found to be a significant predictor of the development of internalizing disorders such as anxiety (Harrington, 2001; Hicks et al. 2009, Jaser et al. 2005; Kendler et al. 1995, Kessing, Agerbo, & Mortensen, 2003).

In adolescents, multiple examinations of the relationship between stress and psychological wellbeing have uncovered that exposure to stress during adolescence is related to clinically significant symptomology including both major depression and anxiety (Byrne, Davenport, & Mazanov, 2007; Charbonneau, Mezulis, & Hyde, 2009; Moksnes, Moljord, Espnes & Byrne, 2010). Additional evidence suggests that rumination over stressful life events mediates the relationship between psychological stress and depressive symptoms in adolescents (Marks, Sobanski, and Hine, 2010; Skitch & Abela, 2008). Overall, these findings indicate a clear relationship between excessive levels of stress and negative repercussions on psychological functioning and subsequent behaviors (Ben-zur & Zeidner, 2012; Grzywacz & Bass, 2003).
High levels of psychological stress have also been associated with increased symptoms of depression and anxiety in children (Aronen et al., 2005). Juffer and colleagues (2011) noted that adopted children with early life stressors, adversity, and/or trauma tend to exhibit high rates of externalizing and internalizing behavior problems. Specifically, excessive levels of stress in children are associated with rapid changes in mood, irritability, agitation, aggression, oppositional behaviors, conduct problems, attention problems, hyperactivity, feelings of hopelessness, and a sense of isolation from others (Juffer et al., 2011; Smith, Segal, & Segal, 2013).

**Cognitive Effects**

Although the physical and psychological effects of stress have been well established, the investigation into the effects of stress on cognitive functioning is a burgeoning area of research. Optimal functioning of the stress response occurs in situations involving stimulation (i.e., acute transient exposure to a mild stressor) and may be reinforcing as exposure to acute stressors enhance dopaminergic transmission into the nucleus accumbens (Piazza & Le Moal, 1997; Sapolsky, 2003). Research involving nonhuman subjects suggests that the catecholamines increase glucose utilization in the brain (Cahill, Prins, Weber, & McGaugh, 1994; McGaugh, 1989). However, prolonged exposure to even a mild stressor may have aversive effects on hippocampal-dependent cognitive functioning (Sapolsky, 2003). The range of mild to severe and transient to chronic stressors and their relationships to optimal cognitive functioning forms an inverse-U pattern of enhanced functioning with mild, transient stressors and disruption of functioning with more severe, chronic stressors (Bodnoff et al. 1995; Conrad, Galea, Kuroda, & McEwen, 1996; Luine, Villegas, Martinez, and McEwen, 1994).
As discussed in the section above, chronic psychological stressors tend to inhibit neurological growth (Rao et al., 1989; Starkman et al., 1992; Tessner et al., 2007). Building on the idea that stress affects cognitive processes, Coy and colleagues (2011) explored the effects of naturalistic stressors (i.e., exams) on multiple components of working memory, suggesting that increased levels of cognitive interference are associated with higher levels of examination-related stress in adults. Moreover, chronic low-level stress decreases one’s ability to think critically and problem solve, as well as attend to a task at hand (Deffenbacher, 1978). One explanation for these findings may be that an increase in psychological stress occupies the limited cognitive energies that would otherwise be diverted to an individual’s executive functions (Eysenck & Calvo, 1992). Because working memory is a component of an individual’s executive functions, this explanation of limited cognitive energies may also explain the relationship between increased levels of stress and subsequent deficits in working memory abilities specifically. It has also been suggested that prefrontal cortex structures mediate the relationship between early life stressors and later deficits in executive functioning (Hanson et al., 2012; Sapolsky, 1994). Further, because the maturation of the prefrontal cortex during adolescence is delayed compared to the subcortical structures and other cortical regions, this period is particularly susceptible to long-lasting neural disruption from stressors (Casey, Giedd, & Thomas, 2000; Konrad, Firk, & Uhlhaas, 2013; Lenroot & Giedd, 2006; Leussis, Lawson, Stone, & Andersen, 2008).

Processing efficiency theory states that high levels of stress drain cognitive resources (Eysenck & Calvo, 1992). Building on the original concepts of the processing efficiency theory, Eysenck and colleagues (2007) developed the attentional control theory
for explaining the relationship between perceived stress (i.e., anxiety) and performance. Attentional control theory states that anxiety affects cognitive processing by: (1) occupying attentional and working memory resources and impairing performance; and (2) identifying the task as important, increasing the individual’s effort and improving performance. These effects suggest that increased physiological arousal occurring in reaction to perceived stress may have both an inhibitory and beneficial effect on cognitive functioning, in that higher order resources may be occupied, while attention and motivation for the task are increased. Further, this theory also suggests that perceived stress characteristically impairs two types of attentional control (i.e., negative/inhibitory and positive control) and tends to affect processing efficiency more than processing effectiveness (Eysenck et al., 2007). This suggestion indicates that situations that evoke high levels of perceived stress will tend to impair cognitive efficiency and will require extra on-task effort from the individual.

Utilizing a processing efficiency theoretical framework, Ng and Lee (2010) demonstrated that perceived stress (i.e., test anxiety) negatively affected processing efficiency in 10-year-old public school students in Singapore by inducing school-related psychological stress and measuring performance outcomes on a mathematics test. These findings suggest that acute naturalistic stressors (i.e., academic anxiety) may impair cognitive processing efficiency in individuals as young as 10 years old. Moreover, increased levels of academic stress resulted in decrease in academic performance on this measure of mathematics for these students. However, one potential limitation of this study is a lack of explanation of the role of working memory in this relationship between increased academic stress and academic performance.
Working Memory

The distinction between primary memory and long-term memory was first proposed by William James in 1890. Primary memory, which later became known as short-term memory, was described as having a limited capacity (James, 1890). The term working memory was first coined in the 1960’s by Miller, Galanter, and Pribram to describe the manipulation of temporary information held in the memory (Baddeley, 2010). As it is defined today, working memory describes an intricate system of holding information in the mind while performing complex mental tasks such as comprehension, reasoning, and learning (Atkinson & Shiffrin, 1971; Baddeley, 2010). It is distinct from short-term memory in that working memory is more than just simple recall. It allows for both manipulation and synthesis of information taken in by the sensory memory (Baddeley & Hitch, 1974).

Building on the work of Miller and colleagues, researchers Atkinson and Shiffrin (1968) formulated a model of sensory, working, and long-term memory, which was collectively referred to as the modal model of memory and serves as a framework from which later researchers understood the construct of human memory (Baddeley & Hitch, 1974). However, this model of working memory encountered two major problems: the assumption that maintenance of material alone triggers long-term learning and the assumption that the absence of short-term memory would create an inability to learn new information (Baddeley, 2003). Both of these assumptions proved false as the degree of long-term learning depends more on associations with meaning rather than maintenance and the fact that patients with impaired short-term memory appear to show normal long-term learning (Baddeley & Hitch, 1974; Craik & Lockhart, 1972).
Baddeley and Hitch (1974) attempted to address these discrepancies in the model by proposing a three-component model, arguing that working memory is comprised of multiple subsystems that hold and allow for manipulation of information. As it was originally conceptualized, the multicomponent model suggested that the central executive is responsible for directing attention to relevant information, suppressing irrelevant information, and coordinating cognitive processes of the slave systems, which consisted of the phonological loop and the visuo-spatial sketchpad (Baddeley, 2000; Baddeley & Hitch, 1974). A fourth component was later added to the model, the episodic buffer, which holds representations that integrate phonological, visual, spatial, and semantic information (Baddeley, 2000).

As it exists today, Baddeley and Hitch’s multicomponent model of working memory consists of both fluid and crystallized systems that are represented by the central executive, which coordinates attention and integrates information from the two slave systems: the phonological loop and the visuo-spatial sketchpad, which are moderated by the episodic buffer (Baddeley, 2003). Because of the interconnections between working memory and other executive functions, it is difficult to isolate working memory from other abilities such as attention, planning, and inhibition. Within this model of working memory, executive functions including working memory, attention, and inhibition are all controlled by the central executive. The central executive acts as the supervisory system that controls the information to and from its slave systems. The phonological loop, consisting of two parts: the short-term phonological store and the articulatory rehearsal component, temporarily stores and refreshes verbal information. The visuo-spatial sketchpad stores visual and spatial information, and consists of the visual subsystem (e.g.,
shape, color) and a spatial subsystem. The episodic buffer is capable of holding multidimensional episodes or chunks of information, which combine visual, spatial, auditory information, and information from other senses such as taste or smell. It is accessible through conscious awareness and is appears to have a limited capacity of four chunks/episodes (Baddeley, 2000; 2007; 2010).

Research using neuroimaging indicates that the central executive component of working memory may recruit various areas of the prefrontal cortex and depends largely on the parietal regions of the brain. Further, it has been suggested that executive functions rely on a cerebral network of neurological structures and must be understood in terms of the interactions between these regions (Collette, Van der Linden, Juillerat, & Meulemans, 2003). Similar investigations of patients with selective deficits in phonological processing suggest that the phonological loop component of working memory is localized in the left hemisphere of the brain, specifically the inferior part of the parietal lobe (Paulesu, Frith, & Frackowiak, 1993; Shallice & Vallar, 1990). Further explorations indicate that the phonological store is localized within the supramarginal gyrus and the articulatory rehearsal process within Broca’s area (Paulesu et al., 1993).

Evidence for the localization of the visuo-spatial sketchpad within specific brain structures is much less clear. Some studies involving visuo-spatial sketchpad deficits suggest that this component of working memory may be controlled by a variety of different structures such as the frontal region of the right hemisphere and the posterior parietal lobe near the junction with the occipital lobe (Hanley, Young, & Pearson, 1991; Warrington & James, 1967). However, other investigations indicate that the spatial and visual working memory subsystems may activate different areas of the brain (Paulesu et
al., 1993; Jonides et al., 1993; Smith & Jonides, 1997). In regard to the possible localization of the episodic buffer, Baddeley (2013) stated that it may not be possible to identify a single area of the brain that is responsible for this component of the multicomponent model of working memory, as it may in fact be an emerging property of a number of different brain areas working together.

**Stress and Working Memory**

As discussed above, psychological stressors trigger the secretion of catecholamines and glucocorticoids, ratios of which vary depending on the level of exposure to the stressor and affect the delivery of oxygen and glucose to the brain (Manning, Ragozzino, & Gold, 1993; Sapolsky, 1994). Parfitt and colleagues (2012) found that while mild to moderate stress can improve memory, chronic stress negatively affects memory retention, a finding that can in part be explained by the inverse-U pattern of enhanced functioning with mild, transient stressors that may be mediated by catecholamines, which increase brain glucose levels (Bodnoff et al. 1995; Conrad et al., 1996; Luine et al., 1994; Sapolsky, 1994).

However, high levels of glucocorticoids have negative effects on learning and memory (Jenike & Albert, 1984; Newcomer, Craft, Hershey, Askins, & Bardgett, 1994; Starkman, Schteingart, & Schork, 1981; Varney, Alexander, & Macindoe, 1984; Wolkowitz, Reuss, & Weingartner, 1990). Individuals who experience high levels of chronic psychological stress associated with severe anxiety show reduced working memory ability (Beilock & Carr, 2005). Specifically, some evidence suggests that glucocorticoids disrupt the filtering process of irrelevant stimuli (Newcomer et al., 1994). Herman and Cullinan (1997) asserted that relationships between sub-cortical structures
that respond to stress (i.e., hippocampus, amygdala) and the prefrontal cortex affects working memory processes.

Investigations into the relationship between psychological stress and working memory have since revealed that chronic stress has been shown to impair both an individual’s inhibition and working memory abilities on a variety of different tasks (Al’Absi, Hugdal, & Lovallo, 2002; Elzinga & Roelofs, 2005; Hoffman & Al’Absi, 2004; Mika et al., 2012; Morgan, Doran, Steffian, Hazlett, & Southwick, 2006).

Specifically, some research suggests that increased stress negatively affects the central executive and phonological loop (Moriya & Sugiura, 2012), which directly affect verbal comprehension and retention of verbal information. Rapee (1993) hypothesized that adverse effects of naturalistic stressors would be more acute for the processes involving the phonological loop due to the fact that worrisome thoughts associated with anxiety typically involve verbal activity rather than imagery.

Other investigations have found that stress related deficits might be seen in difficult visual-spatial reasoning tasks as well as measures of processing speed involving high working memory load (Derakshan & Eysenck, 1997; Markham & Darke, 1991). Similarly, a longitudinal study exploring the effects of emotional abuse in childhood found that increased levels of stress in childhood were associated with decreased spatial working memory in adulthood (Majer, Nater, Lin, Capuron, & Reeves, 2010). The use of structural MRI scans with adolescents revealed that cumulative life stress and decreased spatial working memory are related to smaller volumes in the prefrontal cortex. Further explanations of these results suggest the development of prefrontal cortex structures determines the relationship between early life stressors and their effect on working
memory ability (Hanson et al., 2012). Taken together, the results of these studies suggest that excessive amounts of psychological stress are associated with decreased functioning across multiple components of the working memory system including the central executive, phonological loop, and visuo-spatial sketchpad.

**Stress in Childhood**

Childhood and adolescence are unique developmental periods with respect to stress sensitivity compared to their adult counterparts (Eiland & Romeo, 2013). The younger the child is at the time of the individual’s exposure to stressful life experiences, the more powerful and lasting are the biological effects (Sox & Greenfield, 2009). Charmandari and colleagues (2009) observed that for children who experience early life stressors, the prolonged activation of the stress response can initiate long-standing and serious issues in a child’s development including endocrine, metabolic, autoimmune, and psychological problems. Current research suggests that the stress response has a strong influence on physical growth patterns of children, as the activation of the HPA axis reduces appetite and suppresses growth hormones (Dautzenberg et al., 2001; Johnson & Gunnar, 2011; Romero, Dickens, & Cyr, 2009). Moreover, early childhood stressors are associated with delayed catch-up relative to same-age peers (Rutter, 1979; Rutter & Sonuga-Barke, 2010; van Ijzendoorn, Bakermans-Kranenburg, & Juffer, 2007). The experience of excessive stress at an earlier age is also associated with later psychological problems (Compas 1987; Compas, Howell, Phares, Williams, & Giunta, 1989). Brain structures indicated in social, emotional, and behavioral regulation, (e.g., the cerebellum, prefrontal cortices, and parietal lobes) have been identified as particularly vulnerable to
early stressors (Bauer, Jeckel, & Luz, 2009; Carrion et al., 2009; De Bellis et al., 2002; Hanson et al., 2012; Richert, Carrion, Karchemskiy, & Reiss, 2006).

Executive function skills increase dramatically during early childhood and are believed to coincide with growth spurts in the frontal cortex, which occur between birth and 2 years, 7 and 9 years, throughout adolescence, and into early 20’s (Jurado & Rosselli, 2007; Willoughby, Wirth, & Blair, 2012). Although research involving the link between increased levels of psychological stress and the effect on executive functions of young children is limited, some evidence suggests that elevated cortisol levels are associated with lower performance on executive functioning tasks (Berry, 2013; Blair et al., 2011; Dawson, Ashman, & Carver, 2000; De Bellis et al., 2000; Hughes, 2011). However, results of other studies suggest that cortisol response to minor stressors is associated with increases in executive functions, specifically enhanced inhibitory control (Blair, Granger, & Peters Razza, 2005; Davis, Bruce & Gunnar, 2002). This discrepancy may be due to elevated cortisol levels noted in these studies staying within the typical range, and may therefore be reflective of the optimal levels believed to support executive functions (Davis, Bruce, & Gunnar, 2002).

Early childhood stressors are also linked to long-lasting alterations in neural development (Vanderwert et al., 2010). Glucocorticoids tend to reduce brain derived neurotrophic factor (BDNF) levels, which promote neuron survival and growth, especially in adolescents (Issa et al., 2010; Webster et al., 2002). Specifically, elevated glucocorticoid levels suppresses myelination, reducing amino acid levels in the hippocampi (Belanoff et al., 2001; Damsted et al., 2011). Further, stressors during childhood are linked to deficits in brain volume as well as decreased white and grey
matter, representing reduced neural connections and neuron volume, which can affect higher-order cognitive functions and are also associated with volumetric differences in limbic structures including the amygdala and hippocampus (Hart & Rubia, 2012; Mehta et al., 2009; Pyter, Adelson, & Nelson, 2007; Tottenham et al., 2010). Within the area of memory, stressors in childhood are associated with impairments in paired-associate learning tasks, spatial working memory, and episodic memory (Bos et al., 2009; Desmarais et al., 2012; Pollak et al. 2010).

In a longitudinal study, Evans and Kim (2013) found that childhood poverty is linked to elevated allostatic load even into early adulthood. Although an environment of poverty includes many factors other than psychological stress (e.g., poor nutrition, lack of healthcare), the results of this study underscore the potential ramifications of childhood experiences, which extend into adulthood. Other researchers have investigated the relationship between chronic stress and deficits in children’s executive functions as measured by attention control, working memory, inhibition, delay of gratification, and planning (Blair, 2010; Blair & Raver, 2012; Colvert et al., 2008; Pears et al., 2012). In a study involving low-income preschoolers, psychological stress was predictive of hypocortisolism, which was also predictive of higher risk for being overweight after controlling for nutrition, general health, and access to health care (Lumeng et al., 2014).

Overall, substantial evidence suggests that stress takes a double toll on children and adolescents compared to their adult counterparts (Compas, 2006). Children and adolescents who report high levels of psychological stress at are high risk for negative outcomes such as internalizing disorders, substance abuse, and low academic achievement (Galaif, Sussman, Chou, & Willis, 2003; Martin, Kazarian, & Breiter, 1995;
Sellers, Caldwell, Schmeelk-Cone & Zimmerman, 2003). It is also important to note that HPA activity that is affected by early stress can lead to long-term dysregulation of HPA responses to future stressors (Bruce et al., 2009; Dozier et al., 2006).

Individual differences in response to early stressors have created the need for explanations regarding the development of coping strategies and their role in perceived stress. Perceived stress refers to the relationship among external stressors, physiological stress responses, and the individual’s cognitive and emotional response to the stressors as within or exceeding the individual’s ability to deal with that particular stressor (Compas, 2006; Lazarus & Folkman, 1984). Adaptation to the stressor, or coping style, may be described as self-regulation in response to stress. Compas and colleagues (2001) proposed a dual process model of response to stress: automatic processes and controlled responses to stress (i.e., coping), which serves as an explanation of one of the factors indicated in differences between individuals and their reactions to psychological stress.

**Working Memory and Academic Achievement**

Cognitive functioning influences every aspect of a student’s participation in school. A classroom setting requires that a student is able to attend to and concentrate on instruction, utilize short-term and working memory, problem-solve, and inhibit distracting behavior (Gathercole, Lamont, & Alloway, 2006). Many different classroom activities require students to utilize their working memory abilities in particular. These tasks may be academic or may be part of daily classroom routines such as following multiple-step directions (Gathercole & Alloway, 2008; Gathercole et al., 2008; Gathercole et al., 2006). Further, poor working memory affects educational achievement across many different academic subjects (Gathercole et al., 2004; Swanson & Jerman,
2007; Swanson, Jerman, & Zheng, 2008). Students who have been identified as having special education needs are approximately six times more likely to have impairments in working memory ability than typical peers (Gathercole et al., 2006; Pickering & Gathercole, 2004; Sabol & Pianta, 2012).

Working memory has been implicated in several specific areas of academics. Mathematics is the most extensively researched academic area affected by working memory, including subareas such as mental addition, math skill, multi-digit operations, and general math achievement (Alloway & Passolunghi, 2011; Caviola, Mammarella, Cornoldi, & Lucangeli, 2012; Gathercole & Alloway, 2008; Heathcote, 1994; Bull, Espy, & Wiebe, 2008; Jarvis & Gathercole, 2003; Maybery & Do, 2003; Passolunghi, Mammarella, & Altoè, 2008). More recent investigations suggest that achievement in geometry is significantly linked to working memory abilities (Aydın & Ubuz, 2010; Giofrè et al., 2013).

General reading ability, as well as fluency and decoding skills, have also been linked to working memory (Carretti, Borella, Cornoldi, & De Beni, 2009; Dahlin, 2011; Gathercole & Alloway, 2008; Holmes & Gathercole, 2013). Working memory has also been implicated in nonverbal problem solving skills, written language skills, and language comprehension (Daneman & Carpenter, 1980; Rasmussen & Bisanz, 2005). Moreover, poor working memory ability is associated with academic problems and symptoms of anxiety and depression (Aronen, et al., 2005). Owens and colleagues (2008) found that verbal working memory accounted for approximately 51% of the association between stress and academic performance.
Preliminary evidence suggests that working memory training significantly improves achievement in math and reading (Dahlin, 2011; Holmes et al., 2009; Holmes & Gathercole, 2013). Moreover, cognitive load theory states that working memory constraints may reduce instructional effectiveness. Researchers have suggested that intrinsic cognitive load (e.g., originates from the material) should be maintained, however extrinsic (extraneous) cognitive load should be reduced in order to minimize depletion of cognitive energies as an unnecessarily high cognitive load may overwhelm the student (Halford, Cowan, & Andrews, 2007). Taken together, the findings of these investigations underscore the importance of working memory ability in a variety of academic areas by showing a positive association between improvements in working memory and achievement in multiple academic subjects. Additionally, because excessive psychological stress negatively affects different features of working memory, it has been hypothesized that working memory may act as the central mediator between psychological stress and academic achievement (Alloway et al., 2005; Daneman & Carpenter, 1980).

**Academic Stress**

While increased levels of stress may affect an individual’s role as a student, the role of the student also affects the individual’s experience of psychological stress. Academic stress can be conceptualized as mental distress with respect to frustration associated with fear of academic failure and is the product of a combination of academic related demands that exceed the adaptive resources available to the individual (Gupta & Khan, 1987; Kadapatti & Vijayalaxmi, 2012). Academic stress is psychological strain caused by a scholastic workload and the expectations of the student and other significant
individuals, such as teachers, parents, and peers. Numerous factors, both external and internal to the individual, contribute to a student’s experiences of academic stress.

Past research has identified several external factors that directly affect academic stress levels, including: evaluation procedures, homework material and load, expectations of teachers and parents, peer relationships, and study habits (Berg & Keinan, 1986; Clift & Thomas, 1983; Feld, 2011; Kadapatti & Vijayalaxmi, 2012; Kahlon, 1993; Verma & Gupta, 1990; Zeidner, 1994). More specifically, researchers Tan and Yates (2011) noted that high teacher and parental expectations of academic achievement were associated with increased levels of academic stress experienced by high school and college students. Additionally, parental support and positive relationships with teachers have been found to be protective factors in buffering the negative effects of academic stress (Dotterer & Lowe, 2011; Hilsman & Garber, 1995; Leung & He, 2010).

Other studies examining the competitive atmosphere of medical schools have revealed that competitive peer relationships are a direct result of grading procedures and school climate and contribute to an increased level of student stress (Jacobs et al., 2013). Similarly, changing teacher expectations, inconsistent instruction, classroom support, and community resources have been identified as significant factors influencing both academic achievement and student stress levels (Kadapatti & Vijayalaxmi, 2012; Torsheim & Wold, 2001). Notable internal factors that contribute to increased academic stress include: poor attitude towards school, poor relationships with teachers and parents, high expectations for one’s self, and lower cognitive ability (Kadapatti & Vijayalaxmi, 2012; Verma & Gupta, 1990). Conversely, a sense of academic self-efficacy has been found to be a protective factor in defending against the effects of academic stress.
(Dotterer & Lowe, 2011; Leung & He, 2010). Students’ direct interaction with these factors greatly influences their experiences of academic stress.

Currently, most work in the area of academic stress has been conducted with college age-students, with estimates of 20-40% of undergraduate and graduate college students experiencing academic-related stress that affects their academic performance (Misra & Castillo, 2004). Although college-age students have been the most extensively studied demographic group in regard to academic-related stress, surveys by Harris (2013) suggest that academic stress occurs equally as frequently among younger students, and affects approximately 50% of middle school students. It is estimated that 25-30% of high school students reported experiencing somatic symptoms (e.g., changes in sleep patterns, changes in eating behaviors) as a result of their academic-related stress (Harris, 2013).

Far less research has addressed elementary school students with regard to their experiences of academic stress. However, a few investigations have utilized parent opinions of elementary student stress. In a survey of parents from the San Francisco Bay area, 63% of parents reported that they believed that the amount of work expected of their elementary school student was a significant source of stress for the child. Moreover, 53% reported that they believe the pressure to excel in school was a significant stressor for their child (Loveless, 2007). However, this study reviewed only parent perceptions of the degree and sources of elementary student stress, and did not account for self-reported perceptions of stress by the students themselves. Researchers Bauwens and Hourcade (1992) explored the school-related sources of stress for elementary, middle, and high school students, from the students’ perspectives of their experiences of stress. Of the 197 student participants who completed the survey, approximately 60% of elementary the
elementary school students reported that schoolwork (e.g., tests, in-class assignments, and homework assignments) was a significant source of school-related stress. Moreover, schoolwork represented the most significant source of stress for student participants in this study (Bauwens & Hourcade, 1992).

Although excess stress can be maladaptive to a student and hinder academic potential, the experience of stress may also fall within a relatively healthy range. The difference between healthy and unhealthy levels of academic stress can be difficult to define and cannot be categorized by a single disparate feature. The influence of stress on academics resembles the general inverted-U theory of arousal and performance first proposed by Yerkes and Dodson in 1908 (as cited in Duffy, 1957). This theory states that individuals perform at their peak when they feel moderately aroused/stressed, and perform less well when experiencing no or extreme arousal (as cited in Duffy, 1957). Students who experience low levels of stress are more likely to demonstrate higher academic performance than students who experience little to no stress and students who experience excessive stress. It therefore appears that academic strain can sometimes act as a motivator, pushing students toward higher achievement.

However, as discussed above, excessive levels of academic stress may have a variety of detrimental effects. When academic stress reaches an unhealthy level, students often experience a decrease in self-esteem and academic efficacy (Yusoff et al., 2010). Enduring stress for extended periods of time fosters a sense of burnout, reducing the student’s motivation to learn and undermining confidence in ability to perform. Alternatively, some students react to the strain of academic demands with extreme effort. Feld (2011) noted that students enrolled in a high-achieving college preparatory school
often managed their rigorous academic schedules by neglecting to sleep. Although these
reactions to stress represent opposite ends of the coping spectrum, neither is an efficient
or effective means of managing stress related to academics.

Excess stress also affects a student’s physical and emotional wellbeing. Misra and
McKean (2000) noted that excess academic stress in college students was accompanied
by physical and psychological impairment. Because excessive levels of stress are
associated with decreased physical stamina, cellular immunity, and other physical
ailments, students experiencing a high allostatic load and subsequently suffer from poor
health may be limited in their classroom participation (Segerstrom & Miller, 2004; van
Steenbergen & Ellemers, 2009). When examining academic stress specifically, it has
been found that school-related stress is associated with increased consumption of high-
sugar foods and contributes to the development of a variety of health complaints (Aro,
Paronen, & Aro, 1987; Kim, Yang, Kim, & Lim, 2013; Torsheim & Wold, 2001; Wagner

Similarly, high levels of stress have been associated with increased symptoms of
depression and anxiety (Aronen et al., 2005; Byrne et al., 2007; Charbonneau et al., 2009;
2003). Possible explanations for the psychological effect of excessive academic stress
include excessive stress having been known to decrease serotonin levels and activate the
inflammasome complex (Duval et al., 2001; Iwata et al., 2012). Psychological problems
caused by chronic stress can shape a child’s role as a student as well as social experiences
with peers.
Increased levels of stress reduce cognitive functioning and affect an individual’s experiences across a wide range of environments, including academic settings. The pressure to succeed generates academic-related stress, which in turn negatively affects a student’s cognitive abilities and subsequent academic potential (Coy et al., 2011). Because chronic stress impairs working memory abilities, an individual who experiences stress for a long period of time is less able to participate in learning than a student who does not experience this stress. As different cognitive functions have been linked to a variety of academic skills and behaviors, it can therefore be surmised that chronic stress that negatively affects students’ cognitive functioning is also harmful to their learning and academic functioning (Coy et al., 2011; Deffenbacher 1978; Goleman, 1995).

Specifically, increased stress levels have been associated with decreased ability to perform arithmetic word problems (Amir & Bomyea, 2011). Some research suggests that increased stress and subsequent increase in glucocorticoids disrupts the filtering process of irrelevant stimuli and negatively affects components of working memory the central executive, phonological loop, and visuo-spatial sketchpad (Newcomer et al., 1994; Moriya & Sugiura, 2012).

**Conclusion**

Robust research exists demonstrating the relationship between excessive stress and its negative physical, psychological, and cognitive consequences. Specifically, investigations into the relationship between psychological stress and working memory have since revealed that chronic stress has been shown to impair working memory (Jenike & Albert, 1984; Herman & Cullinan, 1997; Mika et al., 2012; Newcomer et al., 1994; Starkman et al., 1981; Varney et al., 1984; Wolkowitz et al., 1990). Because
childhood and adolescence are unique developmental periods with respect to stress sensitivity, early exposure to stressful life events will have significant and lasting effects on these individuals (Eiland & Romeo, 2013).

Because children spend a significant amount of their day in formal educational settings, capturing the bidirectional relationship between stress and academic performance is pivotal in understanding the experiences of students in relation to their exposure to chronic stressors (Goleman, 1995). As working memory in particular is associated with writing skills, reading, and language comprehension, it can be inferred that working memory acts as a mediator between chronic psychological stress and academic achievement (Alloway et al., 2005; Daneman & Carpenter, 1980). Moreover, poor working memory ability is associated with academic problems and symptoms of anxiety and depression (Aronen et al., 2005). However, it is important to note that the majority of past research in the area of academic stress is relational and not necessarily causal. Therefore, it is difficult to say with certainty that excessive levels of stress in children directly influence physical, psychological, or cognitive deficits.

Although academic stress is encountered at all levels of education, the experiences of elementary school students have been somewhat neglected in past literature. Research in the area of academic stress has centered mainly on adolescent and college-age students. Therefore, less is currently known about the effect of academic stress on younger children. The question of whether elementary-aged children experience stress related to academics has not been entirely answered. Further, although some studies have explored the relationship between stress and working memory, and others have examined the role of executive functions in academic achievement, there is
currently a gap in the knowledge regarding the relationship between academic stress, working memory, and student achievement.
CHAPTER III

RESEARCH METHOD

The purpose of this study was to investigate the nature of the relationships among academic stress, working memory, and academic achievement in elementary school students. Based on previous literature, academic stress was conceptualized as students’ perceptions of internal and external factors relating to their experiences at school including: perceived teacher and parent expectations, homework load, perceived peer competition, attitude towards school, school climate, and academic self-efficacy (Berg & Keinan, 1986; Clift & Thomas, 1983; Feld, 2011; Kadapatti & Vijayalaxmi, 2012; Kahlon, 1993; Verma & Gupta, 1990; Zeidner, 1994). The design of this study was loosely based on the framework of attentional control theory, which provides an explanation for the reduction in storage and processing capacity of the working memory system when experiencing elevated levels of psychological stress (Eysenck et al., 2007).

Participants

Participants in this study included 41 fifth grade students from a public gifted and talented charter school with grades kindergarten through 8 in the Denver metro area. It is important note that at the time of data collection, one of the criteria for admission to the school was a minimum full-scale standard score of 125 on one of two standardized measures of cognitive ability. Therefore, these participants represent of a select group of students who are enrolled in a gifted and talented curriculum and may be exposed to different academic stressors than students enrolled in typical academic settings.
Additionally, their above average full-scale cognitive levels suggest relatively high working memory abilities for the group as a whole. Fifth grade students were chosen for this investigation based on evidence that students at this developmental level possess the cognitive abilities necessary to reflect on and describe their experiences of academic stress (Omizo et al., 1988). Further, because a central facet of attentional control theory depends on an individual’s central executive ability to moderate attention and working memory, it was considered developmentally appropriate to evaluate this process in fifth grade students whose executive functioning abilities are in the process of development (Baddeley, 2000; Eysenck et al., 2007).

A nonprobability, convenience sampling procedure was used in this study. Although the initial scope of this investigation examined the experiences of typical elementary school students rather than gifted and talented students, the sample utilized in this study was largely a result of the willingness of the school to participate in this study. Therefore, the generalizability of the findings was somewhat limited to gifted and talented elementary school students and may not necessary apply to typical elementary students. After initial contact was made with the district and the individual school, parents of potential participants were given information about the objectives of the study and the possible benefits and costs associated with their child’s participation. Specifically, letters recruiting individuals for the study as well as consent forms were sent home to the parents of all fifth grade students at the school (see Appendices C & D). Participants were also offered the opportunity to have their names entered into a lottery for their chance to win one of five gift cards to Barnes and Noble Bookstores.
Because of the nature of the measures used to collect data, exclusion criteria for participation in the study included: motor or vision impairments that would prevent the individual from tapping blocks or completing a multiple-choice test, verbal impairments that would prevent the individual from reciting verbal information to an examiner (e.g., selective mutism), and a history of significant verbal, reading, and/or nonverbal learning impairment (i.e., at least two grade levels below same-age peers) that could account for deficits in performance of verbal or visual-spatial working memory abilities.

Exclusionary criteria were explained in the consent form, which included a statement allowing individuals to self-select out of participation based on the above-mentioned criteria. However, none of the consent forms returned had selected this option. A total of 43 individuals returned consent forms, however two participants were unable to complete all of the measures during data collection due to time constraints, and were subsequently excluded from the data analyses.

Participants were asked to complete a demographics questionnaire, which included information regarding each student’s race, sex, age, years at current school, and parents’ education level (see Appendix A). It is important to note that because the question addressing parents’ levels education was not answered by 27 of the participants (66%), these data were excluded from the analyses. Although estimated family income levels could not be calculated based on these excluded data, an overall approximation of school socio-economic status (SES) can be inferred based on the relatively low percent of students who qualify for free or reduced lunch (2% of students). Because of the relatively high SES of the school as a whole, the generalizability of the findings of this study may be limited to students of similar SES backgrounds and may not describe the experiences
of other elementary school students. Details of the demographic information for the student sample can be found in Table 1. A comparison between the demographic makeup of the sample and the information available for the school suggests that the sample was relatively representative of the population of the school as a whole.

Table 1

Sample Demographics

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td>51</td>
</tr>
<tr>
<td>Male</td>
<td>20</td>
<td>49</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
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<td>61</td>
</tr>
<tr>
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<td>9</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Prefer not to Answer</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 years</td>
<td>23</td>
<td>56</td>
</tr>
<tr>
<td>11 years</td>
<td>17</td>
<td>42</td>
</tr>
<tr>
<td>Years at Current School</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>32</td>
</tr>
<tr>
<td>6</td>
<td>17</td>
<td>42</td>
</tr>
<tr>
<td>≤ 5</td>
<td>11</td>
<td>27</td>
</tr>
</tbody>
</table>

Instrumentation

Four main variables were examined in this study: (1) academic stress level, (2) academic achievement, (3) verbal working memory ability, and (4) visual-spatial working memory ability. In addition to a demographics questionnaire, this study utilized five instruments for data collection: the Letter-Number Sequencing subtest of the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003), the Backward Span of the Corsi Block-Tapping Task (Corsi, 1972), the Survey form of the Basic Achievement Skills Inventory, (BASI – Survey; Bardos, 2004), the Student Rating
of Environmental Stressors Scale (StRESS; Suldo, Dedrick, Shaunessy-Dedrick, Roth, & Ferron, 2015), and an Academic Stress Questionnaire (Do2Learn, 2010) (see Appendix B).

**Letter-Number Sequencing**

The Letter-Number Sequencing subtest (LNS) of the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003) was used to determine participants’ verbal working memory abilities. The LNS subtest is an untimed measure of working memory involving listening to and remembering a string of digits and letters read aloud, then recalling the information by repeating the numbers in numeric order, followed by the letters in alphabetical order. This instrument was selected based on its conceptual approach to assessing working memory. Specifically, it requires examinees to utilize not only temporarily storage for verbal information, but also to mentally manipulate this information and access the working memory system. Scores on the LNS subtest are measured in scaled scores that have a mean of 10 and a standard deviation of 3. The LNS subtest of the WISC-IV has an internal consistency of $r = .90$ and a test-retest reliability of $r = .83$ (WISC-IV; Wechsler, 2003).

**Backward Span of the Corsi Block-Tapping Task**

The Backward Span of the Corsi Block-Tapping Task (Corsi, 1972) was used to represent the participants’ visual-spatial working memory ability. It utilizes an apparatus consisting of a series of nine blocks arranged irregularly on a flat board. The blocks are tapped by the examiner in randomized sequences of increasing length. Immediately after a tapped sequence, the participant is asked to reproduce the sequence in reverse order. For the purposes of this investigation, the lengths of the sequences ranged from two
blocks to eight blocks, with two trials for each level. Blocks were tapped at the rate of one block per second. Although administration of this instrument is not standardized, administration procedures for this study were based on Corsi’s original design of the task and its past use in the field of neuropsychology (Berch, Krikorian, & Huha, 1998). Research assistants were trained on the administration procedures prior to data collection. Scores for this measure were calculated based on the number of sequences accurately reproduced. When used with 12 year olds, the Corsi Block-Tapping Task has been found to have a test-retest reliability of $r = .73$ and a $r = .36$ correlation with the Digit Span subtest of the WISC-R, suggesting a relatively weak relationship between these two measures of verbal and visual-spatial working memory (Orsini, 1994).

**Basic Achievement Skills Inventory - Survey**

The Survey form of the Basic Achievement Skills Inventory (BASI – Survey; Bardos, 2004) is a multi-level, norm-referenced achievement test that consists of two subtests measuring math and verbal skills. It is a timed measure of academic achievement that uses a multiple-choice response format. This measure was selected based on its ability to provide an overall view of academic functioning in the areas of math and verbal skills, as well as its group-administration format. Scores on the BASI – Survey are reported as standard scores, with a mean of 100 and a standard deviation of 15. When used with 12-year-old participants, internal consistency for the math subtest was found to be $r = .87$, and $r = .90$ for the verbal subtest. Test-retest reliabilities are $r = .55$ for the math subtest and $r = .63$ for the verbal subtest (Bardos, 2004).
**Academic Stress Questionnaire**

The Academic Stress Questionnaire (Do2Learn, 2010) is a Likert-scale survey designed for younger individuals using visual aids to help students identify their stress triggers. It consists of 65 items covering multiple sources of student stress, with potential responses ranging from “Does not bother me at all” to “I’m going to explode!” This instrument was selected based on its age appropriateness and its school-related stress content, which includes items measuring: attitude toward school, perceptions of workload, relationships with teachers and peers, perceptions of academic self-efficacy, and perceptions of classroom environment. This instrument has a readability of 3.9 as measured by the Flesch-Kincaid Grade Level Formula. Scores on the Academic Stress Questionnaire are reported as a raw sum of the endorsed items, with higher numbers representing greater levels of academic stress.

Scores on the Academic Stress Questionnaire have a possible range of 65-325. Psychometric properties including means, standard deviations, and internal consistency for this instrument were investigated during this study. It should be noted that one criterion for utilizing this instrument in the present study was a minimum Pearson correlation with the StRESS of $r = .80$, which would have suggested a strong correlation between the ASQ and an instrument with validated psychometrics. Consequently, due to the fact that the Academic Stress Questionnaire did not have adequate concurrent validity with the StRESS (correlation with StRESS $r = .61$) for which psychometric properties had been previously established, it was not utilized in the final data analyses.
Student Rating of Environmental Stressors Scale

The Student Rating of Environmental Stressors Scale (StRESS; Suldo et al., 2015) is a self-report measure of environmental stress relevant to students. It was initially developed to measure environmental stress levels in high school students enrolled in Advanced Placement and International Baccalaureate courses. It consists of 37 items ranging across the domains: Academic Requirements, Parent-Child Conflict, Academic and Social Struggles, Financial Problems, Cultural Issues, and Major Life Events. Test-retest reliability for the five factors of the StRESS exceed .70, while Cronbach Alpha reliability estimates range from .67-.88 (StRESS; Suldo et al., 2015). However, because this measure was created for use with adolescent children, the language and presentation was less tailored to elementary school students, therefore the scale was adapted by adjusting the vocabulary of some items to be more appropriate for elementary school students (e.g., problems related to romantic relationships was changed to problems related to friendships).

High scores on this measure indicate a high level of academic stress with possible self-rating scores ranging from 13-65. In addition to being utilized to validate the Academic Stress Questionnaire, the StRESS was ultimately used as the measure of student perceptions of academic stress (i.e., Academic Requirements subscale) and home related stress (i.e., Major Life Events subscale). The Academic Requirements subarea was used to measure the variable of academic stress and consists of 13 items with a test-retest reliability of .87. Items within this factor were related to academic demands such as: workload and requirements, difficulty of materials, and competition among peers. The Major Life Events subarea was used to measure the variable of home stress. The subarea
consists of 5 items with a test-retest reliability of .71 and questions related to potentially disruptive life events such as: a family move, divorce or separation, death or sickness of a family member, changes in living situations, and health concerns (Suldo et al., 2015).

**Procedure**

All sampling and methodological procedures were approved by the University of Northern Colorado’s Institutional Review Board (IRB) as well as the school district’s research director before data collection was initiated. After informed consent from parents and verbal assent from students was obtained, participants were asked to complete the instruments listed above. Participants were also asked to complete a demographics questionnaire, which included information regarding each student’s race, sex, age, number of years at current school, and parents’ education level (see Appendix A). It is important to note that because the question addressing parents’ levels education was not answered by 27 of the participants (66%), these data were excluded from the analyses.

Each participant completed the same five measures, however the demographics questionnaire, the BASI – Survey (Bardos, 2004) and the Academic Stress Questionnaire were administered in a group format, while LNS and the Corsi Block-Tapping Task were administered individually. Although counterbalancing the order of the administration of each instrument is a common method used to account for the effects of priming, past research in this area suggests that randomizing the order of administration may have created irrelevant differences in the measured stress levels of participants in the different groups (Kadapatti & Vijayalaxmi, 2012; Ng & Lee, 2010). Therefore, the order of administration of each instrument remained consistent for every participant (i.e., StRESS,
BASI – Survey, and demographics) in a group format and then LNS and Corsi Block-Tapping administered individually. Total time of participation in the study involved approximately 90 minutes for each participant.

Parents were informed that during the course study, if students were identified as experiencing high levels of academic stress, the principal investigator would notify their parents or guardians of the students’ perceptions of their stress levels via telephone for the purposes of intervention and stress reduction. High levels of academic stress were defined as responding with a 4 or 5 on at least 25% of the items on the Academic Stress Questionnaire. Over the course of data collection, no students were identified as experiencing high levels of stress, as defined above. Students’ identities and the identity of the school were kept confidential. Only the principal investigator and the research advisor have access to raw data and identifying information. All sources of raw data were stored in a locked file cabinet and on a password-secure laptop.

Data Analysis

Descriptive statistics were used to calculate means and frequencies for demographic information such as years at their current school, race, sex, and age. It should be noted that raw scores, as opposed to standard or scaled scores, from all instruments were utilized in data analysis procedures to allow for greater range and variability in participant scores. The following procedures were used to analyze the results.

Q1 To what extent is perceived academic stress associated with verbal working memory in elementary school students?

This question was addressed by constructing a simultaneous multiple linear regression model using participants’ raw scores on the LNS subtest of the WISC-IV as
the outcome variable and participants’ scores on the Academic Requirements subscale of the StRESS as the predictor variable of interest. The model contained terms to account for participants’ number of years at current school, perceived stress at home, and current level of academic achievement. The inclusion of these independent variables was based on the need to address potentially confounding sources of stress (i.e., transition stress and stress related to the home environment) as well as accounting for the relationship between achievement and working memory. Hypotheses for this analysis are listed below:

\[ H_0: \beta_1 = \beta_2 = \beta_3 = \ldots = \beta_k = 0 \]

\[ H_1: \text{At least one } \beta \neq 0 \]

**Q2** To what extent is perceived academic stress associated with visual-spatial working memory in elementary school students?

This question was addressed by constructing a simultaneous multiple linear regression model using participants’ scores on the Backward Span of the Corsi Block-Tapping Task as the outcome variable and participants’ scores on the Academic Requirements subscale of the StRESS as the predictor variable of interest. The model contained terms to adjust for participants’ current level of academic achievement, number of years at current school, and perceived stress at home. Hypotheses for this analysis are listed below:

\[ H_0: \beta_1 = \beta_2 = \beta_3 = \ldots = \beta_k = 0 \]

\[ H_1: \text{At least one } \beta \neq 0 \]
Q3 To what extent does verbal working memory serve as a mediator between perceived stress and academic achievement?

This question was addressed by conducting a series of simultaneous multiple linear regression (MLR) analyses. Scores on the BASI – Survey were used as the outcome variable while participants’ perceptions of academic stress (i.e., scores on the StRESS) was used as the predictor variable of interest while adjusting for verbal working memory ability using participants’ raw scores on the LNS subtest of the WISC-IV. If no significant relationship had been found between participants’ academic achievement and their perceptions of academic stress when adjusting for verbal working memory, this would have suggested that verbal working memory ability was a significant mediator of the relationship between academic achievement and academic stress in this model.

Hypotheses for these analyses are listed below:

H₀: β₁ = β₂ = β₃...βₖ = 0

H₁: At least one β ≠ 0

H₀: β₁ = β₂ = β₃...βₖ = 0

H₂: At least one β ≠ 0

H₀: β₁ = β₂ = β₃...βₖ = 0

H₃: At least one β ≠ 0

Q4 To what extent does visual-spatial working memory serve as a mediator between perceived stress and academic achievement?

This question was addressed by conducting a series of simultaneous multiple linear regression (MLR) analyses. Scores on the BASI – Survey were used as the outcome variable while participants’ perceptions of academic stress (i.e., scores on the StRESS) were used as the predictor variable of interest while adjusting for visual-spatial
working memory ability using participants’ scores on the Corsi Block-Tapping Task. If no significant relationship had been found between participants’ academic achievement and their perceptions of academic stress when adjusting for visual-spatial working memory, this would have suggested that visual-spatial working memory ability was a significant mediator of the relationship between academic achievement and academic stress in this model. Hypotheses for these analyses are listed below:

H₀: β₁ = β₂ = β₃...βₖ = 0
H₁: At least one β ≠ 0
H₀: β₁ = β₂ = β₃...βₖ = 0
H₂: At least one β ≠ 0
H₀: β₁ = β₂ = β₃...βₖ = 0
H₃: At least one β ≠ 0
CHAPTER IV

RESULTS

The purpose of this study was to investigate the nature of the relationships among academic stress, working memory ability, and academic achievement in elementary school students. Specific relationships between verbal working memory, visual-spatial working memory, and academic achievement were also examined. The demographics of the sample are discussed, followed by descriptions of the variables used in the multiple linear regression (MLR) analyses. Finally, each research questions is addressed using the results of a series of MLR analyses and by testing a potential mediator relationship between working memory, academic stress, and achievement.

Sample Performance

Participants in this study included 41 fifth grade students from a public gifted and talented kindergarten-eighth charter school in school in the Denver metro area. Mean achievement levels, which were converted to standard scores ($M = 100, SD = 15$) for the purposes of describing performance levels, indicate that the participants’ performances on the academic measures were relatively high for both verbal and math skills ($M = 127$ and $M = 121$, respectively). Additionally, the mean verbal and visual-spatial working memory abilities of the sample, which were also converted to scaled scores ($M = 10, SD = 3$), were within the high average and average ranges ($M = 13$ and $M = 11$, respectively). Additionally, overall perceptions of academic stress reported by participants were above average when compared to all possible self-report scores on this instrument ($M = 39$).
High self-report scores on the StRESS can be interpreted as relatively high levels of academic stress (scores between 52-65), while low self-report scores indicate relatively low levels of academic stress (13-26). See Table 2 for details of participant performance and self-ratings.

Table 2

**Participant Performance: Academic Stress, Achievement, Verbal Working Memory, and Visual-Spatial Working Memory**

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achievement</td>
<td>41</td>
<td>73.23</td>
<td>11.03</td>
</tr>
<tr>
<td>Academic Stress</td>
<td>41</td>
<td>49.80</td>
<td>10.17</td>
</tr>
<tr>
<td>V WM</td>
<td>41</td>
<td>12.98</td>
<td>5.33</td>
</tr>
<tr>
<td>V-S WM</td>
<td>41</td>
<td>10.46</td>
<td>6.02</td>
</tr>
</tbody>
</table>

*Note. Achievement = combined raw scores from the BASI Verbal and Math subtests; Academic Stress = Academic Requirements subscale of the StRESS; V WM = LNS; V-S WM = Backward Span of Corsi Block-Tapping Task.*

**Variable Characteristics**

Four main variables were examined: (1) academic stress level, (2) academic achievement, (3) verbal working memory ability, and (4) visual-spatial working memory ability. The multiple linear regression analyses used to address the primary research questions of this investigation require that independent and dependent variables share linear relationships. Therefore, an examination of scatter plots of participants’ working memory abilities and academic stress levels tested linearity among these variables. As discussed in the previous chapter, verbal working memory abilities were measured using LNS, visual-spatial working memory was measured using the Backwards Span of the Corsi Block-Tapping Task, academic achievement was measured using the raw scores on the BASI – Survey, and academic stress levels were measured using the Academic
Requirements subarea of the StRESS. Scatter plots revealed an indirect linear relationship between the variables of verbal working memory and academic stress level, as well as an indirect linear relationship between visual-spatial working memory and academic stress. This suggests direct proportionality in these relationships and indicates that the variables of academic stress level and working memory abilities can be appropriately included in subsequent multiple linear regression analyses.

For the research questions examining working memory as a potential mediator between academic stress and academic achievement, it was important to first test the significance of the relationships among working memory ability, academic stress level, and academic achievement. Pearson correlations were used to examine the relationships among these variables. However, due to the multiple comparisons between variables, a Bonferroni adjustment was utilized to reduce the familywise error rate, and an adjusted alpha level of .013 was used to test for significance among correlations. Significant correlations between verbal working memory, academic achievement, and academic stress levels were demonstrated (see Table 3). Similarly, visual-spatial working memory, academic achievement, and academic stress were also significantly correlated. The positive correlations between working memory and achievement suggests that high working memory abilities were associated with high academic achievement among participants. However, the negative correlations between academic stress levels and working memory abilities as well as between stress levels and achievement indicates that increased academic stress was associated with lower working memory abilities and lower academic achievement.
### Table 3

**Independent Variable Intercorrelations**

<table>
<thead>
<tr>
<th></th>
<th>Academic Stress</th>
<th>Achievement</th>
<th>V WM</th>
<th>V-S WM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Stress</td>
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</tr>
<tr>
<td>Achievement</td>
<td>-.27*</td>
<td>1.00</td>
<td>.</td>
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</tr>
<tr>
<td>V WM</td>
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<td>.44*</td>
<td>1.00</td>
<td>.</td>
</tr>
<tr>
<td>V-S WM</td>
<td>-.46*</td>
<td>.37*</td>
<td>.54*</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Note.* * indicates significance set at the .05 level (.013 adjusted)

Academic Stress = Academic Requirements subscale of the StRESS; Achievement = combined raw scores from the BASI Verbal and Math subtests; V WM = LNS; V-S WM = Backward Span of Corsi Block-Tapping Task.

Scatter plots of residuals, partial plots, and normal probability plots of residuals were used to test the assumptions of a multiple linear regression analysis. The assumption of multivariate normality was investigated by examining the Q-Q-Plots of each variable. Data for each variable were found to follow a normal distribution. Therefore, no transformations were required to interpret the multiple linear regression analyses. The underlying assumption of little to no multicollinearity in the data was explored using Pearson correlations among all independent variables. Because none of the correlations exceeded the threshold of \( r = .80 \), the analysis suggests that no two variables were closely related. Additionally, tolerance levels were not below .10 and Variance Inflation Factor (VIF) levels were below 10, indicating that independent variables did not significantly influence each other. It is also important to note that the dependent variables of verbal working memory, visual-spatial working memory, academic stress level, and academic achievement displayed similar amount of variance across the aforementioned independent variables.
Data Analysis and Results

All participants completed a battery of five instruments including: LNS, the Backward Span of the Corsi Block-Tapping Task, the StRESS, the BASI – Survey, and a demographics questionnaire. It is important to clarify that the BASI – Survey is composed of two subtests: Verbal Skills and Math Skills. Participants’ scores on each of these subtests were combined into an overall academic achievement score. Raw scores on each of these subtests were not transformed into standard scores, allowing for greater range in academic achievement scores. To account for potentially confounding variables related to participants’ perceived levels of stress, all analyses included terms for number of years at current school and perceived stress at home. A simultaneous data entry method was selected for the following MLR analyses based on the relatively small set of independent variables used in each analysis and for the purpose of investigating how much variance is represented by each independent variable included in the model.

Research Question 1

Q1 To what extent is perceived academic stress associated with verbal working memory in elementary school students?

To analyze Research Question 1, a simultaneous multiple regression model was constructed using participants’ scores on the LNS subtest as the outcome variable and participants’ scores on the Academic Requirements subarea of the StRESS as the predictor variable of interest. This model also contained combined verbal and math scores from the BASI – Survey to account for participants’ current level of academic achievement, scores from the Backward Span of the Corsi Block-Tapping Task to account for visual-spatial working memory abilities, as well as terms to account for
variability due to potentially confounding variables (i.e., number of years at current school and perceived stress level at home).

Table 4 displays the results of the predictor variables in the simultaneous multiple regression analysis. The model suggests that approximately 44% of the variance in verbal working memory abilities was accounted for by the predictor variables included in the analysis, $F(5, 34) = 5.36, p = .001, R^2 = .44$. However, considering the results of the beta weights and the statistical significance of each predictor variable, it appears that only academic achievement showed significance at the .05 alpha level, $b = .28, t = 2.10, p = .025$. This suggests that only academic achievement was statistically related to verbal working memory in this model. Examination of the correlation coefficient reveals that academic stress was not a significant predictor of verbal working memory in this model, $b = -.23, t = -1.50, p = .143$. See Table 4 for beta weights of predictor variables.

Table 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>p</th>
</tr>
</thead>
<tbody>
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<td>Academic Stress</td>
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<td>-.23</td>
<td>.143</td>
</tr>
<tr>
<td>V-S WM</td>
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<td>.39</td>
<td>.33</td>
<td>.053</td>
</tr>
<tr>
<td>Years Attended</td>
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<td>-.16</td>
<td>.240</td>
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<tr>
<td>Home Stress</td>
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<td>-.35</td>
<td>.949</td>
</tr>
<tr>
<td>Achievement</td>
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<td>.05</td>
<td>.28</td>
<td>.025</td>
</tr>
</tbody>
</table>

*Note. Academic Stress = Academic Requirements subarea of the StRESS; Achievement = combined raw scores from the BASI Verbal and Math subtests; V-S WM = Backward Span of Corsi Block-Tapping Task; Years Attended = number of years attended current school; Home Stress = Major Life Events subscale of the StRESS.*
Research Question 2

Q2 To what extent is perceived academic stress associated with visual-spatial working memory in elementary school students?

To address Research Question 2, a simultaneous multiple regression model was constructed using participants’ scores on the Corsi Block-Tapping Task as the outcome variable and participants’ scores on the Academic Requirements subarea of the StRESS as the predictor variable of interest. This model also contained combined verbal and math scores from the BASI – Survey to account for participants’ current level of academic achievement, scores from LNS, to account for verbal working memory abilities, as well as terms to account for variability due to potentially confounding variables (i.e., number of years at current school and perceived stress level at home).

Table 5 displays the results of the predictor variables in the simultaneous multiple regression analysis. The model suggests that approximately 47% of the variance in visual-spatial working memory abilities was accounted for by the predictor variables included in the analysis, $F (5, 34) = 5.92, p = .001, R^2 = .47$. A review of the correlation coefficients and statistical significance of each predictor variable indicates that academic stress showed significance at the .05 alpha level, $b = -.34, t = -2.41, p = .022$. Therefore, it can be inferred that academic stress level was a significant predictor of visual-spatial working memory and represented a statistically significant amount of the variance explained in this model.
Table 5

*Multiple Linear Regression Model with as the Visual-Spatial Working Memory as the Dependent Variable*

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Stress</td>
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<td>.01</td>
<td>-.34</td>
<td>.022</td>
</tr>
<tr>
<td>V WM</td>
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<td>.07</td>
<td>.32</td>
<td>.053</td>
</tr>
<tr>
<td>Years Attended</td>
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<td>.01</td>
<td>.971</td>
</tr>
<tr>
<td>Home Stress</td>
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<td>.09</td>
<td>-.25</td>
<td>.069</td>
</tr>
<tr>
<td>Achievement</td>
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<td>.02</td>
<td>.32</td>
<td>.041</td>
</tr>
</tbody>
</table>

*Note.* Academic Stress = Academic Requirements subscale of the StRESS; Achievement = combined raw scores from the BASI Verbal and Math subtests; V WM = LNS; Years Attended = number of years attended current school; Home Stress = Major Life Events subscale of the StRESS.

**Research Question 3**

Q3 To what extent does verbal working memory serve as a mediator between perceived stress and academic achievement?

Research Question 3 was addressed by conducting a series of multiple linear regression (MLR) analyses. First, examination of a correlation matrix and scatter plot revealed statistically significant relationships among the measures of verbal working memory, academic stress, and academic achievement. See Table 3 for the details of these correlations. For the following regression analyses, it is important to note that all models used to establish the mediator relationship contained terms to adjust for potentially confounding variables (e.g., number of years at current school and perceived stress at home). The relationship between academic achievement and verbal working memory ability was established by conducting a simultaneous MLR utilizing participants’ raw scores on the BASI – Survey as the outcome variable and participants’ raw scores on LNS as the predictor variable of interest, $b = .41, t = 2.78, p = .009$. Third, a significant
relationship between verbal working memory and academic stress was established by conducting a simultaneous MLR utilizing participants’ raw scores on LNS as the outcome variable and participants’ scores Academic Requirements subarea of the StRESS as the predictor variable of interest and included to terms to adjust for number of years at current school and perceived stress at home, $b = -.38, t = -2.51, p = .017$.

Finally, the mediator role of verbal working memory was tested by conducting a stepwise MLR utilizing participants’ academic achievement as measured by scores on the BASI – Survey as the outcome variable. Participants’ perceptions of academic stress became the predictor variable of interest while adjusting for verbal working memory ability using participants’ raw scores on the LNS subtest of the WISC-IV during the second step of the analyses procedure. No statistically significant relationship was found between participants’ academic achievement and their perceptions of academic stress when adjusting for verbal working memory, $b = -.19, t = 1.20, p = .236$. Therefore, verbal working memory ability was a significant mediator of the relationship between academic achievement and academic stress in this model. Please refer to Figure 1 for details of these relationships.
Figure 1. Standardized regression coefficients for the relationship between academic stress and academic achievement as mediated by verbal working memory. The standardized regression coefficient between academic stress and academic achievement, controlling for verbal working memory, is in parentheses. * indicates significance at the .05 alpha level.

Research Question 4

Q4 To what extent does visual-spatial working memory serve as a mediator between perceived stress and academic achievement?

This question was addressed by conducting a series of multiple linear regression (MLR) analyses. A correlation matrix and scatter plot was used to observe associations between measures of visual-spatial working memory, academic stress, and academic achievement (see Table 3 for details of these relationships). All models used to establish the mediator relationship contained terms to adjust for potentially confounding variables (e.g., number of years at current school and perceived stress at home). A statistically significant relationship between academic achievement and visual-spatial working memory ability was established by conducting a MLR analysis utilizing the sum of participants’ scores on the BASI – Survey as the outcome variable and participants’ scores on the Corsi Block-Tapping Task as the predictor variable of interest $b = .41, t = 2.86, p = .007$. Next, the relationship between visual-spatial working memory and academic stress was tested and found to be statistically significant by conducting a MLR analysis utilizing participants’ scores on the Corsi Block-Tapping Task as the outcome variable and participants’ scores on the Academic Stress Questionnaire as the predictor variable of interest $b = .38, t = 3.41, p < .001$. The standardized regression coefficient between visual-spatial working memory and academic stress, controlling for academic achievement, is in parentheses. * indicates significance at the .05 alpha level.
variable and participants’ scores on the Academic Requirements subarea of the StRESS as the predictor variable of interest $b = -0.46, t = -3.06, p = 0.004$.

Finally, the mediator role of visual-spatial working memory was examined by conducting a stepwise MLR analyses utilizing participants’ academic achievement as measured by scores on the BASI-Survey as the outcome variable. Participants’ perceptions of academic stress became the predictor variable of interest while including the variable of visual-spatial working memory ability in the second step of this model. No statistically significant relationship was found between participants’ academic achievement and their perceptions of academic stress when adjusting for visual-spatial working memory, $b = -0.24, t = 1.52, p = 0.138$. Therefore, visual-spatial working memory ability was a significant mediator of the relationship between academic achievement and academic stress in this model. See Figure 2 for details of these relationships.

![Diagram](image)

Figure 2. Standardized regression coefficients for the relationship between academic stress and academic achievement as mediated by visual-spatial working memory. The standardized regression coefficient between academic stress and academic achievement, controlling for visual-spatial working memory, is in parentheses. * indicates significance at the .05 alpha level.

**Post Hoc Analyses**

Research questions 1 and 2 utilized verbal and visual-spatial working memory abilities as outcome variables with academic stress level as the predictor variable of interest for both analyses. These multiple linear regression models also included
academic achievement, number of years at current school, home stress level, and verbal/visual-spatial working memory as additional independent variables. The initial notion of including the alternate working memory ability (i.e., including visual-spatial working memory as an independent variable for the verbal working memory outcome model and verbal working memory as an independent variable for the visual-spatial outcome model) was based on the multicomponent model, which conceptualizes verbal and visual-spatial working memory as controlled by different slave systems (Baddeley, 2010). Therefore, it was possible that each alternate working memory ability would hold unique variance in each model and would need to be accounted for among the other independent variables.

The nonsignificant result of the multiple linear regression model for research question 1 (i.e., academic stress level did not explain a significant amount of variance in verbal working memory) suggested that the model may have included too many independent variables, which masked the true significance of the independent variable of interest (i.e., academic stress level). To test this hypothesis, the analyses for research questions 1 and 2 were redesigned, excluding the alternate working memory abilities from the independent variables. A simultaneous multiple regression model was constructed using verbal working memory ability as the outcome variable. Independent variables in this model included: academic stress level (variable of interest), academic achievement, number of years at current school, and home stress level.

Table 6 displays the results of the predictor variables in the simultaneous multiple regression analysis. The model suggests that approximately 38% of the variance in verbal working memory abilities was accounted for by the four predictor variables included in
the analysis, $F(4, 35) = 5.24, p = .002, R^2 = .38$. When considering the beta weights and significance of each predictor variable, it appears that both academic stress level and academic achievement showed significance at the .05 level. Academic achievement represented the greatest amount of explained variance in verbal working memory, $b = .43, t = 3.05, p = .004$, while academic stress level also explained a significant amount of variance in this model, $b = -.38, t = -2.80, p = .008$. See table 6 for details.

These results suggest that both variables are statistically related to verbal working memory in this model and that the inclusion of the alternate working memory ability masked the significance of the other independent variables. Further, after reviewing the discrepancy between the original results of the analysis used to address research question 1 and the results of the post hoc analysis, it appears that verbal and visual-spatial working memory represented similar sources of variance and should not have been included as independent variables in the MLR models used to address questions 1 and 2.

Table 6

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>SE $B$</th>
<th>$\beta$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
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<td>-.38</td>
<td>.008</td>
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<tr>
<td>Achievement</td>
<td>.13</td>
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<td>.004</td>
</tr>
</tbody>
</table>

*Note.* Academic Stress = Academic Requirements subarea of the StRESS; Achievement = combined raw scores from the BASI Verbal and Math subtests; Years Attended = number of years attended current school; Home Stress = Major Life Events subscale of the StRESS.
To reanalyze research question 2, a simultaneous multiple regression model was constructed using visual-spatial working memory ability as the outcome variable and academic stress level as the predictor variable of interest. This model also contained the independent variables: academic achievement, number of years at current school, and perceived stress level at home. The model suggests that approximately 40% of the variance in visual-spatial working memory abilities was accounted for by the predictor variables included in the analysis, $F(4, 35) = 5.88, p = .001, R^2 = .40$. A review of the correlation coefficients and statistical significance of each predictor variable indicates that academic stress showed significance at the .05 alpha level, $b = -.46, t = -3.46, p = .001$. Therefore, it can be inferred that academic stress level was a significant predictor of visual-spatial working memory and represented a statistically significant amount of the variance explained in this model. See Table 7 for additional details.

Table 7

<table>
<thead>
<tr>
<th>Variable</th>
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<th>$SE$</th>
<th>$\beta$</th>
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</tr>
</thead>
<tbody>
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<td>.001</td>
</tr>
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<td>Years Attended</td>
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<td>Home Stress</td>
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<tr>
<td>Achievement</td>
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<td>.02</td>
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</table>

*Note.* Academic Stress = Academic Requirements subscale of the StRESS; Achievement = combined scores raw from the BASI Verbal and Math subtests; Years Attended = number of years attended current school; Home Stress = Major Life Events subscale of the StRESS.
Summary of Results

The results of this study suggest multifaceted relationships among the variables of perceived academic stress, academic achievement, and working memory abilities. Research questions 1 and 2 investigated the amount of variance in working memory abilities that was potentially explained by self-ratings of academic stress. When examining perceptions of academic stress as related to verbal working memory ability, initial analyses reveal that academic stress was not a significant predictor of verbal working memory in this model. However after redesigning the model to exclude visual-spatial working memory ability as an independent variable, academic stress level became a significant predictor of participants’ verbal working memory. When investigating perceptions of academic related stress and visual-spatial working memory ability, results of both multiple linear regression analyses indicate that academic stress level was a significant predictor of visual-spatial working memory and represented a statistically significant amount of the variance explained in these models.

Research questions 3 and 4 were concerned with the role of working memory as a potential mediator between academic achievement and student experiences of stress. Because no statistically significant relationship was found between participants’ academic achievement and their perceptions of academic stress when adjusting for working memory abilities, both verbal and visual-spatial working memory abilities were found to be significant mediators of the relationship between academic achievement and academic stress in these models.
CHAPTER V
DISCUSSION

The purpose of this study was to investigate the relationships among academic stress, working memory, and academic achievement in elementary school students. More specifically, the aim of this inquiry was to gain a better understanding of elementary students’ experiences with academic stress and to examine any potential associations with academic performance as well as with verbal and visual-spatial working memory abilities. This chapter provides an overview of the study, the procedures used, a presentation of results, discussion of the findings, and implications for practice. This chapter concludes with limitations of the study and recommendations for future research.

Background and Discussion of Findings

Students’ academic stress results from the perception of academic demands that exceed the individual’s coping resources. A student’s increased awareness of the importance of personal academic success may lead to frequent and intense experiences of academic stress, even at the elementary school level. Enduring stress for extended periods of time fosters a sense of burnout, reducing students’ motivation to learn and undermining their confidence in abilities to perform (Yusoff et al., 2010). A significant amount of past research suggests that excessive levels of stress affect the cognitive functions associated with learning, specifically impacting executive functioning abilities.

When examining working memory as a subarea of executive functioning, implications of past investigations indicate that increased stress negatively affects
multiple components of the working memory system including the central executive, phonological loop, and visuo-spatial sketchpad, directly impacting retention of verbal and visual information (Majer et al., 2010; Moriya & Sugiura, 2012). Working memory is associated such academic skills as reading, mathematics, writing skills, and language comprehension, and it has previously been demonstrated to be a mediator between academic stress and academic performance. Therefore, if students are experiencing academic stress, this may be negatively associated with their working memory abilities, and may also be associated with academic achievement.

The design of the study was based on the framework of attentional control theory, which provides an explanation for the reduction in storage and processing capacity of the working memory system when experiencing elevated levels of psychological stress (Eysenck et al., 2007). Because the vast majority of research in this area has focused on adolescents and young adults, this study was able to expand on the previous literature by exploring the experiences of elementary age students and their perceptions of academic-related stress. Additionally, this investigation provided more information regarding the relationship between academic stress and two different components of working memory (i.e., the phonological loop and visuo-spatial sketchpad), as well as their specific relationships with academic achievement.

**Academic Stress and Working Memory**

Findings from the current study suggested dissimilar relationships between participants’ perceived levels of academic stress and verbal versus visual-spatial working memory abilities. Results of the initial analysis addressing academic stress and its relationship with verbal working memory indicated that participants’ perceptions of
academic stress was not a significant predictor of verbal working memory ability. Although academic stress level and verbal working memory were negatively correlated, the inclusion of academic stress in the predictor model did not account for a significant amount of variance in overall verbal working memory ability. It can therefore be inferred that although an increase in academic stress was associated with a decrease in verbal working memory, this relationship was largely accounted for by the other variables included in the regression model and not by stress level alone.

The most likely explanation for the lack of a significant relationship between academic stress level and verbal working memory lay in the inclusion of visual-spatial working memory as an irrelevant independent variable in the regression model addressing variance in verbal working memory. Because verbal and visual-spatial working memory represented similar sources of variance, including each alternate working memory ability as independent variables in the MLR models used to address research questions 1 and 2 was not appropriate and masked the significance of the other independent variables. Results of the post hoc analyses, which excluded alternate working memory abilities (e.g., excluding visual-spatial working memory from the independent variables in the verbal working memory outcome MLR), suggest that academic stress level was a significant predictor of verbal working memory in this model, representing a significant relationship. Utilizing visual-spatial working memory as an independent variable within this analysis may have masked the significance of the independent variable of interest due to minor correlations between variables that were not great enough to violate the assumption of minimal multicollinearity (Andrews, 1974).
Removing visual-spatial working memory from the independent variables in the MLR model for research question 1 revealed that there was indeed a statistically significant relationship between academic stress level and verbal working memory ability. The result of this analysis suggests that increased academic stress was significantly related to a decrease in participants’ abilities to retain and mentally manipulate verbal information. These findings align with previous research, which has found that increased stress levels impaired functioning of the central executive and the phonological loop, directly impacting verbal comprehension and the retention of verbal information (Moriya & Sugiura, 2012). Additionally, previous research with high school and undergraduate students suggests considerable levels of academic-related stress among these populations affecting academic performance (Misra & Castillo, 2004). Research investigating this relationship in middle school students suggests a higher proportion of students who experience considerable academic stress associated with academic declines as well as somatic symptoms (Bauwens & Hourcade, 1992; Harris, 2013). These results indicate that the discrepancy between significance of academic stress between the initial MLR model and the post hoc MLR model for research question one was likely due to the inclusion of different independent variables in each analysis (i.e., excluding visual-spatial working memory in the model explaining variance in verbal working memory ability).

Results of both the initial and post hoc analyses addressing the relationship between stress levels and visual-spatial working memory suggest that participants’ perceptions of academic stress was a significant predictor of visual-spatial working memory ability, in that it accounted for a significant amount of variance in the model.
Specifically, an increase in academic stress level predicted a decrease in visual-spatial working memory as measured by the Corsi Block-Tapping Task. These findings demonstrate that differences in participants’ abilities to remember visual-spatial information was explained by the levels of academic stress experienced by individual students. It therefore appears that a decreased ability to retain visual-spatial information was associated with higher levels of academic stress. These results are concurrent with previous studies illustrating stress related deficits in difficult visual-spatial reasoning tasks involving high working memory load (Derakshan & Eysenck, 1997; Markham & Darke, 1991).

The results of the current study suggest somewhat dissimilar relationships between participants’ perceived levels of academic stress and verbal versus visual-spatial working memory abilities. Although academic stress was found to be a significant predictor of participants’ visual-spatial working memory in both initial and post hoc analyses, academic stress was not found to be a significant predictor of verbal working memory during the initial analysis, but became significant after removing the independent variable of visual-spatial working memory from the model. This may suggest a stronger relationship between stress levels and the retention of visual-spatial information compared to verbal information in this study. A possible explanation for this difference may be related to the neurological pathways associated with each type of working memory (i.e., phonological loop versus visuo-spatial sketchpad).

Differences between the neurological pathways of the phonological loop and visuo-spatial sketchpad offer a theoretical explanation for these somewhat discrepant findings. Studies utilizing neuroimaging suggest that the visuo-spatial sketchpad
component of working memory may be controlled by a greater variety of brain structures compared to the phonological loop (Paulesu et al., 1993; Jonides et al., 1993; Smith & Jonides, 1997). High levels of stress that may be affecting multiple areas of the brain are therefore more likely to affect temporary retrieval of visual-spatial information compared to auditory information. This explanation could account for the differences in the relationships among verbal versus visual-spatial working memory found in this study.

Overall these findings suggest that processing and mental manipulation of visual-spatial and verbal information was significantly related to higher levels of perceived academic stress. Because of the relatively stronger relationship between stress level and visual-spatial working memory, it is feasible that the perception of academic related stress interferes more with an individual’s ability to process and manipulate visual-spatial information compared to verbal information. Markham and Darke (1991) hypothesized that relatively automatic verbal information would not be affected by increased levels of psychological stress in the same way as complex verbal information. It is therefore possible that the verbal stimuli presented during the LNS task was moderately automatic and was less affected by increased levels of academic stress for this reason.

**Working Memory as a Mediator between Stress and Achievement**

The results of the analyses exploring verbal working memory as a potential mediator between academic achievement and academic stress revealed that verbal working memory ability was a significant mediator of the relationship between achievement and stress in this model. This relationship can be identified as a lack of a significant association between participants’ academic achievement and their perceptions of academic stress when adjusting for verbal working memory. This model suggests that
an increase in academic stress would likely be related to a decrease in verbal working memory ability. A decrease in verbal working memory ability would correspond to a similar decrease in academic achievement.

Therefore, students who experience higher levels of academic related stress tend to show a decreased ability to recall verbal information as well as lower academic achievement. This mediator analysis suggest that the relationship between higher levels of stress and decreased academic performance was likely mediated by reduced verbal working memory ability, which corresponds to students’ perceptions of higher levels of academic stress. In short, the decrease in achievement associated with an increase in stress level was likely mediated by the decrease in verbal working memory ability.

Similarly, the analyses addressing visual-spatial working memory as a mediator yielded similar results, as the relationship between participants’ academic achievement and the perceptions of academic stress was shown to be nonsignificant after controlling for visual-spatial working memory. Although an increase in stress level was associated with a decrease in achievement, this relationship can largely be accounted for by compromised visual-spatial working memory ability associated with increased stress levels, rather than through a directed relationship between academic stress and academic achievement. Holding visual-spatial working memory constant reveals no relationship between stress level and achievement, so it can be concluded that visual-spatial working memory performed as mediator between stress levels and achievement in this model.

The results of the analyses testing the mediator effects of both verbal and visual-spatial working memory abilities support the findings of previous investigations into similar mediator relationships. Owens and colleagues (2008) found that verbal working
memory accounted for approximately 51% of the association between stress and academic performance. Findings of similar studies also supported the hypothesis that working memory acts as a central mediator between psychological stress and academic achievement (Alloway et al., 2005; Daneman & Carpenter, 1980). The results of the present investigation provide further confirmation that both verbal and visual-spatial working memory act as mediators between stress levels and overall academic achievement as represented by verbal and mathematics achievement. The current investigation was able to apply these findings to an elementary student population and to link a specific type of stress, academic related stress, to the relationship between reduced working memory ability and lower academic performance. This study also explored visual-spatial working memory and expanded upon working memory as mediator to include both verbal and visual-spatial abilities.

**Implications for Practice**

The current findings suggest a unique perspective from which educators may view elementary students’ experiences of academic stress. It is important to acknowledge that students at this age are affected by academic-related demands and subject to the negative impacts of excessive levels of academic stress. Although it is sometimes believed that children do not suffer from stress and its negative consequences as adults do, all types of stress are experienced by adults, as well as by children (Read et al., 2001). Although adults may be more aware of the causes and repercussions of stress, children are equally affected by the harmful potential of excess stress. Because childhood is a period of rapid neurological growth, the effects of unnecessary academic stress may be even more pronounced.
Academic stress is the product of a combination of academic-related demands that exceed the adaptive resources of the individual and is represented as the mental distress associated with academic failure, apprehension of such failure, or even an awareness of the possibility of failure. When academic demands create short, infrequent increases in sympathetic nervous system arousal (e.g., increased stress on the day of an important exam) that are interjected with periods without significant stressors, students are experiencing excessive levels of acute stress. If academic demands generate more frequent occurrences or constant demands of schoolwork that are a part of the individual’s ongoing routine academic stress can be perceived as being inescapable and never-ending. Students at any level of education, from early childhood to post-secondary, may experience psychological stress associated with academic demands and are susceptible to the negative repercussions of excessive academic stress.

Implications from the present study suggest that disproportionate levels of academic stress correspond to deficits in working memory abilities as well as decreased academic achievement. Efforts to reduce academic stress at any level would benefit not only the psychological wellbeing of students, but may actually be related to increased cognitive functioning and may benefit overall academic achievement. Teaching students appropriate strategies for reducing stress and for dealing with the pressure of academic demands would be to the advantage of the students themselves as well as to educators. Additionally, if educators and other practitioners are aware of the relationship between stress and working memory, interventions targeting working memory ability may also benefit students experiencing high levels of academic stress. It is important to understand the different factors that may contribute to the experience of academic stress and to
recognize that student awareness of academic demands plays a significant role in their perceptions of academic stress.

Educators and other practitioners within educational settings who are concerned with student stress levels may seek to utilize specific programs or activities to reduce academic stress as well as stress related to nonschool factors. These interventions often focus on mindfulness, teaching students to be aware of their environments and physical and emotional reaction to their settings. Strategies based in Mindfulness-Based Cognitive Therapy (MBCT) and Mindfulness-Based Stress Reduction (MBSR) offer instruction in different mindfulness skills such as recognizing worry, harnessing the power of attention, creating distance from thoughts and emotions, and dealing with unpleasant feelings (Napoli, Krech, & Holley, 2008). The use of these programs in educational settings may be highly beneficial in reducing student stress levels and reducing subsequent consequences and impact of this stress.

It should be noted that the participants in the present study were made up of gifted and talented students who attended a school that implemented a gifted and talented education (GATE) curriculum. It is therefore possible that there are significant differences in the educational environments between typical educational programs and GATE settings that may influence students’ experiences of academic stress. Notable differences include stressors related to an increased likelihood of mismatch in educational setting, unsupportive social and school environments, and highly competitive atmospheres within GATE programs (Fimian, 2006; Reis & Renzulli, 2004). Further, although this sample of students did not demonstrate extremely high levels of academic stress, the
relationships among stress levels, academic achievement, and working memory ability were still found to be significant.

**Limitations**

This study was not without limitations. One primary limitation is that the current study was correlational in nature, and although it can be said that academic stress levels were related to both working memory and academic achievement, a causal relationship among variables was not investigated. Although higher levels of academic stress were associated with decreased working memory abilities and academic achievement levels, it cannot necessarily be said that excessive stress levels caused student working memory ability nor academic performance. Similarly, although working memory was established as playing a mediator role between academic-related stress and achievement, it cannot be concluded that working memory directly affected academic achievement nor was directly influenced by student stress levels.

A second limitation to this study can be seen in its generalizability. Participants in this study included students from a single gifted and talented school in the metro-Denver area. It is possible that environmental factors unique to this educational setting contributed to student perceptions of academic stress. Other students in dissimilar settings may not share the experiences of these students, and therefore the findings of this study may not be generalizable to a wider range of elementary students. Further, the relationships among working memory, achievement, and academic stress may be somewhat different in student general populations compared to students in gifted and talented settings. Conversely, although utilizing gifted and talented students in this sample reduces external validity somewhat, the limited variability in performance scores
and self-ratings increases the rigor of the analyses used to address the research questions by limiting the range and variability of the performance and self-report stress scores for the sample as a whole.

Another limitation of this study can be found when considering the inclusion of independent variables in the original multiple linear regression models addressing research questions one and two. Because academic stress level was not a significant predictor of verbal working memory during initial analyses, but was found to be significant after removing visual-spatial working memory as an independent variable from the model, it can be inferred that the original concept of including alternate working memory abilities in the MLR models was unnecessary and suggested inaccurate results. The inclusion of visual-spatial working memory as an extra independent variable appeared to mask the true significance of the variable of interest (i.e., academic stress level). An additional limitation related to the demographics questionnaire is the fact that only 34% of the participants answered the item related to parent education levels. Therefore, these data were excluded from the analysis and the variable of parent socioeconomic status (SES) was not addressed. However, it can be said that approximately 2% of the students who attend the school were eligible for free or reduced lunch, suggesting an overall high SES for the school as a whole when compared to state averages.

**Future Research**

The current findings provide a useful starting point for researchers who are interested in exploring the experiences of elementary school students’ perceptions of academic-related stress. Although the results of this study established relationships
among working memory abilities, academic stress, and achievement, they were not able to determine causation. Future research in this area could expand on these correlational findings by investigating whether academic stress directly impacts either working memory ability or academic achievement. By establishing these underlying associations, researchers could more confidently report the cognitive and psychological effects of excessive levels of stress in children. Further, direct interventions could be better designed to address the impact of academic stress.

Other inquiries could also focus on the experiences of students who do not participate in GATE programs. Although it is possible that no significant differences exist between students enrolled in GATE and general education students, it may be interesting to explore perceptions of students from different educational settings and investigate the relationship among cognitive abilities, general executive functioning, and experiences of academic stress. Further, comparing other student groups and their experiences of academic stress and its relationship with both working memory and achievement may yield important differences in these relationships and may shed additional light on specific student samples. Individualized interventions may be necessary to address both working memory deficits and perceptions of academic demands among different students in various educational settings.

It may also be valuable to further investigate the differences in the relationship between excessive academic stress and verbal versus visual-spatial working memory. Because current and past research suggests that these specific working memory abilities may variances in their relationships with stress levels, exploring the possible explanations for these differences may provide a deeper understanding of how these variables relate.
Moreover, additional research in these areas may direct further inquiry into the manifestations of deficits in both verbal and visual-spatial working memory and their implications in particular academic areas such as reading, mathematics, and written expression. These inquiries may also benefit from addressing the role of visual-spatial versus verbal working memory abilities in different academic areas (e.g., the role of verbal working memory in mathematics achievement), and their relationships with academic stress levels.

**Summary**

The present study investigated the relationships among academic stress, working memory, and academic achievement in elementary students. While the findings suggested that academic stress was not a significant predictor of verbal working memory in the initial analysis, result of the post hoc analysis suggested a significant relationship between academic stress levels and verbal working memory abilities. Similarly, results of both initial and post hoc analyses addressing visual-spatial working memory indicated a significant relationship between academic stress and visual-spatial working memory. In line with previous research, both verbal and visual-spatial working memory were found to be significant mediators between student stress levels and academic achievement, suggesting that the relationship between academic performance and academic stress can be explained by variance in working memory ability.

Students within formal educational settings may experience high expectations for overall learning outcomes, especially those who participate in gifted and talented education programs. They may experience academic stress as a product of academic demands that exceed their current coping strategies and resources for managing this
stress. Moreover, they may perceive excessive mental distress associated with the potential for academic failure. Recognizing that students at any age may experience excessive stress in response to academic demands helps school psychologists and educators better understand these perceptions. Further exploration in this area may lead researchers and practitioners to more effectively address academic stress and its relationship with executive functions. Most importantly, assisting students to develop appropriate strategies for reducing stress and managing academic pressures will help school psychologists and mental health staff to support students’ cognitive functioning, academic achievement, and overall psychological wellbeing.
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APPENDIX A

DEMOGRAPHICS QUESTIONNAIRE
Demographics Questionnaire

ID #: __________

Please answer the following questions. If you do not know the answer to a question, please leave it blank.

How old are you?

What is your sex?

Please circle your race.

- American Indian/Alaskan Native
- Asian/Pacific Islander
- Black
- Hispanic
- White (not Hispanic)
- Other
- two or more races
- prefer not to answer

Including this year, how many years have you attended this school?

Please circle the highest degree of education completed by your mother/guardian?

- No High School Diploma
- High School Diploma/GED
- Trade School
- Associates Degree (2 years of college)
- Bachelor’s Degree (4 years of college)
- Master’s Degree (6-7 years of college)
- Doctorate (7+ years of college)

Please circle the highest degree of education completed by your father/guardian?

- No High School Diploma
- High School Diploma/GED
- Trade School
- Associates Degree (2 years of college)
- Bachelor’s Degree (4 years of college)
- Master’s Degree (6-7 years of college)
- Doctorate (7+ years of college)

Other than stress related to your schoolwork, how much stress do you experience at home? (Not including stress you feel about homework or studying when at home)

1 2 3 4 5
No stress A little stress Some stress Moderate stress Extreme stress
APPENDIX B

ACADEMIC STRESS QUESTIONNAIRE
Academic Stress Questionnaire

ID #: _______________________________ Date: ______________________________

Directions: Read each item and answer honestly. Take your time as you complete this. Ask for help if you don’t understand an item. Rate each item from 1 – 5.

1 = Does not bother me at all
2 = Makes me feel a little uncomfortable
3 = Makes me feel stressed
4 = This upsets me
5 = I’m going to explode!

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<thead>
<tr>
<th>Item Description</th>
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<th>2</th>
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<th>4</th>
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<td>A teacher gives me feedback / constructive criticism.</td>
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<td>Someone or something interrupts me while I am working.</td>
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<td>A teacher tells me to correct a mistake.</td>
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<td>When I don’t understand what someone is saying to me.</td>
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<td>When I disagree with classmate.</td>
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<td>When a classmate asks for help.</td>
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<td>Homework.</td>
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<td>When a teacher tells me to do something.</td>
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<td>Group work with peers / classmates.</td>
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<td>When others make suggestions on how to do something.</td>
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<td>Event</td>
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<td>When one of my ideas is not included in a project / activity.</td>
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<td>When someone starts “small talk” with me.</td>
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<td>When I am excluded from an activity or conversation.</td>
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<td>Meeting new people.</td>
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<td>Getting a lower grade on a test, quiz, or paper.</td>
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<td>When someone points out a mistake I made.</td>
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<td>Greeting people.</td>
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<td>Taking tests.</td>
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<td>When I make a mistake.</td>
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<td>Reporting to school on time.</td>
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<td>Writing papers.</td>
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<td>Wearing specific clothing (i.e. long pants, coat)</td>
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<td>School bells or loudspeaker announcements.</td>
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<td>Fire drills.</td>
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<td>When a classmate disagrees with me.</td>
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<td>Surprise quizzes (pop quizzes).</td>
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<td>Tornado drills.</td>
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<td>When I am late to work / school.</td>
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<td>When I have to do something new or different.</td>
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<td>Hearing other people’s music /radio.</td>
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<td>When others touch me (i.e. handshake, pat on back).</td>
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<td>Large crowds.</td>
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<td>When I have to wait for something.</td>
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<td>Teasing by others.</td>
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<td>Crowded hallways.</td>
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<td>Peer pressure.</td>
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<td>When my daily routine is changed.</td>
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<td>Loud places.</td>
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<td>Specific noises (i.e. beeping, humming).</td>
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<td>Certain smells (examples: perfumes, foods).</td>
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<td>Math assignments.</td>
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<td>Big projects.</td>
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<td>When a teacher / authority figure tells me no.</td>
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<td>Changing classes.</td>
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<td>Bright lighting (i.e. fluorescent).</td>
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<td>When I have to do something in a different way from usual.</td>
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<td>Big classrooms.</td>
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<td>When I don’t understand a certain idea or concept.</td>
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<td>When I don’t finish something on time.</td>
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<td>Getting wet (i.e. hands, shoes).</td>
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<td>Field trips.</td>
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<td>When someone talks to me about something that I am not interested.</td>
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<td>Certain textures (examples: in clothing, paint, glue, chalk).</td>
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<td>Changes in noise level.</td>
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<td>Deadlines, time pressures.</td>
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<td>Sitting at a desk for long periods of time.</td>
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<td>Reading assignments.</td>
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<td>When other people are talking near me.</td>
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<td>Small spaces (i.e. cubicles).</td>
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<td>Asking for help.</td>
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<td>When I am confused about a task / activity.</td>
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<td>When I have to follow specific instructions.</td>
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<td>Physical activity (i.e. in health class or P.E.).</td>
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<td>Large spaces (i.e. auditoriums, gyms, conference rooms).</td>
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<td>When I have to organize my things.</td>
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APPENDIX C

CONSENT FORM
CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF NORTHERN COLORADO

Project Title: **Academic Stress and Working Memory in Elementary School Students**
Principal Investigator: Maile Blashill, Doctoral Student in School Psychology
e-mail: Blas6104@bears.unco.edu
Research Advisor: Michelle Athanasiou, Ph.D. e-mail: Michelle.Athanasiou@unco.edu

The purpose of this study is to investigate the relationships among academic stress, academic achievement, and working memory abilities in elementary school students. As a participant in this study, your child will be asked to complete three measures while in a large-group: a questionnaire related to their experiences of stress at school, a measure of academic skills, and a demographics questionnaire. Your child will also be asked to complete two measures of working memory in a one-on-one format. All instruments will be administered by the principal investigator or by a research assistant, who is trained in the administration of each of the measures. Data collection will begin 10 minutes after the end of the school day in the cafeteria.

For the purposes of this study, both your child’s identity and your child’s school will be kept completely confidential. Only the principal investigator and the research advisor will have access to raw data and identifying information. Further, all raw data will be stored in a locked file cabinet and on a password-secure laptop.

Risks to your child are minimal and do not exceed those of typical participation in a classroom environment. After the conclusion of the study, the principal investigator will hold an optional in-service presentation focusing on coping skills and stress management for students, parents, and teachers. This presentation will have a particular emphasis on how to maintain healthy levels of academic/occupational stress and strategies to cope with stress in these settings. However, if you are concerned that your child is experiencing excessive levels of stress or anxiety, please notify the principal investigator who will contact the school’s mental health professional. Additionally, you will be notified if your child endorses items on the Academic Stress Questionnaire that suggest that he or she may be experiencing excessive stress. The benefits to your child include: the opportunity to practice academic skills, increasing awareness of the experiences of academic stress, acquiring effective strategies for addressing academic stress, and supporting graduate research at the University of Northern Colorado. Additionally, as a participant in this study your child will have the option of being entered into a lottery for their chance to win one of five gift cards to Barnes and Noble Bookstores.

Participation is voluntary. You may decide that your child will not to participate in this study. If your child begins participation, you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like your child to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your child’s selection or treatment as a research participant, please contact the principal investigator of this study, contact information for whom may be found above.

**Please select one of the following:**

( ) My child will participate in the study.

( ) My child would like to participate, but cannot because of the exclusion criteria.

Parent/Guardian’s Signature __________________________ Date ________________

Researcher’s Signature __________________________ Date ________________
APPENDIX D

LETTER TO PARENTS
Dear XXXX Parent,

Hello, my name is Maile Blashill and I am a doctoral student in the school psychology program at the University of Northern Colorado. I am pleased to announce that I will be conducting the study for my dissertation at XXXX school this fall and am currently searching for student participants. The topic of the dissertation is the relationships among academic stress, working memory, and academic achievement.

I am looking for approximately 60 fifth grade participants who would be willing to contribute to the project. The students will be asked to complete two brief questionnaires about stress they feel at school related to academic demands, a demographics questionnaire, and a measure of academic achievement called the Basic Achievement Skills Inventory, which will allow the students to demonstrate their current level of academic knowledge in math and verbal skills on a 1st-12th grade continuum. The students will then be asked to take part in two measures of working memory (1) remembering numbers and letters and (2) tapping blocks in order.

The portion of the study involving student participants will be conducted in one afternoon, with an additional afternoon offered for students who would like to participate in the study, but cannot make it to the first data collection session. However, each student will only be required to be present for one of the two days. Data collection will occur after school in an empty classroom or the cafeteria, and will take up no more than 90 minutes of each participant's time. As an incentive for taking part in the study, all participating students will have the option of being entered into a lottery for their chance to win one of five $10 gift cards to Barnes and Noble Bookstores. However, if you prefer that your child not be entered into this lottery, his or her name does not have to be included in the drawing. Following the conclusion of data collection, a flyer will be sent home to parents giving them the opportunity to withdraw their child’s name from this drawing.

Participation is voluntary. If you are interested in your student participating in this study, please sign and return the attached consent form to the front office at XXXX school. If you are interested in the study but would like more information, please email me at blas6104@bears.unco.edu and I will be happy to provide you with more details.

I am very excited to be able to work with XXXX students and would be extremely grateful for your support and your student’s participation in this project. I believe it will be a wonderful opportunity for students to learn about and contribute to the graduate research process. Moreover, the implications of this project are directly related to supporting student well-being, cognitive functioning, and academic achievement.

Thank you very much for your consideration!

Maile Blashill  
Doctoral Student in School Psychology  
University of Northern Colorado  
blas6104@bears.unco.edu
APPENDIX E

IRB LETTER OF APPROVAL
Institutional Review Board

DATE: January 16, 2015

TO: Maile Blashill, BA FROM: University of Northern Colorado (UNCO) IRB

PROJECT TITLE: [662714-4] Academic Stress and Working Memory in Elementary School Students

SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVED

APPROVAL DATE: January 12, 2015

EXPIRATION DATE: January 12, 2016

REVIEW TYPE: Expedited Review

Thank you for your submission of Amendment/Modification materials for this project. The University of Northern Colorado (UNCO) IRB has APPROVED your submission. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on applicable federal regulations.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of January 12, 2016.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Sherry May at 970-351-1910 or Sherry.May@unco.edu. Please include your project title and reference number in all correspondence with this committee.

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Maile -

Thank you for addressing all of the items requested in my previous review. Your research is now approved and you may proceed with participant recruitment and data collection. Please be sure to use all of these revised and amended forms in your protocols.

Best wishes with your interesting research. Don't hesitate to contact me with any IRB-related questions or concerns.

Sincerely,

Dr. Megan Stellino, UNC IRB Co-Chair

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.

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