EMOTIONAL WORKING MEMORY: AN INDIVIDUAL DIFFERENCES APPROACH TO UNDERSTANDING ATTENTION CONTROL

By

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To my loving father who is my ever-encouraging beacon

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EMOTIONAL WORKING MEMORY: AN INDIVIDUAL DIFFERENCES APPROACH TO UNDERSTANDING ATTENTION CONTROL

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Emotion affects how we respond to events, how we think about them, and how we remember them. Researchers from a variety of domains have investigated these aspects of "emotional cognition." What seems to have received less attention in the literature, however, are the effects of emotion on short-term, working memory. Many commonly held ideas (i.e., "I need to cool off before responding" or "I wasn't thinking; I was caught up in the heat of the moment.") suggest there is an effect of emotion on working memory. This dissertation will review key research on the storage (STM) and process (executive functions) components of working memory as well as research on emotion and attention. After the brief review, a two-part experiment will be described that investigated the characteristics of an affective working memory.

The study aimed at investigating individual differences in working memory capacity and their relationship to attention control. There is research suggesting that working memory measures actually reflect two aspects of attention control: the ability to maintain attention in the face of distraction, and the ability to maintain task set. The current investigation was intended to replicate these findings and explore how well these measures can predict performance on

attention-intensive tasks that include emotional materials. Another aim of this investigation was to measure the impact that emotion has on working memory capacity. Can a measure of working memory that incorporates emotion predict attention control performance better than traditional working memory measures?

Results showed that overall, individual differences on the emotional measure of working memory capacity were a better predictor of performance (for both errors and latencies) on an Emotional Stroop task than the neutral measure whereas the neutral measure of working memory was a better predictor (for latencies) in the classic Stroop task (color-naming). This pattern of results would seem to support the construct of emotional working memory – that is, one's ability to maintain emotional words in working memory was specifically a better predictor of performance on other tasks involving emotion, while the ability to maintain neutral words was a better predictor of attention control in the classic Stroop task.

CHAPTER 1
INTRODUCTION

The idea that emotion and cognition may be intertwined is not new. This view may have originated with Aristotle's opposition to his mentor Plato, who deemed cognition, emotion, and motivation to be completely separate- the "tripartite soul." Aristotle, in contrast, proposed "an infinity of parts" by which the soul can be divided, all of which could be influenced by emotion. Although Plato's view was widely accepted well into the Renaissance, in 1641 Descartes proposed the concept of dualism between the separate entities of mind and body. While Descartes suggested emotion and cognition were inherently intertwined entities, he provided no mechanism or empirical support for this claim. As Descartes' dualism approach flourished, the function of, and relation between these constructs became of great interest.

Contemporary views of how emotion and cognition are related have often taken an evolutionary perspective, beginning with Darwin (*The Expression of the Emotions in Man and Animals*, 1872/1999), who suggested that humans have adapted and changed over time to more successfully accommodate the ever-changing environment. This evolutionary view has led researchers to describe emotions as "functional" (i.e., taxonomy in Keltner & Haidt, 2001, pp. 196). "The primary *function* of emotion is to mobilize the organism to deal quickly with important interpersonal encounters, prepared to do so by what types of activity have been adaptive in the past (Ekman, 1998)."

With respect to cognition, humans evolved an increasing ability to process complex materials and tasks. Consequently, this has been the focus of a substantial amount of research on cognitive processes now known as executive functions. The term *executive functions* typically include planning, inhibition, task management, motivation, and working memory.

If executive functions and emotions serve in concert to guide behavior, then this should be evident in neuroanatomy as well, with specific regions or structures engaged in both cognitive and affective processes. The prefrontal cortex (PFC) has been implicated in brain imaging research on executive functioning as well as research on differential processing of affective relative to neutral stimuli.

PFC activation has been shown in a variety of executive functions: working memory and content monitoring (Petrides et al., 1993), task switching while working memory is engaged (D'Esposito et al., 1995), rule-driven working memory (Smith, Patalano, & Jonides, 1998), computations in working memory (Smith & Jonides, 1997), and in spatial selective attention and working memory tasks (Awh & Jonides, 2001). Consistent with this idea, some researchers have even gone so far as to say that working memory capacity is actually a measure of PFC integrity (Engle & Oransky, 1999; Kane & Engle, 1998).

PFC activation is also found when affective stimuli are processed in a variety of situations: risk perception (Davidson & Irwin, 1999), the Emotional Stroop task with words (slower times naming the color of emotional, than neutral, words) (Herrington et al., 2005), affective picture viewing (Northoff et al., 2000), similarity judgments with task-irrelevant faces (Bishop, Duncan, Brett, & Lawrence, 2004), and simple feature processing of affective pictures (Simpson et al., 2000).

More important, however, is research showing interactive effects of affective processing and working memory in PFC activation. These include demonstrations of induced-mood effects on working memory performance (Gray, Braver, & Raichle, 2002), selective attention to subjective emotion responses (Lane et al., 1997), and effects of affective stimuli on modified delayed-match to sample working memory performance (Perlstein, Elbert, & Stenger, 2002).

Such interactions are strong evidence for a relationship between cognition and emotion, since statistical independence suggests functional independence, even if the same brain region shows activation. This paper will build upon the finding of a similar underlying cognitive and neural architecture for emotion and working memory processes with the goal of specifying the nature of this association, and describing possible research approaches that may help in that effort.

The research introduced above stresses the similarity of underlying neural structures for the processing of affective stimuli, executive functions broadly, and working memory specifically. While much of this paper elaborates this theme, there is a need to first put this research into a broader memory perspective. There has been a substantial amount of research investigating the effects of emotion on both long-term and short-term memory (Kleinsmith & Kaplan, 1963, 1964; Levinger & Clark, 1961; Quevedo et al., 2003). Although there are some intriguing exceptions, these studies have generally found little or no effect of emotion on short-term memory (e.g., no difference in immediate recall of emotional vs. neutral stimuli), while there is often a substantial effect of emotion on long term memory (e.g., better delayed-recall of emotional vs. neutral stimuli). At a physiological level, long-term memory effects have been associated with amygdalar involvement for long-term memory consolidation (Cahill, 1997; Cahill & McGaugh, 1996; Packard & Teather, 1998). Animal research suggests that the modulation of memory by emotion via the amygdala is present in long-term memory but not in working or short term memory, and is seemingly independent of these types of memory (Bianchi et al., 1999). The rate of consolidation into long-term memory, independent of other encoding or rehearsal processes, also appears to be more efficient for emotional stimuli (Anderson & Phelps, 2001).

While the amygdala may directly modulate memory for emotional stimuli, there are also numerous psychological factors that may contribute to superior long-term memory for emotional stimuli (Buchanon & Adolphs, 2004). Affective stimuli may capture and sustain attention because they are perceptually more arousing (interesting or important) than are neutral stimuli. Similarly, the depth of encoding and elaborative processes may be greater for emotional relative to neutral stimuli. Additionally, emotional stimuli may be reviewed and rehearsed more often than neutral stimuli and receive the benefit of increased retrieval practice, as every review of an item increases likelihood of later retrieval of an item. Emotions may also serve as retrieval cues for information from long-term memory and facilitate retrieval.

The research outlined so far supports what we may intuitively believe: Emotion affects how we respond to events, how we think about them, and how we remember them. What seems to have received less attention in the literature, however, are the effects of emotion on short-term, working memory. Many commonly held ideas (i.e., "*I need to cool off before I respond.*" or "*I wasn't thinking. I was caught up in the heat of the moment*.") suggest there is an effect of emotion on working memory. The goal of the current investigation is to determine how, and when, emotion may modulate storage (STM) and process (executive functions) components of working memory.

The use of individual difference variables has been a powerful tool in emotion and personality research. Some of these variables reflect potential differences in processing, such as emotional valence or arousal focus (Feldman Barrett & Gross, 2001), ability to regulate emotion (Gross, 1998), personality (Canli, Zhao, Desmond, Gross, & Gabrielli, 2001), gender (Kesler-West et al., 2001), and psychopathology (Patrick, Cuthbert, & Lang, 1994; Winton, Clark, & Edelmann, 1995), to name a few. Similarly, cognitive researchers have used individual differences in working memory capacity to better understand the mechanisms involved in working memory (Engle, 2001). There has been little work, however, on individual differences in emotional working memory.

"Privileged perceptual processing of emotional events provides a means of not only indexing occurrences of value but facilitating their availability to other cognitive domains (Dolan, 2002, pp. 1192)." Research on the relationship between emotion and attention suggest that emotion can affect attention allocation at the earliest pre-attentive level (Keil et al., 2002; Schupp, Junghofer, Weike, & Hamm, 2003; Smith, Caccioppo, Larsen, & Chartrand, 2003), as well as in controlled attention situations (Andersen, 2005; Keil & Ihssen, 2005; Ohman, Flykt, & Esteves, 2001).

Since emotion tends to bias attention, a process which has been implicated as a crucial aspect of working memory, one would expect that emotional stimuli would influence working memory processes as well. The potential usefulness of the concept of "affective working memory" has been mentioned by some researchers (Davidson, 1999; Mikels, Reuter-Lorenz, & Fredrickson, 2003; 2004) and addressed, to varying degrees, by others (Gray, Braver, & Reichel, 2002; Kensinger & Corkin, 2003; Mikels, Larkin, Reuter-Lorenz, & Cartensen, 2005). Surprisingly, research efforts on this topic have been relatively scarce.

Recent research investigating the effects of emotion on working memory has generally taken three approaches: (a) manipulating mood and looking at subsequent working memory performance (Elliman, Green, Rogers, & Finch, 1997; Gray, 2001; Spies, Hesse, & Hummitzsch, 1996); (b) manipulating emotionality of materials used in non-traditional working memory tasks and looking for differences between neutral and emotional task performance (Mikels, Reuter-Lorenz, & Fredrickson, 2003; 2004); or c) manipulating the emotionality of traditional working memory task materials and looking at differences in performance between neutral and emotional (Kensinger & Corkin, 2003; Perlstein, Elbert, & Stenger, 2002). This investigation will be taking the latter approach.

The Current Study

Working memory is considered to be a key executive function, impacting planning, inhibition, task management, motivation, and other cognitive processes. The specific definition of working memory varies by theory, but generally working memory is the on-line coordination and use of information for a given cognitive task. One widely accepted model of working memory was first proposed by Baddeley and Hitch (1974). The structure of the Baddeley and Hitch model pays tribute to earlier models of human memory proposed by Atkinson and Shiffrin (1968) and Broadbent (1958), which posited distinct stores that "buffered" and transformed information en route to long-term memory. The Baddeley and Hitch model consists of a *central executive* that interacts with two temporary mode-specific information stores, referred to as "slave" systems: the *phonological loop* is responsible for verbally coded information and the *visuo-spatial sketchpad* is responsible for information that has a spatial representation to be coded. Both slave systems have an active rehearsal mechanism and passive store. The active component of the phonological loop is the articulatory loop, and the passive is called the phonological store. The active component of the visuo-spatial sketchpad is the inner scribe and the passive mechanism is the visual cache. Empirical support for the dissociation between verbal and visuo-spatial information has come from many areas of research (e.g., Brooks, 1967; Jonides et al., 1996). For example, Brooks (1968) found there was greater interference on verbal tasks when processing verbal information than spatial information, and more interference on spatial tasks when processing spatial information. Additionally, Jonides et al., (1996) found hemispheric activity differences when processing verbal and spatial information, with tasks utilizing verbal tasks associated with left and spatial tasks associated with the right hemisphere.

Combined, the components within this model are thought to be necessary for the on-line use of information needed to retrieve, monitor, manipulate, and attain everyday cognitive goals (e.g., reasoning, learning, and comprehension to name a few). This view of working memory places emphasis on the temporary storage and maintenance of information from long-term memory as well as encoding and integration of new information for the benefit of accomplishing current goals. The central executive, according to this model, does not store information, but serves to coordinate the slave systems by controlling attention, encoding, retrieval, and manipulation of information held in both active and passive stores within each slave system.

More recently, Baddeley (2000) added another component, the *episodic buffer*. The buffer is a limited-capacity component which merges information from the two slave systems to make a cohesive episodic representation for comprehension. Since introduced, the episodic buffer has not received much theoretical or empirical attention; however, it may provide an interesting theoretical framework for investigating how emotion may affect on-line processing. The episodic buffer may be particularly vulnerable to emotional influences from both attention and storage mechanisms. Attention mechanisms may be impacted by emotion through the central executive. Consistent with the existing literature showing that attention is biased by emotional stimuli, the central executive may serve as an attentional filter for what type of information is attended to and put into temporary storage within the episodic buffer. Additionally, emotion could serve as an organizing or prioritizing cue through which information in long-term memory could be integrated with temporarily held information, consistent with the integrative nature of storage in the episodic buffer, as Baddeley initially proposed.

Individual Differences in Working Memory Capacity and Attention Control

Kane, Engle, and Tuholski (1999, 2004) propose a two-factor theory of executive control to explain individual differences in working memory. This theory is derived from a series of studies suggesting that working memory capacity (WMC) may be "domain-general," with WMC span tasks predicting a wide range of abilities: note-taking (Kiewra & Benton, 1988), following directions (Engle, Carullo, & Collins, 1991), bridge playing (Clarkson-Smith & Hartley, 1990), computer-language learning (Shute, 1991), and novel reasoning (Kyllonen & Christal, 1991). The two-factor theory of executive attention retains domain-specific stores with their traditional duties of coding, storage, and rehearsal as well as the domain-general executive attention component which interacts with the temporary stores.

The two-factor theory of executive control model they (Kane, Engle, & Tuholski, 1999; 2004) propose does not differ in structure from that of Baddeley's original model; however, it does differ in function. It suggests that individual differences in working memory are embedded in the functioning of the central executive, which is responsible for goal maintenance and conflict resolution. Kane et al., posit that working memory capacity is "the capacity for controlled, sustained attention in the face of interference or distraction (p. 104, 1999)." Accordingly, WMC measures (span tasks) are sensitive to individual differences in central executive functioning, and account for their ability to predict a wide range of higher-cognitive abilities. Those with higher WMC are better able to use attention to avoid distraction and perform well on span tasks. Those with low WMC are not as skilled at using attention to avoid distraction, and perform poorly on span tasks. This view clearly moves the emphasis away from storage and type of stimuli used in a given span task, and instead focuses on how differences in attention control, because of its crucial importance in maintaining current goals and response conflict resolution, could account for findings of span tasks predicting a variety of higher cognitive functions.

Empirical evidence supporting the idea that individual differences in WMC are attributable to the functioning of the central executive come from several widely-used attention paradigms: the “anti-saccade” task (Kane, Bleckley, Conway, & Engle, 2001), Stroop task (Kane & Engle, 2001), negative priming (Engle, Conway, Tuholski, & Shistler, 1995) and dichotic listening task (Conway, Cowan, & Bunting, 2001). The findings from these studies highlight two separate functions of WMC: the ability to sustain a task set in memory and the ability to resolve conflicts between a pre-potent response and the one necessary for the current task. Some of these studies will be reviewed below.

Kane and Engle (2003) investigated whether there is a relationship between WMC and Stroop task performance. Briefly, a list of words written in different colors is presented and participants are asked to indicate the color of the word, for both *congruent* (RED written in red) and *incongruent* trials (RED written in blue). The typical finding is of faster responses on congruent trials than on incongruent trials. Kane and Engle hypothesized that successful Stroop performance requires both memory and attention processes: memory for the task goal, which was to say the word color, and attention to inhibit the pre-potent response to read the word on every trial, even the congruent ones. Consistent with their two-factor model, Stroop interference would be the result of (a) failure to maintain task set in memory, and (b) difficulty in conflict resolution on incongruent trials. Therefore, Kane and Engle hypothesized that performance on two different measures that reflect these two processes would be predicted by WMC. To test this idea they varied the list-wise proportion of congruent and incongruent trials within blocks (0% versus 75% congruent). Kane and Engle suggested that in purely congruent or incongruent blocks participants are able to adopt strategies to optimize performance. For example, in purely incongruent blocks the goal is kept active because of the homogeneity of trials within the block: "Every incongruent stimulus therefore reinforces the goal, to ignore the word, and so the task environment acts instead of the central executive." They predicted that the 75% congruent blocks would encourage higher goal maintenance processes, relative to the 0% block.

Kane and Engle took a categorical approach to classifying the working memory capacity of their participants by including those scoring low or high on a widely-used WMC measure called Operation span (OSPAN). This approach is sometimes called extreme-group methodology. OSPAN is a measure of WMC in which participants are asked to read aloud a mathematical operation and verify whether the answer provided is correct, then to read the word immediately following the answer. One typical operation-word string is, "Is (9/3) + 2 = 5? *Drill*." Participants continued reading items aloud, without pauses, until they are presented with a "?????" prompt, indicating that they were to recall all words that followed the operations in a trial. The number of operation-word strings varied randomly between 2-5 items by trial. OSPAN score was determined by the number of sets with correct items recalled in the correct order, so scores range from 0-42 (across three sets of stimuli). The low and high WMC groups were defined as the bottom and top quartile of OSPAN participants. Typically this includes those scoring below 9 and above 19.

Kane and Engle (2003) found that there were systematic differences between low and high working memory capacity groups. Specifically, in the 0% congruent condition, they found that the low-span group exhibited greater response time interference than the high-span group – that is, the low-span group took longer on the incongruent trials relative to the neutral color-naming trials, suggesting they were slower at resolving the conflict between the pre-potent reading response the task response of color-naming. In the 75% congruent condition, the opposite pattern occurred, with greater response time interference for the high-span group relative to the low-span group, suggesting the high-span group was taking longer to resolve the conflict between the pre-potent response and the task response. The response time data on their own would tell a confusing story, but when Kane and Engle analyzed the errors rates across each trial type, they found greater errors in the low-span group than the high-span group for both conditions. Combined, this study suggests that individual differences in working memory capacity can predict performance across two types of tasks, one that requires sustained attention in the face of distraction (0% congruency condition), and another that requires sustained activation of the task set to perform with accuracy (75% condition).

Emotion and Attention

Researchers studying the relation of emotion and cognition have been particularly interested in how attention is allocated in the face of distraction. It has been found that presentation of task-irrelevant emotional stimuli tends to result in an involuntarily allocation of attentional resources to those stimuli (i.e., attentional capture). Physiological measures taken during such tasks have shown that the processing of emotional pictures differs from that of neutral pictures (Keil et al., 2002; Schupp, Junghofer, Weike, & Hamm, 2003; Smith, Caccioppo, Larsen, & Chartrand, 2003). Pictures of threatening stimuli also result in faster detection in visual search tasks: an angry face in a crowd (Hansen and Hansen, 1988), a snake in the grass (Ohman, Flykt, & Esteves, 2001), a schematic emotional face among schematic neutral faces (Ohman, Lundqvist, & Esteves, 2001), or a photograph of an emotional face among photographs of neutral faces (Juth, Lundqvist, Karlsson, & Ohman, 2005).

Further support for attentional capture by emotional stimuli comes from the so-called *Emotional Stroop* task, where color-naming of emotionally evocative words is slowed relative to neutral words (Dalgleish, 1995; Pratto & John, 1991; Williams, et al, 1996). Recently, there has been debate about the similarity and differences in the processes involved in the emotional Stroop task (Algom, Chajut, & Lev, 2004; Chajut, Lev, & Algom, 2005; Dalgleish, 2005). The details of this debate are beyond the scope of this dissertation, but the gist of the debate is rooted in whether the cognitive processes that result in slowed color naming found in the traditional Stroop task (1935) are the same cognitive processes involved in the emotional Stroop task. In the traditional Stroop task there are both congruent (*red* written in red) and incongruent trials (*red* written in blue) with faster responses on the former when compared to the latter. In contrast, in the emotional Stroop task, there are neither congruent nor incongruent trials, as defined above; rather, there are either emotional or neutral words printed in varying colors. An elegant way to investigate the relative attention processes involved in color naming of neutral and emotional words was reported by McKenna and Sharma (2004).

McKenna and Sharma (2004) noted that there has been a wide range of interference effects or slowed responding to emotional words, reported (-1 ms to 400 ms), across the emotional Stroop studies (as reviewed by Williams, Mathews, and MacLeod, 1996). McKenna and Sharma noted that the wide range of interference may be due in part to group differences (psychopathologies) and/or to specific methodologies used: “presentation (card, computer, T-scope), design format (blocked, missed, individual, simultaneous), stimuli (negative, positive, neutral, category neutral), stimulus repetition (a small set of words repeated often, or a larger set repeated less often), intertrial interval (ITI), and so on (p. 383).” They posit that the widespread consensus of the emotional Stroop effects being due to the automatic grabbing of attention (Pratto & John, 1991) by emotional words and the momentary suspension of current content processing is at best not the full story. As an alternative, they suggest that there are two different temporal effects at work in emotional Stroop; one is relatively fast, occurring within a trial, and the other slow, occurring between trials.

McKenna and Sharma (2004) directly tested the relative contributions of both fast and slow effects of emotion on word naming latency within a modified emotional Stroop task (their Experiment 4). There were seven word positions, with all but the first holding neutral words; Position 1 was either a positive (e.g., ROMANTIC), negative (e.g., REJECTED), or neutral (transportation-related) word. Color-naming latency was measured for each position. Latency to name the emotional word at Position 1 was *not* slower than latency for positive or neutral words, suggesting that the fast, within-trial effects of word emotionality were at best small. In contrast, latency to name *neutral* words in Position 2, was substantially slower when following an emotional word, than when following a neutral word. The size of the difference was surprisingly large (75 ms). McKenna and Sharma suggest that the slow effects tend to be the predominant effect seen in non-clinical samples, whereas the fast effects may be reliably found only in clinical samples (e.g., PTSD and Schizophrenia).

Research Questions

The main goal of this research was to explore the impact of emotion on working memory processes. To that end, a measure of working memory that incorporated emotion was developed. The emotional working memory task was identical to the Operation Span task used by Kane and Engle (2003), except the Emotional Operation Span task (ESPAN below) required participants to remember a sequence of emotionally unpleasant words, instead of the emotionally neutral words used by Kane and Engle and others. These words can be found in Appendix C.

Using the extreme-group methodology noted above, individual differences in “emotional working memory” capacity were related to performance on two kinds of tasks involving potential interference and distraction. The first involves the two factors of attention that Kane and Engle argued were central to working memory: maintenance of task set, and maintaining attention in the face of distraction (the Congruence Stroop task). The second involves maintenance of attention in the face of emotional words (the Emotional Stroop task), which previous research suggests distract attention.

Within this framework, a number of specific hypotheses were proposed. These are outlined in Figure 1-1. First, I sought to replicate two Stroop-related findings: (a) Stroop interference is sensitive to context effects (i.e., variations in the list-wise congruency proportion; Kane & Engle, 2003) and (b) the time course of Emotional Stroop effects may be slower than originally thought (McKenna & Sharma, 2004) (Hypotheses 1a and 1b).

Second, I explored whether the ESPAN task would capture an aspect of working memory capacity that is different than traditionally neutral measures of working memory capacity (neutral working memory measure, OSPAN), and so predicted that performance on the two tasks should be at least to some degree dissociable (Hypothesis 2). Third, the current study sought to replicate the relationship between working memory capacity and attention control reported by Kane & Engle (2003) (Hypothesis 3a). Consistent with the hypothesis that the ESPAN measure captures something unique about working memory, it should predict attention control in the face of emotional distraction; specifically, individual differences in ESPAN should predict performance in the Modified Emotional Stroop task (Hypothesis 3b). Moreover, ESPAN should be a stronger predictor for performance in the Emotional Stroop task than the OSPAN measure (Hypothesis 4a), and the OSPAN will be a stronger predictor of performance in the Congruency Stroop than the ESPAN task (Hypothesis 4b).

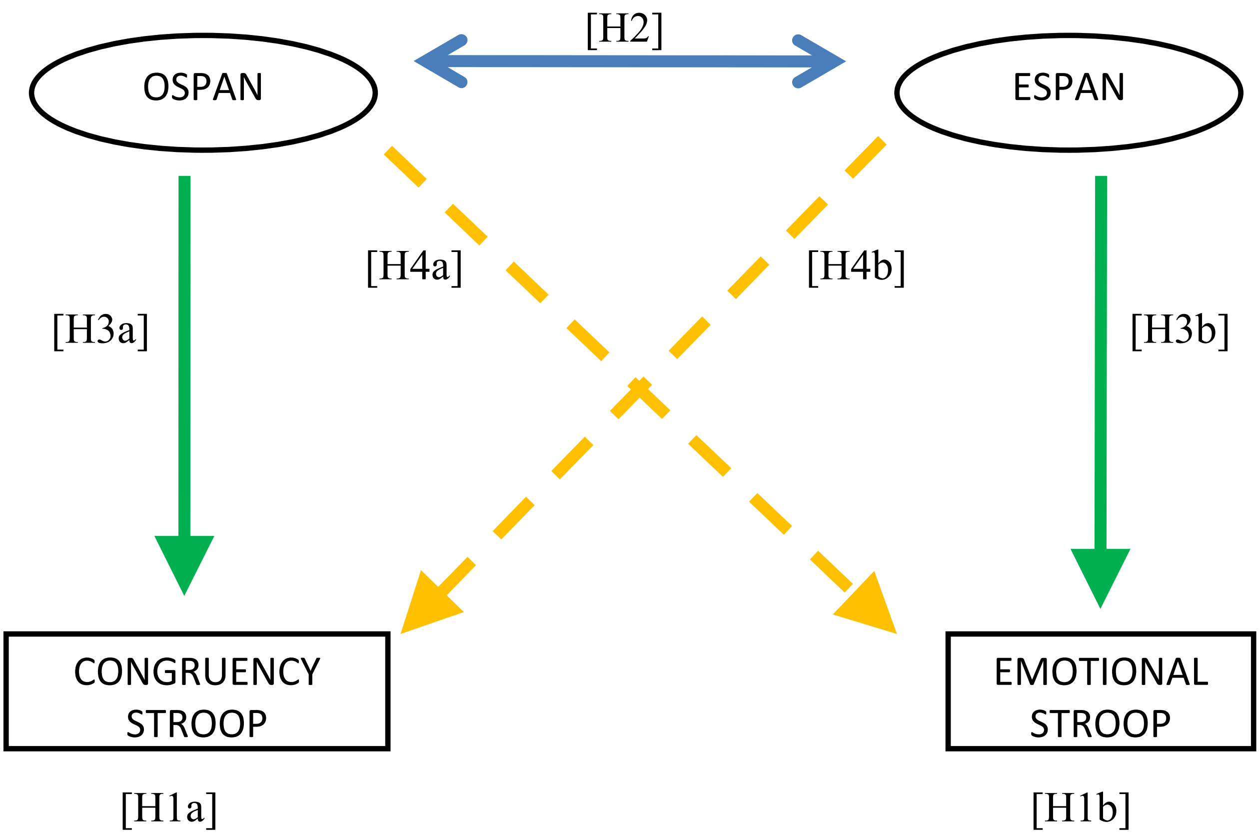


Figure 1-1. Experimental hypotheses: (1a) Congruency Stroop will be replicated. (1b) Emotional Stroop will be replication. (2) OSPAN and ESPAN will be associated, but ESPAN will capture variance associated with emotion processing. (3a) Individual differences in OSPAN will predict Congruency Stroop performance. (3b) Individual differences in ESPAN will predict Emotional Stroop performance. (4a) Individual differences in OSPAN will predict Emotional Stroop performance. (4b) Individual differences in ESPAN will predict Congruency Stroop performance better than OSPAN.

CHAPTER 2
METHOD

Participants

Upon approval from the University of Florida Institutional Review Board (protocol 2007-U-0821), one-hundred and forty-seven undergraduates were recruited from the Introductory Psychology Participant pool for participation. Participants that did not complete all portions of the study were excluded from analyses, resulting in a one-hundred and twenty-five participants.

Design

The present experiment included two types of Stroop tasks: One was the Congruency Stroop and the other was the Emotional Stroop. Within the Congruency Stroop task there were two blocks of trials: One is the 0% Congruency Block that has two types of trials (incongruent and neutral), and the other is the 75% Congruency Block that has three types of trials (incongruent, congruent, and neutral). Within the Emotional Stroop task there were three blocks of trials defined by the emotionality of the critical word in Position 1 (Pleasant, Unpleasant, and Neutral Transportation). Each word in the sequence was given a position number of 1-6, with the critical word being position 1 and neutral filler words appearing randomly at positions 2-6 (See Appendix C). Participants also completed a neutral (OSPAN) and emotional working memory capacity measure (ESPAN). All participants completed all of the above tasks; however, to look at individual differences the sample is split (top third and bottom third) based on their OSPAN and ESPAN scores.

Materials

A Dell computer was used for all tasks: The modified emotional Stroop task (McKenna & Sharma, 2004), Congruency Stroop tasks (Kane & Engle, 2003), the neutral Operation span task used by previous researchers (Unsworth, Heitz, Schrock, & Engle, 2005), the emotional Operation Span task developed for this study, and for the word ratings task.

Operation Span Task

Participants read aloud a mathematical operation and a potential answer ("(9/3) + 2 =6") and indicated whether the answer provided was correct (true) or incorrect (false). They then read a neutral word ("dock") and retain it until asked to recall all words since last recall. Participants continued reading items aloud, without pauses, until they were presented with a "??????" prompt. A recall screen followed, at which time they attempted to recall all words since the previous recall. They were asked to recall the words in the order in which they received them. For example, if they knew that they had seen five words but could only remember three of them to leave the blanks empty for the words that they couldn't remember. Participants were encouraged to keep their overall mathematical performance above 85%, and received feedback as to their overall mathematical accuracy and mean response time. The number of operation strings (and words) participants received (i.e., memory set) varied randomly from 2-5 items. This continued until all trials were completed (total of 48 trials, including practice trials). See Appendix B for the full set of stimuli.

The main dependent measures of interest in study include: (1) Overall mathematical performance accuracy and (2) OSPAN score, defined as the number of sets with all presented items, in the correct order. There may be some other theoretically interesting data, such as the number of intrusions or omissions, but these will not be considered here (see Unsworth & Engle, 2007).

Emotional Operation Span Task

This task is identical to the Operations Span task described above, except instead of using neutral words as memoranda, unpleasant words were used. All words were obtained from the Affective Norms for English Words (Bradley & Lang, 1991).

Emotional Stroop Task

Participants were asked to view words one at a time and indicate the color each word was printed in. The word was presented in blue, brown, red, or green. Responses were made with the index and middle finger of both hands. One of four colors was indicated on stickers (RED, GREEN, BROWN, and BLUE) over the keys of d, f, j, and k respectively. Participants were encouraged to indicate the color as quickly and accurately as possible, and not to correct any mistakes they made while completing the task. Participants received response training before the experimental trials began. The training included making responses with the four keys for a total of 20 trials. For every sequence there were six positions (1-6). In position 1 a critical word is presented that is emotionally unpleasant, pleasant, or neutral (transportation-related) word. In positions 2-6 are neutral (e.g., non-transportation-related) words. Please see Appendix C for a complete list of task stimuli. The type of critical word presented in Position 1 was blocked. Within each block, five sequences were presented randomly six times. After each block, participants were given a brief break (30-60 seconds). In total there were 210 experimental trials. The dependent variables in this task were (a) correct color-naming latency, and (b) color-naming errors.

Congruency Stroop Task

This is the classic Stroop task (1935), where participants are asked to name the color of the presented word orally, as quickly and accurately as possible. Specifically, participants named the word color, and then trained research assistants indicated the participant response by keyboard press. Research assistants did not look at the computer screen while participants named the word color, rather they focused on making their responses on one of three possible keys on the keyboard that were each labeled with one of three colors: RED, BLUE, or GREEN. The only way that this task differs from the original Stroop paradigm in that it consists of two blocks that differ in their list-wise proportion of congruent trials. One has no congruent trials (where the word name and color are the same, 0% congruency) and the other has 75% congruency. Participants always received the 0%, followed by the 75% congruency block.

There are three possible types of critical trials presented: congruent, incongruent, and neutral. The *congruent* trials include the words RED, BLUE, GREEN, in those colors, with each presented 12 times, for a total of 36 trials. The *incongruent* trials include the same words only presented in all of the possible conflicting colors, with each conflicting color being presented 6 times. The *neutral* trials include the letter strings of JKM, XTQZ, and FPSTW, with each of them being presented 4 times in each of the three colors. In the 0% congruent block, there are 144 trials: the 36 critical incongruent trials, 36 critical neutral trials, and 72 filler trials that are incongruent. The 75% congruent block has 288 trials, which includes all three of the critical trial types (3 x 36 trials) and 180 filler trials that are congruent. The dependent variables in this task are: (a) correct color-naming latencies, and (b) color-naming errors.

Word Ratings Task

Participants viewed words, one at a time, and made valence and arousal ratings on a five-point Likert scale. For valence, a "1" indicates the participant perceives the word as very unpleasant, whereas a "5" indicates the participant views the word as highly pleasant. For arousal, a "1" indicates the participant perceives the word as non-arousing, whereas a "5" indicates the participant views the word as highly arousing.

Procedure

There were two experimental sessions, one on each of two consecutive days. Session I was one hour in duration, while Session II was an hour and a half in duration. The order in which participants completed the measures within a given session was counterbalanced across subjects. Regardless of the order of measures, Session I consisted of participants giving their informed consent and then completing one of the Stroop Tasks (Congruency Stroop, or Modified Emotional Stroop), followed by one of the measures of working memory capacity (OSPAN, or ESPAN), and Session II consisted of participants completing the other Stroop Tasks, followed by the other measures of working memory capacity. Session II ended with the Word Rating Task. On each day, only one of the two main tasks involved emotional words; that is, the ESPAN task was always paired with the Congruency Stroop tasks, and the OSPAN task was always paired with the Modified Emotional Stroop task.

CHAPTER 3
RESULTS

Neutral and Emotional Operation Span Task

Participant performance was scored using a strict scoring method, whereby a given recall event was deemed correct if and only if they recalled all words in the order in which they received them. The range of possible scores for both the neutral and emotional Operation Span task was 0-42. In the current sample the range of Neutral Working Memory Capacity scores was 2-39 and the mean was 17.54 (standard deviation = 8.04). The range of scores for the Emotional Working Memory Capacity scores was 0-37 and the mean was 15.27 (standard deviation = 6.60). The difference in OSPAN and ESPAN scores was significant, (paired t-test, $t(124) = 3.50$, $p < .01$), suggesting that overall, having to maintain emotional words in working memory is more difficult than maintaining neutral words. Mathematical operation accuracy was equal for both ESPAN and OSPAN, approximately 95% (paired t-test, $t(124) = -.57$, $p = .565$), indicating that the processes being impacted by the inclusion of emotional stimuli is specific to the temporary maintenance of the words.

The current study is aimed at investigating individual differences in working memory capacity and attention control, the full sample was divided into groups using the extreme group methodology (consistent with Kane & Engle, 2003). Specifically, the top third and bottom third of performers were used in the individual differences analyses presented below. Within the Neutral Operation Span task the low span group included participants who scored at or below 13 ($n = 47$), whereas the high span group included participants who scored at or above 19 ($n = 52$). For the Neutral Operation Span the mean span score for the low span group was 10 and the mean high span group score was 25. Within the Emotional Operation Span task the low span group included participants who scored at or below 12 ($n = 49$), whereas the high span group included participants who scores at or above 17 (n = 45). The mean span score for the low emotional working memory group was 9, and the mean for the high span group was 22.

There was a correlation of .45 between the OSPAN and ESPAN task, thus the individual differences analyses below reflect some degree of overlap in subjects, please see Table 3-1. There are no existing reliabilities for the ESPAN task because it was a novel measure created for assessing whether there is an emotional working memory. Prior research using the OSPAN task has shown reliabilities (Cronbach's alpha) to be approximately .65-.75 (Conway et al., 2002; Engle, Cantor, & Carrullo, 1992; Engle, Tuholski et al., 1999; LaPointe & Engle, 1990). Additionally, the test-retest measure have demonstrated stability for a wide range of intervals: a few minutes (r = .77-.79)(Turley-Ames & Whitfield, 2002), 3 weeks (stability coefficient, r = .82) (Klein & Fiss, 1999), and 3 months (r = .76) (Klein & Fiss, 1999). The correlation between OSPAN and ESPAN addresses Hypothesis 2 in Figure 1-1. An informal comparison of the correlation between ESPAN and OSPAN obtained in the current study to previous test-retest reliabilities of the OSPAN suggest there is a fair amount of unique variance that can be attributed to the cognitive processes that the ESPAN is measuring.

Emotional Stroop Task

In this task, participants completed three blocks of the color-naming task with a series of six-word sequences, each with a critical word in the first position, and neutral words in positions 2-6. The blocks were defined by the emotionality of the position 1 critical word. Critical (position 1) word emotionality could be Pleasant, Unpleasant, or Neutral (transportation-related words). The mean response time for the color-naming task was found for each position within each block. All participants completed each block of trials in a randomly determined order. It is important to note that, upon completion, none of the participants spontaneously reported noticing any emotional words in the tasks. When probed as to whether they noticed the emotional words in the sequence, only a handful reported being aware that there were Unpleasant or Pleasant words in the task.

The results of the current study will be presented as follows: The color-naming error rates will be presented first, followed by the correct color-naming response latencies. The overall ($n = 125$) results will be presented first. The overall analyses presented below address Hypothesis 1b in Figure 1-1, which asked whether the current study replicated the time course of the Emotional Stroop effects reported by McKenna and Sharma (2004). The individual difference analyses that follow the overall analyses will be presented for both the neutral working memory groups (low OSPAN $n = 47$, high OSPAN $n = 52$) followed by the emotional working memory groups (low ESPAN $n = 49$, high ESPAN $n = 45$). The individual differences in neutral working memory analyses that follow address Hypothesis 4a in Figure 1-1, whereas the individual differences in emotional working memory analyses address Hypothesis 3b in Figure 1-1.

Overall Error Rates

As indicated above, McKenna and Sharma found no differences in error rates across the three emotionality blocks, with rates of 3.63% for the Neutral (Transportation-related) blocks, and 3.50% for the Pleasant and Unpleasant blocks. In the current study the mean error rates showed a different pattern, with greatest errors in the Unpleasant block (5.2%), followed by Pleasant (3.5%) and Neutral (transportation-related) (3.4%) blocks, indicated by the significant main effect of emotional block ($F(2, 123) = 8.21$, $p < .001$), please see Figure 3-1. Pair-wise comparisons of errors between blocks reveal that more errors were made in the Unpleasant blocks than in either Pleasant blocks ($p < .001$) or the Neutral (Transportation-related) blocks (both $ps < .001$), while the latter two did not differ ($p = .687$). There were no differences across position ($p = .573$), nor was there any differential effect of block across positions (interaction of block and position, $p = .568$). Importantly, then, more errors were made during sequences which contained unpleasant words, but this effect was not limited to the critical Unpleasant words themselves.

Individual Differences in Error Rates

The error rates above reflect the whole sample. The sections below are the results of using the extreme-group methodology of comparing those that are high in working memory capacity, to those that are low in working memory capacity. The results for the individual differences in working memory capacity will begin with the neutral or traditional working memory capacity groupings, using the Operation Span task, followed by the results when the sample is divided on performance on the emotional working memory capacity measure, the Emotional Operation Span task.

Individual Differences in Neutral Working Memory Capacity (OSPAN)

As can be seen in Figure 3-2, the two OSPAN groups did differ in their overall error rate performance, seen in the significant between-group effect ($F(1, 97) = 139.23$, $p < .001$). Although the low OSPAN group produced more errors overall, the distribution of errors across emotional block and position was essentially identical for the two Span groups. This is confirmed by the absence of interactions between Span group and the other two factors (Span x Emotional Block ($F < 1$, $p = .907$, the three-way interaction between Emotional Block x Position x Span Group ($F(10, 97) = 1.22$, $p = .23$).

Individual Differences in Emotional Working Memory Capacity (ESPAN)

In contrast to the division of participants by OSPAN, the small difference in overall accuracy between high and low ESPAN groups (c. 1.5%) was not significant,($F(1, 92) = 133.41$, $p = .095$), see Figure 3-3. Similarly, the effect of Unpleasant words in the sequence on error rates was overall not greater for the low ESPAN group (Span x Emotional Block interaction, $F(1, 92) =1.22$, $p = .297$), but importantly, was more sustained across position for the low-span group (three-way interaction between Emotional Block x Position x ESPAN group ($F(10, 92) = 1.91$, $p = .039$). Follow-up simple effects of Emotion Block at positions 1 and 2 showed no differences for either the low or high ESPAN groups. In contrast both groups showed an effect of Emotion Block at position 3 (low ESPAN, $F(2, 96) = 7.31$, $p < .01$; high ESPAN, $F(2, 88) = 3.16$, $p < .05$). Pairwise comparisons showed for both the low and high ESPAN group that neutral (transport-related) block resulted in less errors than pleasant or the unpleasant words ($ps < .01$). The remaining positions of 4-6 failed to show any systematic ESPAN differences in errors.

Overall Response Latencies

McKenna and Sharma found significant differences in correct-color naming response latencies between emotional blocks that varied by word position, with the greatest differences being at position 2 - when participants were color-naming a neutral word. In the current study, the response times overall were somewhat slower for the Pleasant block (Mean RT = 845) and the Unpleasant block (Mean RT = 844), relative to the transport block (Mean RT = 836), however these differences were not significant (main effect of block, $F(2, 246) = 1.50$, $p = .224$), please see Figure 3-4. Response times were slower in the earlier positions (main effect of position, $F(5, 615) = 3.83$, $p = .002$); pair-wise comparisons of position showed that position 1 was significantly slower than all other positions (p-values ranging from .001-.050). The interaction between block and position was not significant ($F(10, 123) = 1.74$, $p = .066$), but there was a tendency for the emotional blocks to elicit slower response times across positions 2-4. Follow-up analyses looking at the effect of Emotional Block at positions 1, 2, and 3 were completed. These analyses showed no effect of emotion at position 1 ($p = .835$) and 3 ($p = .371$) but was on the cusp of significance for position 2 ($F(2, 246) = 2.92$, $p = .055$). This is similar to what McKenna and Sharma reported with the emotionality effect greatest at the position following the critical word, and absent for the critical word itself.

Individual Differences in Response Latencies

As was done with the error rates, effects of individual differences in WMC on correct color- naming response latencies will be presented below using two different measures of working memory capacity to divide the sample into high and low working memory capacity groups: One measure will be an emotionally neutral measure (Operation Span), and the other measure will be include emotional stimuli (Emotional Operation Span). These response time analyses will be discussed in turn below.

Individual Differences in Neutral Working Memory Capacity (OSPAN)

The effects of OSPAN capacity on correct color-naming in the modified Emotional Stroop task were analyzed in a mixed-model analysis of variance (ANOVA) with block and position as within-subject variables and span group (low and high OSPAN groups) as the between-subjects variable. As can be seen in Figure 3-5, the two OSPAN groups did not differ in overall response latencies (main effect of OSPAN group $F(1, 97) = .58$, $p = .446$), nor in the effects of emotional block, position, or their combination (Block x OSPAN group, Position x OSPAN group, Block x Position x OSPAN, all Fs < 1.00). Combined, these analyses suggest that individual differences in neutral working memory cannot predict response latencies in an Emotional Stroop task.

Individual Differences in Emotional Working Memory Capacity (ESPAN)

The effects of ESPAN capacity on correct color-naming latency in the Modified Emotional Stroop task were analyzed in a mixed-model analysis of variance (ANOVA) with block and position as within-subject variables and span group (low and high ESPAN groups) as the between-subjects variable. As can be seen in Figure 3-6, the two ESPAN groups did not differ in overall response latencies (main effect of Span group, $F(1, 92) = 1.14$, $p = .287$). Recall, that these group differences in response latencies are similar to those in the OSPAN analyses, with the low span groups having longer latencies overall than the high span groups. There were no

ESPAN group differences in pattern of response latencies across either block or position (n.s. block x span group and position x span group). However, in contrast to the neutral working memory capacity analysis, there was a significant three-way interaction between block, position, and span group ($F(10, 92) = 1.95$, $p = .035$). Follow-up analyses of the high span group response latencies showed that the greatest effect of Emotional Block is at position 1 ($F(2,88) = 3.15$, $p < .05$), please see Figure 3-6. All other follow-up analyses on Emotional block at each position failed to reach significance. Thus for both error rates and response latencies, WMC as assessed by the ESPAN task, but not the OSPAN, is predictive of the effects of the presence of emotional words on color-naming performance.

Congruency Stroop

Kane and Engle (2003) found that the order in which participants received the two list-wise proportion blocks of 0% and 75% influenced whether individual differences in attention control were seen in the errors or the response latencies. If the participants received the 0% congruent condition before the 75% condition, the individual differences in working memory capacity were found in the response time interference and not in the error rates. In contrast, if participants received the 75% congruency condition before the 0% condition, the differences were found in error interference and not in the response latencies.

In the current study participants always received the 0%, followed by the 75% congruency block, so we might expect that any effects of Span group would be seen on response latency rather than accuracy. Nonetheless, both dependent measures were analyzed. To determine whether individual differences in working memory capacity affected performance, a mixed-model analysis of variance with span group as a between-subject factor, and trial type (incongruent and neutral) and congruency (0% or 75% congruent) as the within subject factors. The color-naming error rates will be presented first, followed by the response latencies. As with the Modified Emotional Stroop task above, the overall (n = 125) results for each dependent measure will be followed by the individual difference results for that measure, for both the neutral working memory groups (low OSPAN n = 47, high OSPAN n = 52), and then the emotional working memory groups (low ESPAN n = 49, high ESPAN n = 45). The analysis of individual differences in neutral working memory that follow address Hypothesis 3a in Figure 1-1, whereas that of the individual differences in emotional working memory address Hypothesis 4b in Figure 1-1.

Overall Error Interference

The overall effect of congruency on error rate interference is presented in Figure 3-7. As the Figure suggests, the classic Stroop effect was observed, with incongruent trials resulting in greater errors relative to neutral trials across span groups (incongruent error rates = .10 and neutral error rate = .02), supported by a significant effect for trial type ($F(1,124) = 106.16$, $p < .001$). Additionally, error interference was much greater (on the incongruent trials relative to neutral trials) within the 75% congruency condition (incongruent Mean Error Rate = .16) than in the 0% congruency condition (incongruent Mean Error Rate = .06), seen in the significant main effect of block type ($F(1, 124) = 180.50$, $p < .001$). Thus the incongruent trials are more difficult when they are presented in the context of a large proportion of congruous trials, supported by a significant interaction between trial type and congruency block ($F(1, 124) = 102.02$, $p < .001$). In contrast, the neutral trials seem to be unaffected by the list-wise congruency proportion (Mean Error Rate = .024 for both the 0% and 75% conditions). Interestingly, the congruent trials had slightly fewer errors (Mean Error Rate = .02), suggesting that the match between the semantic content of the congruent trials was helping or facilitating performance slightly. This facilitation is mentioned in the results noted by Kane and Engle (2003), which they explained as due to there being no semantic interference or response competition on these trials, or that the participants were simply reading the words and not color-naming, thus showing greater accuracy on the congruent, relative to the neutral trials.

Individual Differences in Neutral Working Memory Capacity (OSPAN)

In the results that follow, the interference effect will be presented directly in the figures as difference scores between the incongruent and neutral trials, although trial type (incongruent versus neutral) was included as a factor in the ANOVAs. The error interference scores for the low and high OSPAN groups are shown in Figure 3-8. The mixed-model ANOVA (noted above) showed greater errors for the low span group across congruency condition (Mean interference for low-span group, 13%; mean interference for high span group, 7%), supported by a significant interaction between trial type and span group ($F(1, 97) = 11.22$, $p < .001$). There was no interaction between list-wise congruency proportion and OSPAN groups ($p = .279$), nor was there a significant three-way interaction between trial type, list-wise congruency proportion and OSPAN group ($p = .143$). There was, however, a significant interaction between trial type and OSPAN group ($F(1, 97) = 11.22$, $p < .001$), with the low OSPAN group showing larger errors for the incongruent, relative to the neutral trials, for both the 0% to 75% congruity conditions than did the high-span group (see Figure 3-8). Kane and Engle observed WMC effects on response latency and not error rates when the 75% congruent condition followed the 0% condition. The present effect on error rates replicates their findings, with low-span individuals less able to maintain attentional task set in the face of a large proportion of congruent trials.

Individual Differences in Emotional Working Memory Capacity (ESPAN)

The error interference scores for the low and high ESPAN groups are shown in Figure 3-9. The mixed-model ANOVA showed that the low and high span groups had similar error interference rates across Congruency blocks (Mean interference for low-span group, 12%; mean interference for high span group, 9%). In contrast to the neutral working memory results, there was no significant interaction of span group with any variable (trial type x span group (F(1,92) = 2.14, p = .147), congruency proportion x span group (F(1,92) = .001, p = .982), trial type x proportion x span group (F(1,92) = .39, p = .531).

Follow-up Regression Analyses on Error Interference

The following analyses address Hypothesis 2. in Figure 1-1. Stepwise regression, using the full sample of participants (n=125), was used to compare the predictive power of two different models. Model A, looked at how well OSPAN scores alone and then OPSAN and ESPAN combined, predicted error interference in the 0% and 75% Congruency Blocks. Model B looked at how well ESPAN alone, versus ESPAN and OSPAN combined could capture variance in predicting error interference in the 0% and 75% Congruency Blocks. Please see Appendix D for detailed regression tables.

The regression results show that OSPAN scores account for about 4.2% of the variability in predicting error interference for the 0% Congruency Block, whereas the full model including both OSPAN and ESPAN only accounts for 4.4%. This suggests that ESPAN scores are not contributing much toward predicting these scores. We see a similar pattern for the error rates in the 75% Congruency Block where the model with OSPAN alone accounts for 3.7%, whereas the model with both OSPAN and ESPAN only accounts for 4%. Model B was not a significant predictor of error rates for either congruency block.

Overall Response Latencies

Mean correct response latencies for all participants were entered into an analysis of variance, with trial type (incongruent and neutral) and congruency (0% or 75% congruent) as within-subject variables. Extreme latencies were corrected before any analyses, whereby trials with latencies faster than 250 ms were omitted, and latencies greater than 1.7 times the median were set to that value. Overall, across congruency blocks, there is a classic Stroop effect present, with color-naming task taking longer on the incongruent trials (Mean RT = 1311 ms) relative to the neutral trials (Mean RT = 1153 ms), supported by a significant effect for trial type (F(1,124) = 876.47, p < .001), please see Figure 3-10. Additionally, there was a significant interaction between trial type and congruency block (F(1, 124) = 128.83, p < .001) with incongruent trial response latencies longer in the 75% congruency block (Mean RT = 153 ms) relative to the 0% congruency block (Mean RT = 138 ms). Interestingly, the neutral trial response times remain relatively constant across list-wise congruency blocks (CS0% Mean RT = 1147 and CS75% Mean RT = 1160). In the 75% congruency block, when congruent trials were presented, their response latencies are relatively quick (Mean RT = 1083 ms), suggesting that when the lexical content of the trials is consistent with the task goal of color-naming, performance is facilitated. This idea of facilitation will be discussed within the context of individual differences in working memory capacity and attention control below.

Response Time Interference

Response time interference scores were obtained by subtracting the mean color-naming latency for neutral items from color-naming latency for incongruent items. The overall mean interference scores will be presented below, followed by individual differences analyses of the neutral traditional working memory capacity measure, and then by the emotional working memory capacity measure. Response time interference increased with increased congruency proportion (CS0% RT interference = 114 ms, and CS75% RT interference = 200 ms), as seen in the significant main effect of congruency proportion (F(1, 124) = 122.07, p < .001).

Individual Differences in Neutral Working Memory Capacity (OSPAN)

The interaction between span group and congruency proportion failed to reach significance (F (1, 97) = 3.17, p =.078), and the interaction between trial type and span group was not significant (p = .993). The three-way interaction between trial type, list-wise congruency proportion, and OSPAN group, however, was significant (F (1, 97) = 5.37, p =.023): interference scores were slightly lower for the low-span than high-span group in the 0% congruency condition, but this difference was reversed in the CS75% condition (see Figure 3-11) suggesting that working memory capacity groups had different patterns of performance for each trial type between the two congruency proportion blocks.

Individual Differences in Emotional Working Memory Capacity (ESPAN)

Mean response latencies were entered into a mixed-model analysis of variance, with span group as a between-subject factor and trial type (incongruent and neutral) and congruency (0% or 75% congruent) as the within subject factors. Response times were equivalent across Congruency blocks for the ESPAN groups, as seen in the lack of a significant interactions between span group and congruency proportion (F (1, 92) = .23, p =.628). In contrast, the interaction between span group and trial type (F(1,92) = 4.74, p = .032) was significant, with the low span group response latencies longer than the high span group for both the incongruent and neutral trials, see response time interference in Figure 3-12. The three-way interaction (F(1, 92) = 2.93, p =.090) was not significant. Combined, these effects suggest that the emotional working memory capacity measure may be a weak predictor of response time performance within the Congruency Stroop task.

Follow-up Regression Analyses on Response Time Interference

The following analyses address Hypothesis 2 in Figure 1-1. Stepwise regression, using the full sample of participants (n=125), was used to compare the predictive power of two different models. Model A, looked at how well OSPAN scores alone versus OPSAN and ESPAN scores combined could predict interference effects in response latencies in the 0% and 75% Congruency Blocks. Model B looked at how well ESPAN alone, versus ESPAN and

OSPAN scores combined could capture variance in predicting response time interference in the 0% and 75% Congruency Blocks. Please see Appendix E for detailed regression tables.

The regression results show that neither Model A nor Model B is a significant predictor of response time interference in the 75% Congruency Block. In contrast, for the 0% Congruency Block ESPAN is a better predictor than OSPAN, where in Model B, ESPAN accounts for 8.9% of the variability, with the addition of OSPAN to the model adding only .5% of variance accountability (resulting in 9.4%). When Model A is looked at, we see that OSPAN alone only accounts for 3.8%, before adding ESPAN to account for 9.4%. This suggests that EPSAN is in at least one instance measuring some aspect of attention control in a way that is more sensitive that the OSPAN measure to predict response time interference in the 0% Congruency - this is likely the ability to maintain attention in the face of distraction.

Overall Response Time Facilitation

Facilitation is a difference score obtained from subtracting the mean correct response latency of neutral trials from the mean response latency of the congruent trials. Individual differences in working memory are analyzed to see whether the amount of facilitation within the 75% congruent condition varied with ESPAN or OSPAN scores. The mean facilitation response times were analyzed in a mixed-model analysis of variance with span group (low and high) as the between-subject factor and trial type (congruent and neutral) as the within-subject factor. As mentioned in earlier analyses, the congruent trials had faster latencies than the neutral trials across working memory span groups (congruent mean RT = 1082 ms, neutral mean RT=1162 ms) and is supported by a significant main effect of trial type ($F(1, 124) = 245.06$, $p < .000$).

Individual Differences in Neutral Working Memory Capacity (OSPAN)

The main effect of span group was not significant ($F(1,97) = 1.18$, $p = .280$), please see Figure 3-13. There was a significant interaction between trial type and span group ($F(1,97)$ =

7.69, p = .007). The low span group had faster response times for the congruent (Mean RT = 1100 ms) than the neutral trials (Mean RT = 1189 ms), whereas the high span group showed the opposite pattern, with greater response times for the congruent (Mean RT = 1090 ms), relative to the neutral trials (Mean RT = 1149 ms) suggesting that the high OSPAN group was doing the task, and not simply reading the words. This is an indirect measure of the status of the task-set or goals of each group, where the low group is not keeping their color-naming goal active, otherwise they would not have shown such significant benefit in their response times for the congruent versus the neutral trials.

Individual Differences in Emotional Working Memory Capacity (ESPAN)

Similar to the analysis on the individual differences in neutral working memory capacity, the main effect of span group was not significant (F(1,92) = .04, p = .841, and there was a significant interaction between trial type and ESPAN span group (F(1,92) = 7.23, p = .009), please see Figure 3-14. The low span group had faster response times for the congruent (Mean RT = 1072 ms) than the neutral trials (Mean RT = 1092 ms), whereas the high span group showed the opposite pattern, with greater response times for the congruent (Mean RT = 1167 ms), relative to the neutral trials. (Mean RT = 1156 ms). As in the OSPAN groups, the ESPAN groups showed different facilitation patterns, suggesting the low ESPAN group is failing to keep their task-set or goal active, rather that they were simply reading the words. Conversely, we see that the High ESPAN group is keeping their goal active, as seen by the smaller facilitation seen in their response latencies.

Follow-up Regression Analyses on Response Time Facilitation

The following analyses address Hypothesis 2. in Figure 1-1. Stepwise regression, using the full sample of participants (n = 125), was used to compare the predictive power of two different models. Model A, looked at how well OSPAN scores alone versus OPSAN and

ESPAN scores combined could capture variance in response time facilitation in the 0% and 75% Congruency Blocks. Model B looked at how well ESPAN alone, versus ESPAN and OSPAN scores combined, would predict error interference predicted response time facilitation in the 0% and 75% Congruency Blocks. Please see Appendix F for detailed regression tables.

The regression analyses show that ESPAN is a better predictor of response time facilitation because it accounted for 6.4% (compared to 3.9% in Model A). Additionally when OSPAN is added to the model we see that the total variance that is accounted for in predicting response time facilitation is increased to 7.3%, suggesting that OSPAN doesn't contribute much of the total variance when the model contains both OSPAN and ESPAN.

Word Rating Task

Participants rated the words that they encountered in the Neutral and Emotional Working Memory Capacity Measures and the Emotional Stroop task on two dimensions, valence and arousal. The ratings were made on 5-point Likert scales. For valence, a "1" indicates the participant perceives the word as very unpleasant, whereas a "5" indicates the participant views the word as highly pleasant. For arousal, a "1" indicates the participant perceives the word as non-arousing, whereas a "5" indicates the participant views the word as highly arousing. This rating task was included in the current investigation as a verification that the words chosen to represent the emotional categories within the tasks used above, were perceived how we intended them to be perceived. The mean valence and arousal ratings for each category of words can be seen in table (Table 3-1). From the table, we see that the words chosen for each word-type were rated and/or perceived as intended (Appendix C for exact word lists). For example, across all participants, the Unpleasant Emotional Stroop words were rated to be the most unpleasant (Mean Valence Rating = 1.38, standard deviation = .38), relative to the Pleasant and Neutral (transportation-related) words, this is supported by a significant main effect of Word Type (F(3,

372) = 1633.03, $p < .01$) and a significant linear effect of emotion. Similarly with the arousal dimension, the Unpleasant words were rated as most arousing (Mean Arousal Rating = 4.64, standard deviation = .93), followed by the Pleasant words (Mean Arousal Rating = 3.21, standard deviation = 1.13), and Neutral words (Mean Arousal Rating = 2.35, standard deviation = .75), this is supported by a significant main effect of Word Type ($F(3, 372) = 139.90$, $p < .01$) and a significant quadratic effect.

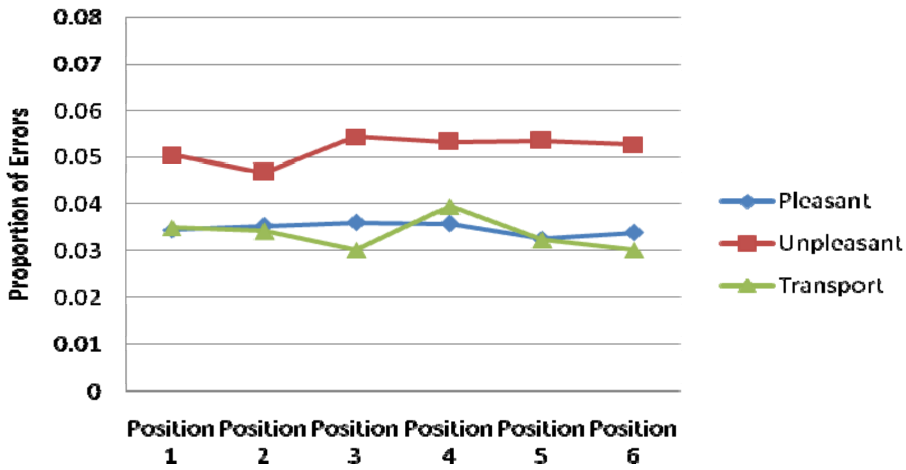
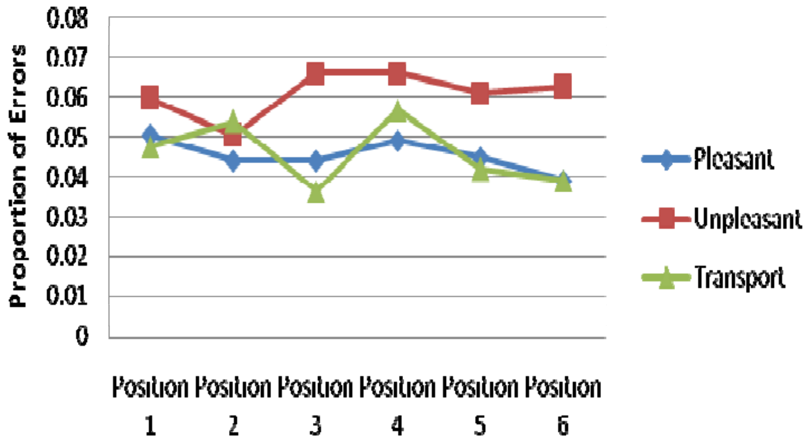


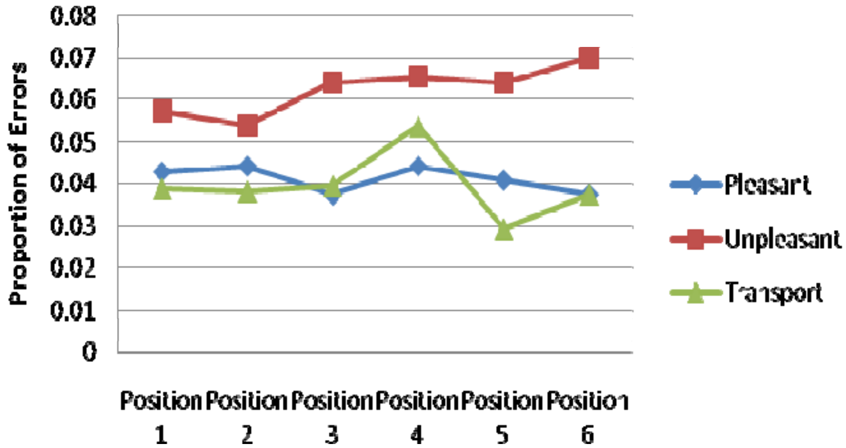
Figure 3-1. Overall Emotional Stroop error rates



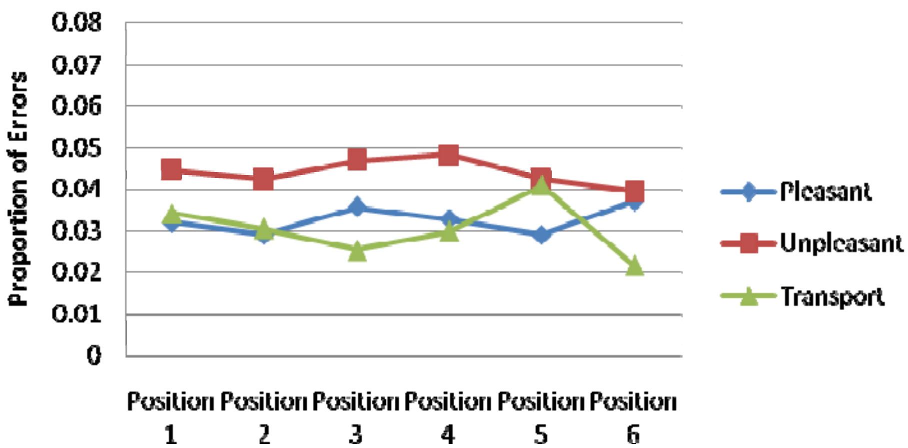
A

B

Figure 3-2. Emotional Stroop: Individual differences in Error Rates for OSPAN groups A) Low OSPAN group, B) high OSPAN group



A



B

Figure 3-3.Emotional Stroop: Individual differences in error rates for ESPAN groups A) Low ESPAN group, B) High ESPAN group

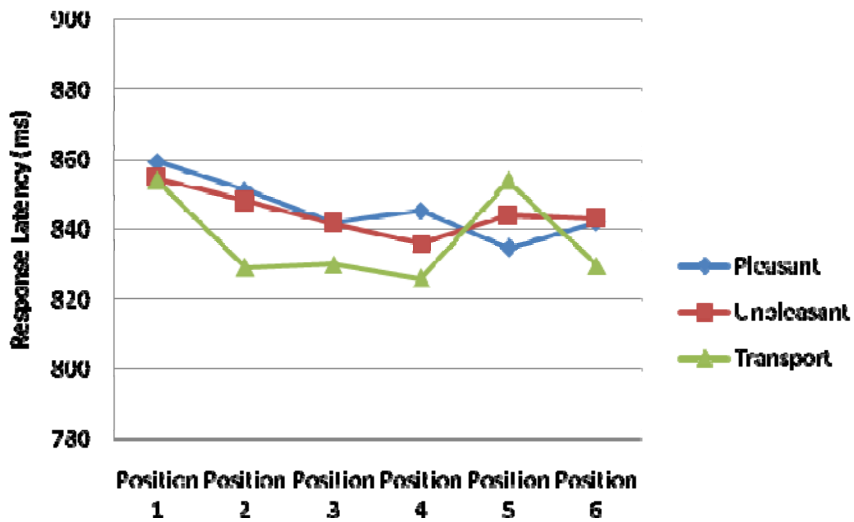
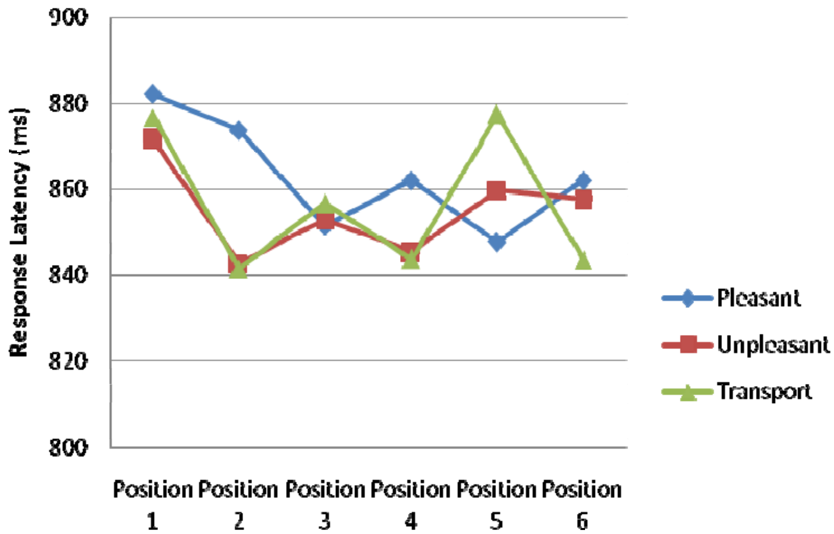
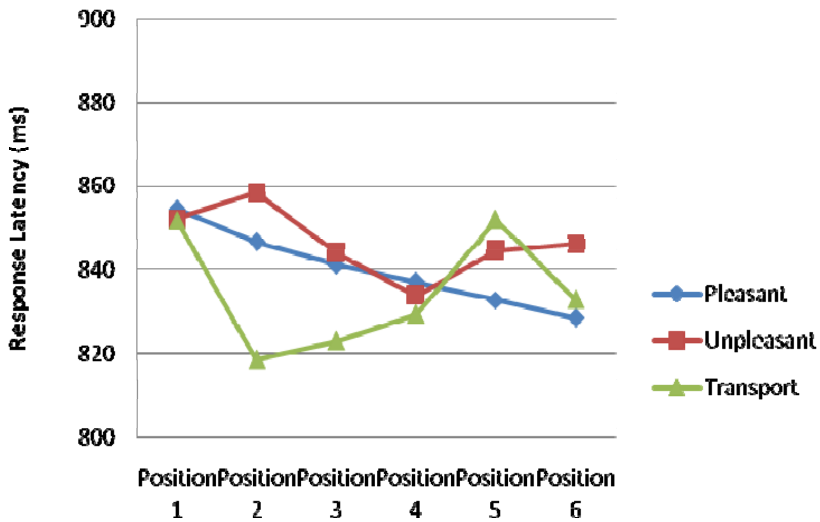


Figure 3-4. Overall Emotional Stroop response latencies

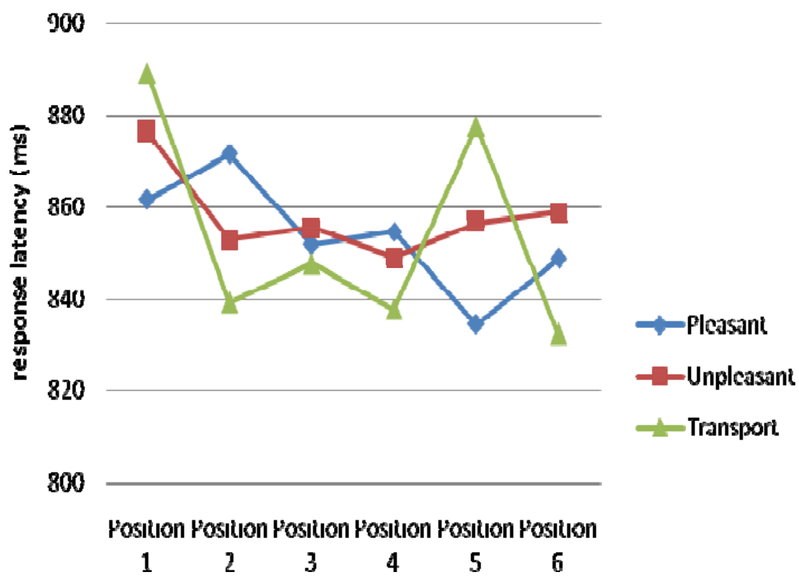


A

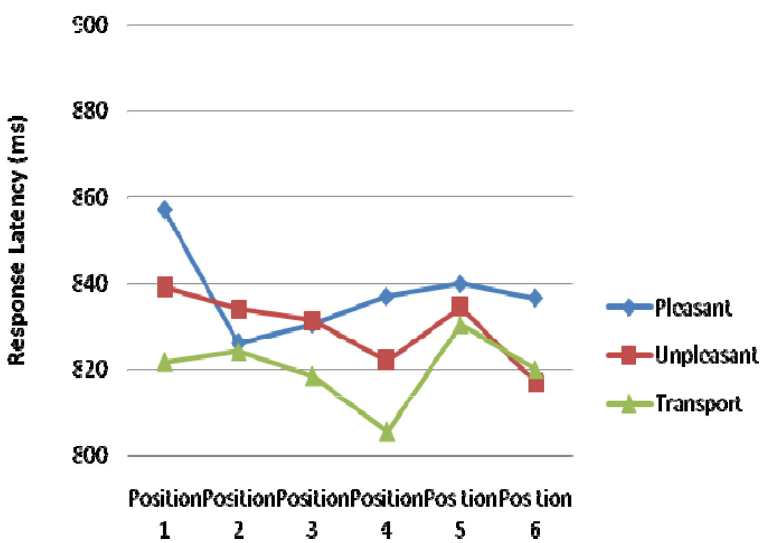


B

Figure 3-5. Emotional Stroop: Individual differences in response latencies for OSPAN groups A) Low OSPAN group, B) High OSPAN group



A



B

Figure 3-6. Emotional Stroop: Individual differences in response times for ESPAN groups A) Low ESPAN group, B)High ESPAN group

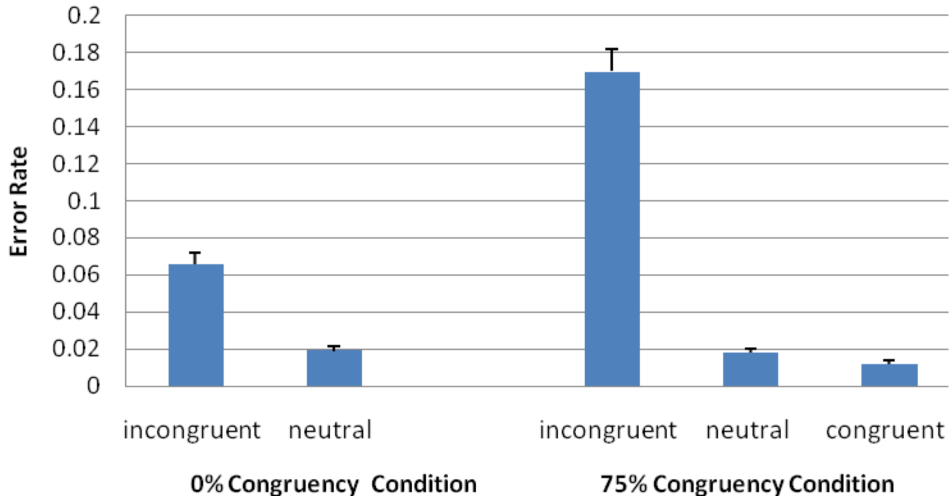


Figure 3-7. Congruency Stroop: Overall mean error rates. On the Left are the error rates for the 0% Congruent condition, and on the Right are the error rates for the 75% Congruent condition.

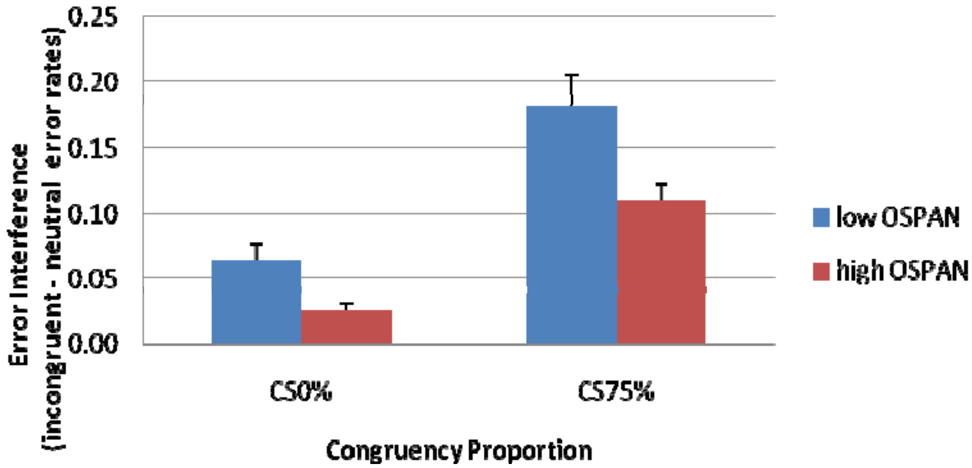


Figure 3-8. Congruency Stroop: Error interference for OSPAN groups

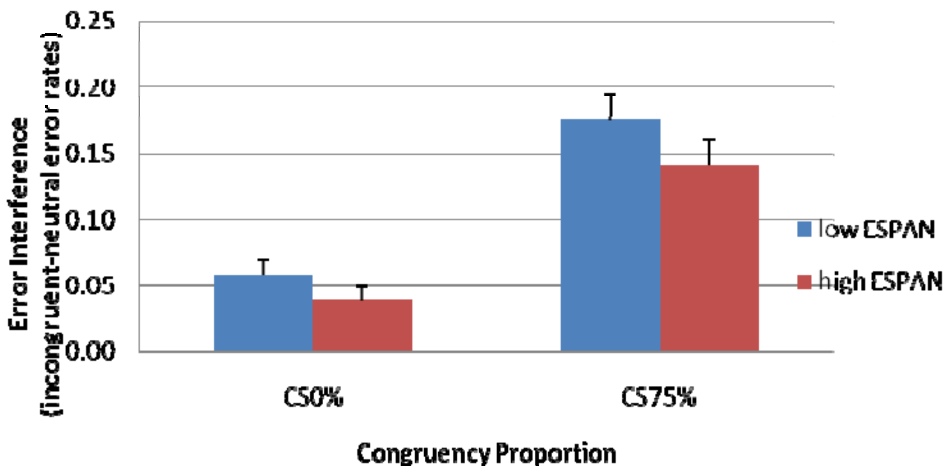


Figure 3-9. Congruency Stroop: Error interference for ESPAN groups

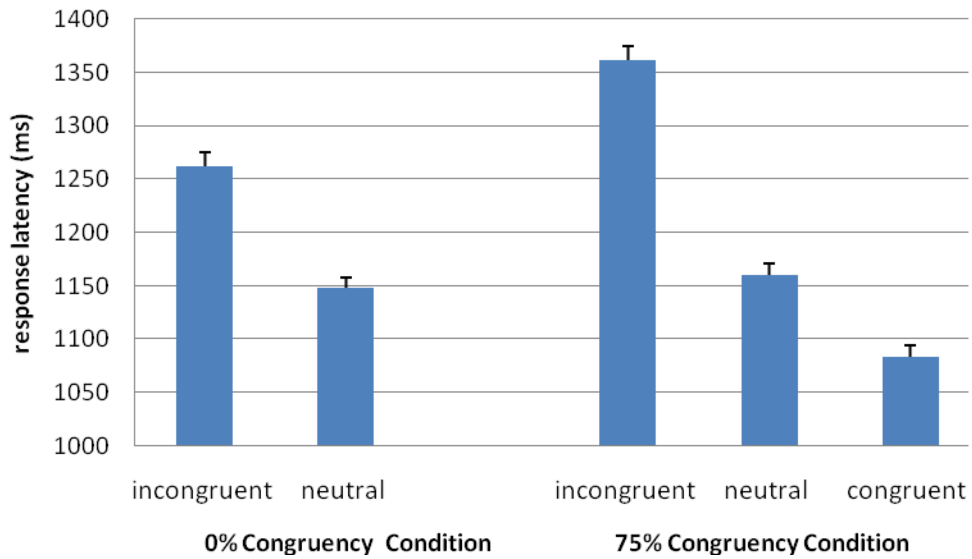


Figure 3-10. Congruency Stroop: Overall response times by trial type

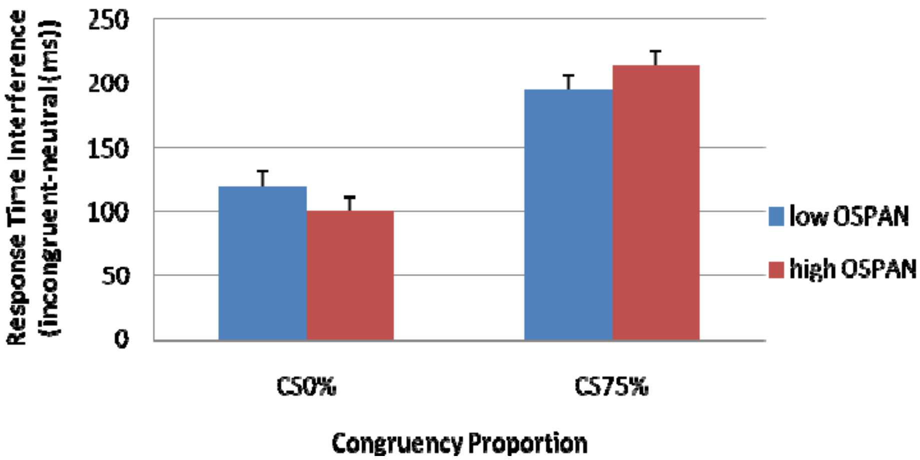


Figure 3-11. Congruency Stroop: Individual differences in response time interference by OSPAN groups

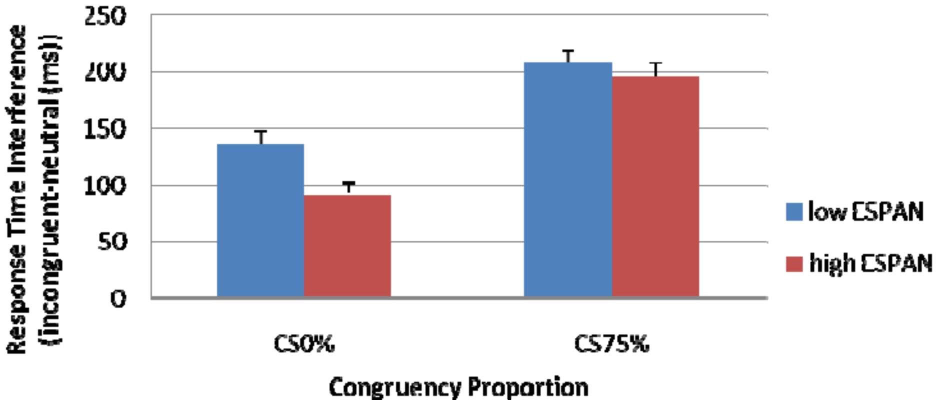


Figure 3-12. Congruency Stroop: Individual differences in response time interference by ESPAN groups

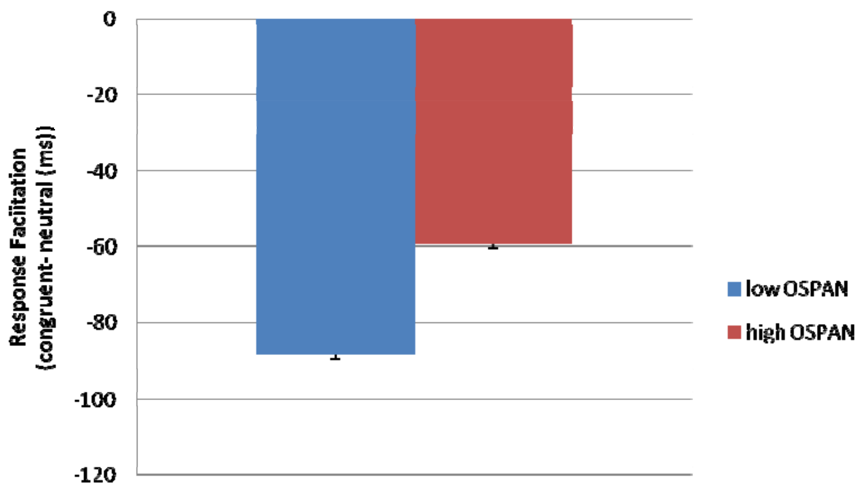


Figure 3-13. Congruency Stroop: Individual differences in response time facilitation by OSPAN groups

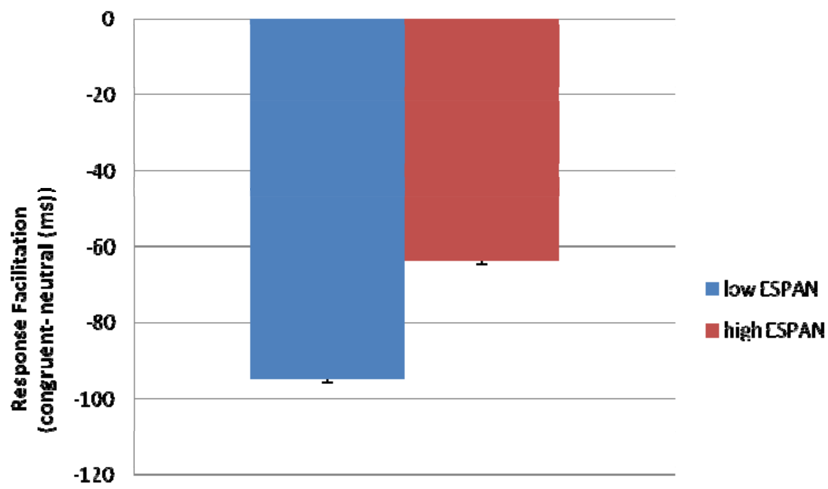


Figure 3-14. Congruency Stroop: Individual differences in response time facilitation by ESPAN groups

Table 3-1. Frequency distribution of OSPAN and ESPAN groups

	ESPAN group			
	Low	Middle	High	Total in OSPAN Group
OSPAN Group				
Low	27	12	9	48
Middle	9	4	13	26
High	14	15	23	52

The frequency distribution shows the group assignments of ESPAN scores based on their OSPAN group. For example, the number of participants who had a high OSPAN score, yet a low ESPAN score was 14.

Table 3-2. Word ratings

Task	Valence	Arousal
Neutral Operation Span	4.59(1.29)	3.10(.68)
Emotional Operation Span	2.36(.67)	4.59(.54)
Emotional Stroop		
Pleasant Block		
Position 1	4.63(.40)	3.21(1.13)
Positions 2-6	3.19(.33)	2.30(.66)
Transport Block		
Position 1	3.25(.45)	2.39(.77)
Positions 2-6	3.10(.31)	2.34(.68)
Unpleasant Block		
Position 1	1.38(.38)	3.85(.92)
Positions 2-6	3.21(.33)	2.34(.67)

*This is a table of mean valence and arousal ratings made for words presented within the neutral working memory (Operation Span), emotional working memory (Emotional Operation Span) and the Emotional Stroop tasks. The values in parentheses are the standard deviations associated with each mean rating.

CHAPTER 4
DISCUSSION

The overarching goal of this investigation was to explore the concept of an emotional working memory. Working memory is a psychological construct representing a temporary memory system that maintains information temporarily, via code-specific stores, and serves as an interface between perception and long term memory structures. Since the introduction of this construct, there has been little work done to investigate how emotional stimuli might impact the working memory system. The current research approached this question by investigating the impact that emotionally-charged stimuli have on the storage and processing capabilities of working memory. The "storage" question was approached from a psychometric standpoint, and the processing question was approached via performance in several attention tasks.

To evaluate the role that emotion has on storage capabilities of working memory, a novel measure of working memory capacity was developed that incorporates emotional stimuli, and an individual differences approach to performance on storage of emotional stimuli was used to predict performance in attention-rich tasks. The relative predictive power of the working memory capacity with emotional stimuli (the ESPAN task) was compared to that of a traditional working memory capacity measure (the OSPAN task) that has only neutral stimuli for two types of attention tasks. The attention tasks were chosen to tap two specific attention abilities that are thought to be measured by working memory capacity measures such as the Operation Span task, and its emotional modification, used in this study. The two abilities thought to be measured in the Operation span task are (a) the ability to maintain attention in the face of distraction, and (b) the ability to maintain task set or goals across time. Both attention tasks used in this investigation were variations of the traditional color-naming interference task of Stroop (1935). One was a modified Emotional Stroop task, wherein accuracy and latency of color-naming for words were compared across blocks of trials that differed in whether an emotional or neutral word appeared in every sixth position (McKenna & Sharma, 2004). The other was the Congruency Stroop task, wherein accuracy and latency of color-naming for words was compared across blocks of trials where the list-wise proportion on congruent (color words that matched the to-be-named color) trials was either low (0%) or high (75%) (Kane & Engle, 2003). The Emotional Stroop task was chosen to tap the ability to maintain attention in the face of an emotional word, whose semantic content is likely to distract attention. The Congruency Stroop was chosen to test both abilities measured by working memory capacity measures where the material to be maintained in working memory was not of an emotional nature.

Among a sample of more than 100 students, working memory capacity (WMC) scores ranged widely, with some participants doing very well, and some, very poorly. The range of Neutral Working Memory Capacity scores was 2-39, and the range of scores for the Emotional Working Memory Capacity scores was 0-37. While the ranges were similar, overall capacity was significantly lower for ESPAN (Mean = 15.3) than ESPAN (Mean = 17.5). This effect is notable, since as reviewed in the introduction, emotion typically helps long-term memory, and has little effect on traditional short-term memory tasks. This is the first demonstration, to my knowledge, of a direct cost of emotion in working memory.

Consistent with the notion that maintaining emotional material in working memory is a specific skill on which individuals may vary, the correlation of OSPAN and ESPAN scores was +.45. Although significant, this correlation is substantially lower than the test-retest reliability typically reported for OSPAN itself over similar lags in time of test (+.66 - +.85), and shows that only about 25% of the variance in ESPAN scores is accounted for by OSPAN scores. Additionally, the scores across both measures were significantly different from each other, yet the accuracy scores remained constant across both. This is remarkable, given that, except for the use of emotional words versus neutral words, the tasks were identical in every aspect. This is perhaps our strongest evidence in support of the reality of an "emotional working memory." These findings support Hypothesis 2, presented in Figure 1-1.

The ability of the ESPAN scores to predict performance in two very different tasks involving attentional focus and control, and indeed to be more closely associated with performance in the task that also involved emotional materials (the Emotional Stroop) than in the task that did not (the Congruency Stroop), further demonstrates the value of the emotional working-memory construct. (Importantly, the variability of ESPAN and OSPAN scores in our sample was comparable, so any difference in their association with target variables is unlikely due to any range restriction issues.) The findings from each of these target tasks will be summarized in turn.

McKenna and Sharma (2004) had found that the "emotional Stroop" effect – slower color-naming latencies to emotional words than neutral words – was not seen in latency to the emotional word itself, but to words "downstream" from it, when the response-stimulus interval (RSI) was minimal (< 20 m). They argued that this "delayed" effect of emotionality reflected not a rapid, automatic interference from the emotional word's processing, but a slower, more temporally spread-out attentional triggered by that automatic processing of the word's meaning. Moreover, they found this difference only for blocks where the critical word was unpleasant, and not pleasant. The current study aimed to replicate their findings, please see Hypothesis 1b., Figure 1-1.

In broad terms, the current study did replicate these findings, as the greatest differences in color-naming latencies for type of emotional block were found on color-naming of neutral words that appeared just *after* the emotional word was responded to (Position 2, see Figure 3-4); but in contrast to the results of McKenna & Sharma, it was an overall emotionality effect (found for both Pleasant and Unpleasant blocks) that resulted in faster, not longer latencies. Moreover, the effect appeared more sustained across subsequent positions, with a trend, a least, toward continued interference at positions 3 and 4. Also in contrast to McKenna & Sharma, the current investigation found an emotionality effect for errors, with significantly more errors for blocks with Unpleasant critical words then for Pleasant or Neutral (Transportation-related). The effect on errors was even more diffuse and sustained across position than was that for response latency (see Figure 3-2).

The extension of the McKenna and Sharma (2004) Emotional Stroop study was to determine whether there are individual differences in working memory capacity on color-naming performance that would be better predicted when the WMC measure itself involved emotional materials. In the current investigation, then, two measures of working memory capacity (neutral and emotional) were used to predict performance within the Emotional Stroop task (Hypothesis 4a. and 3b respectively, Figure 1-1). Results showed that overall, individual differences in the emotional measure of working memory capacity (ESPAN) were better predictor of performance (for both errors and latencies) in the Emotional Stroop task than the neutral measure (OSPAN). Although the detailed patterns of how WMC affected the profile of emotionality effects across position in this task are complex, ESPAN as a factor was a significant modulator of this pattern for both error scores and latency, while OSPAN was not. (As noted above, the difference in outcome for ESPAN and OSPAN measures cannot be due to greater variance in the ESPAN scores, since they were in fact comparable. Also, as will be reviewed below, the OSPAN factor was more predictive than ESPAN scores, for the neutral Congruency Stroop task, on several measures.)

An additional goal of the current study was to evaluate whether a novel measure of working memory capacity that incorporates emotional stimuli could predict performance in a Stroop task with nonemotional stimuli, where the list-wise proportion of congruent trials was varied between blocks (Hypothesis 4b., Figure 1-1). This type of Stroop task was chosen to test the ability of participants to maintain the color-naming task goal across a series of trials where accuracy could be obtained without doing the color-naming, but rather by reading the words presented. The results of this analysis were mixed. On the one hand, OSPAN as a factor was significantly associated with the pattern of interference effects across the 0% and 75% congruence conditions for response latencies (Hypothesis 3a., Figure 1-1), while ESPAN was not. The current study showed that the emotional working memory measure was not a good predictor of performance, neither error rates nor response latencies, on this type of attention task. On the other hand, regression analyses using the full range of scores and sample of 125 individuals suggested that ESPAN scores may be better predictors of some of interference (0%) and facilitation effects in this task than is OSPAN.

Overall, however, the present pattern of working memory capacity analyses suggest a dissociation between emotional and neutral working memory consistent with the overarching hypothesis of this dissertation: individual differences in emotional working memory capacity (Emotional Operation Span Task) were better predictors of performance in the Emotional Stroop task; conversely, individual differences in performance on a neutral working memory capacity (Operation Span Task) can predict error rates and response interference latencies in the Congruency Stroop task, whereas differences in the emotional working memory measure were less able to do so. The one index of performance that both OSPAN and ESPAN groups show individual differences on is response facilitation in the Congruency Stroop task.

This pattern of results would seem to support the construct of emotional working memory laid out in the introduction; one's ability to maintain emotional words in working memory (the ESPAN task) was specifically a better predictor of performance in other tasks involving emotion, while the ability to maintain neutral words was a better predictor of attention control in the classic Stroop task.

The current investigation looked at the impact of emotional stimuli on working memory capacity and attention control. The approach used in the current study was to vary the emotionality of stimuli within the working memory capacity measure as well as within the Stroop paradigm. The measurement and impact of emotional stimuli was assessed using verbal stimuli. It may be that emotional words require more cognitive processing for the emotionality dimension to be culled, thus making differences by emotionality a bit more difficult to detect. Future research should evaluate the role of emotion on working memory and attention allocation using other stimuli, such as pictures or videos where the emotionality of the stimuli can be derived faster, without the need to verbally process the stimuli.

Future research should also employ a variety of working memory measures. In the current task the Operation Span and its emotional derivative, the emotional Operation Span task, were the only measures of working memory capacity employed. It seems likely that with a variety of working memory capacity of measures, and their emotional derivatives, a better picture of emotions' impact on measurement could be better understood. Additionally, by employing multiple measures of working memory capacity, more sophisticated statistical routines could be employed where more of the variance in predictive power could be captured because presumably there would be some different cognitive processes being used in one measure, and not in another measure.

Another interesting approach to studying emotional working memory would be to see how it is related to general intelligence. In other words: How much error variance can a measure such as ESPAN capture within a latent variable analysis aiming to measure general intelligence? The general goal of latent variable analysis is to account for error variance across two sources: error associated with multiple measurements of the same construct, as well as error variance attributed to the individuals tested on each of the measures. The theory behind this analysis is that after the error variance from the measurement tools and individuals' performance on these measures is found and extracted, only error variance associated with the tasks used to measure the construct of interest is left. It is this remaining error which provides insight as to the nature of the construct. Kane et al., (2004) conducted a latent variable analysis on a variety of span measures in an effort to determine whether WMC is a domain specific or domain general construct, and to explore the relationship of WMC to other constructs (e.g., general intelligence and short term memory). An extension of this type of study could be done to determine whether a measure of emotional working memory can contribute to measuring the construct of general intelligence.

Finally, there has been a good deal of interest recently in the concept of "emotional intelligence." It would be interesting to see if measures like ESPAN, targeted to emotional working memory, might be especially useful in predicting variation in executive function tasks requiring such emotional cognition. Some people, presumably, with greater control over emotional working memory, are better able to avoid having to say, *"I don't know what I was thinking; I was caught up in the heat of the moment."*

APPENDIX A
INFORMED CONSENT

Project Title: Working Memory: An individual differences approach to understanding attention control.

Principal Investigator: Cynthia E. Kaschub
Department of Psychology
PSY 052/ (352) 392-0601 Ext. 367
ckaschub@ufl.edu

This study is conducted under the supervision of Dr. Ira Fischler, as part of my doctoral training in cognitive psychology. In this study, we are interested in working memory and your ability to control your attention within tasks. We will ask you to participate in two experimental sessions, the first of which will last about one hour, and the second session about one and a half hours.

In both sessions you will be asked to complete a color-naming task, followed by a working memory task. The color-naming task requires you to indicate the color that each of a series of words is printed in. In the working memory task, you verify if a simple mathematical equation (for example, (6 / 2) + 1 = 4?) is correct, then read and try to remember a word that is presented after your response. You will retain the words that appear after each answer-verification until you receive the recall prompt, at which time you will be asked to type the words that you received, in the same order, since the last recall. Precise instructions for the experiment will be shown on the computer screen before you start the experiment.

In the first experimental session, the color-naming task will include words representing a variety of concepts, objects and events, some of which may be considered emotionally evocative. In the second experimental session the color-naming words will be emotionally neutral. In the second experimental session the working memory task will include emotionally evocative words. After you complete this task, you will be shown a word and will be asked to rate the word on two nine-point scales. The scale will be provided to you on the computer screen following the word presentation. Precise instructions for the task will be shown on the computer screen before you start the experiment.

You will receive five credits towards the research participation requirements in your class and have a chance to learn about the use of working memory measures to study attention-related processes. The data from this experiment will help us to better understand individual differences in attention control.

Time required for this experiment is about two and a half hours total. If you have any question about the purposes or procedures of the experiment that need to be clarified before you give your consent to participate, I would be happy to answer them now. Remember that at any point during the experiment you are free to ask further questions or to withdraw your consent and discontinue participation without penalty. Your identity will be kept confidential to the extent provided by law. Your information will be assigned a code number. Your name will not be used in any report. After your data is collected, we destroy any linking of your name and the data files. There are no direct benefits from participating in this experiment. There are no more than minimal risks nor are there any anticipated direct benefits to you during this study.

If you have questions about the experiment please contact: Cynthia Kaschub at 392-0601 x 367 or my supervisor Ira Fischler at 392-0601 x 228 Dept. of Psychology, University of Florida, Gainesville, Fl. 32611. Questions or concerns about the research participant's rights can be directed to the UFIRB office, PO Box 112250, University of Florida, Gainesville, FL 32611-2250.

Project title: Working Memory: An individual differences approach to understanding attention control.

PARTICIPANT'S CONSENT: I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Participant: ____ Date: _______

Principal Investigator: ___________________________________ Date: _______

APPENDIX B
OPERATION SPAN STIMULI

OPERATIONS	OSPAN WORDS	ESPAN WORDS
(9 / 3) - 2 = 2	humble	rape
(8 / 4) - 1 = 1	stomach	roach
(6 / 2) + 1 = 4	book	anger
(6 x 3) - 2 = 11	jelly	tumor
(4 x 2) + 1 = 9	unit	bomb
(10 / 2) + 4 = 9	ketchup	torture
(10 / 2) - 3 = 2	village	revolt
(10 / 10) - 1 = 2	truck	killer
(7 / 1) + 2 = 7	custom	hostage
(3 / 1) - 2 = 3	gender	anxious
(2 x 1) - 1 = 1	ballot	hatred
(10 / 1) + 3 = 13	integer	leprosy
(9 x 2) + 1 = 18	rattle	tornado
(9 / 1) - 7 = 4	hawk	betray
(8 x 4) - 2 = 32	writer	python
(9 x 3) - 3 = 24	phase	panic
(4 / 1) + 1 = 4	statue	ulcer
(10 / 1) - 1 = 9	news	assault
(8 x 4) + 2 = 34	horse	slap
(6 x 3) + 2 = 17	salad	surgery
(6 / 3) + 2 = 5	army	bees
(6 x 2) - 3 = 10	column	snake
(8 / 2) + 4 = 2	invest	scream
(8 / 2) - 1 = 3	frog	evil
(9 / 1) - 5 = 4	chair	quarrel
(6 / 2) - 2 = 2	quiet	burn
(7 x 2) - 1 = 14	paint	fear
(6 x 2) - 2 = 10	tower	thief
(2 x 2) + 1 = 4	cannon	violent
(7 x 1) + 6 = 13	engine	dreary
(3 / 1) + 3 = 6	context	poison
(10 / 1) + 1 = 10	farm	divorce
(4 x 4) + 1 = 17	mantel	horror
(3 x 3) - 1 = 8	detail	brutal
(3 x 1) + 2 = 2	circle	chaos
(4 / 2) + 1 = 6	lamp	demons
(5 / 5) + 1 = 2	minute	cancer
(2 x 3) + 1 = 4	salute	failure
(9 / 3) - 2 = 1	humble	pain
(10 / 2) - 4 = 3	locker	stress
(5 / 1) + 4 = 9	council	crash
(10 x 2) + 3 = 23	watch	trauma
(7 / 1) + 6 = 12	milk	danger

(3 x 2) + 1 = 6	decade	unhappy
(6 x 4) + 1 = 25	highway	abuse
(9 / 3) - 1 = 2	century	danger
(8 / 1) - 6 = 4	glass	rage
(9 x 1) + 9 = 1	number	victim

APPENDIX C
EMOTIONAL STROOP WORD STIMULI

	1	2	3	4	5	6
Unpleasant Words	REJECTED	SYMPHONY	QUANTITY	REDUCING	ELECTRON	SUITABLE
	FAILURE	CLOTHES	KITCHEN	PROJECT	SOMEONE	SOMEONE
	SUICIDE	BUFFALO	COLLECT	CAMPING	FLOWING	OBSCURE
	ABUSE	BOOTS	BRICK	CREAM	ESSAY	LEMON
	HURT	ITEM	LAWN	BOOK	COIN	TOOL
	SAD	ARC	BAG	ERA	ICE	ODD
Pleasant Words	ROMANTIC	COVERING	MOUNTAIN	COMPOSER	SENTENCE	FRONTIER
	SUCCESS	BALANCE	DEVELOP	OBVIOUS	MANAGER	PRODUCT
	MIRACLE	ANGULAR	CHANNEL	CONFIRM	FARMING	GLIMPSE
	LUCKY	ALIKE	BRASS	CLOCK	DAIRY	INPUT
	LOVE	FLAG	HAWK	MEEK	CELL	BOWL
	JOY	AIM	ROW	CUP	FLY	NET
Transport (Neutral) Words	AIRPLANE	BASEMENT	EQUATION	THURSDAY	FREQUENT	FOURTEEN
	STATION	COMPLEX	MEASURE	QUICKLY	ATTEMPT	SITTING
	RAILWAY	CABINET	COMBINE	EMBASSY	GRADUAL	PACKING
	FERRY	AWAKE	CHEEK	CROWN	LABEL	LOBBY
	BOAT	ROCK	KNOT	PART	NEWS	CHIN
	BUS	COW	BAY	FED	MUD	SUM

APPENDIX D
CONGRUENCY STROOP ERROR INTERFERENCE REGRESSION MODEL COMPARISONS

		Overall Model					Predictor Variable	
Model A	Step	R^2	ΔR^2	Adj R^2	F	p-value	OSPAN	ESPAN
0% Congruent Error Interference								
	1	0.042		0.035	5.449	0.021	-0.206	
	2	0.044	0.002	0.029	2.827	0.063	-0.184	-0.049
		Overall Model					Predictor Variable	
Model B	Step	R^2	ΔR^2	Adj R^2	F	p-value	ESPAN	OSPAN
0% Congruent Error Interference								
	1	0.017		0.01	2.19	0.142	-0.132	
	2	0.044	0.027	0.029	2.827	0.063	-0.049	-0.184

		Overall Model					Predictor Variable	
Model A	Step	R^2	ΔR^2	Adj R^2	F	p-value	OSPAN	ESPAN
75% Congruent Error Interference								
	1	0.037		0.029	4.767	0.031	-0.193	
	2	0.04	0.003	0.024	2.541	0.083	-0.167	-0.058
		Overall		Model			Predictor Variable	
Model B	Step	R^2	ΔR^2	Adj R^2	F	p-value	ESPAN	OSPAN
75% Congruent Error Interference								
	1	0.018		0.018	2.248	0.136	-0.134	
	2	0.04	0.022	0.04	2.541	0.083	-0.058	-0.167

Model A compares OSPAN as a sole predictor to a model that includes OSPAN and ESPAN as predictors of the dependent variable present. Model B compares ESPAN as a sole predictor to a model that includes ESPAN and OSPAN as predictors of the dependent variable. For Step 1, dfs = 1, 124; for Step 2, dfs = 2, 124.

APPENDIX E
CONGRUENCY STROOP RESPONSE TIME INTERFERENCE REGRESSION MODEL COMPARISONS

	Overall Model						Predictor Variable	
Model A	Step	R^2	ΔR^2	Adj R^2	F	p-value	OSPAN	ESPAN
0% Congruent Response Time Interference								
	1	0.038		0.031	4.901	0.029	-0.196	
	2	0.094	0.056	0.079	6.302	0.002	-0.075	-0.264
	Overall Model						Predictor Variable	
Model B	Step	R^2	ΔR^2	Adj R^2	F	p-value	ESPAN	OSPAN
0% Congruent Response Time Interference								
	1	0.089		0.082	12.035	0.001	-0.299	
	2	0.094	0.005	0.079	6.302	0.002	-0.264	-0.075

	Overall Model						Predictor Variable	
Model A	Step	R^2	ΔR^2	Adj R^2	F	p-value	OSPAN	ESPAN
75% Congruent Response Time Interference								
	1	0.003		-0.005	0.413	0.52	0.058	
	2	0.015	0.012	-0.001	0.954	0.388	0.114	-0.123
	Overall Model						Predictor Variable	
Model B	Step	R^2	ΔR^2	Adj R^2	F	p-value	ESPAN	OSPAN
75% Congruent Response Time Interference								
	1	0.005		-0.003	0.626	0.43	-0.071	
	2	0.015	0.01	-0.001	0.954	0.388	-0.123	0.114

Model A compares OSPAN as a sole predictor to a model that includes OSPAN and ESPAN as predictors of the dependent variable present. Model B compares ESPAN as a sole predictor to a model that includes ESPAN and OSPAN as predictors of the dependent variable. For Step 1, dfs = 1, 124; for Step 2, dfs = 2, 124.

APPENDIX F
CONGRUENCY STROOP RESPONSE TIME FACILITATION REGRESSION MODEL COMPARISONS

		Overall Model					Predictor Variable	
Model A	Step	R2	ΔR^2	Adj R2	F	p-value	OSPAN	ESPAN
		75% Congruent Response Time Facilitation						
	1	0.039		0.031	4.99	0.027	0.198	
	2	0.073	0.034	0.058	4.79	0.01	0.103	0.207
		Overall Model					Predictor Variable	
Model B	Step	R2	ΔR^2	Adj R2	F	p-value	ESPAN	OSPAN
		75% Congruent Response Time Facilitation						
	1	0.064		0.057	8.46	0.004	0.254	
	2	0.073	0.009	0.058	4.79	0.01	0.207	0.103

Model A compares OSPAN as a sole predictor to a model that includes OSPAN and ESPAN as predictors of the dependent variable present. Model B compares ESPAN as a sole predictor to a model that includes ESPAN and OSPAN as predictors of the dependent variable. For Step 1, dfs = 1, 124; for Step 2, dfs = 2, 124.

LIST OF REFERENCES

Algom, D., Chajut, S., & Lev, S. (2004). A rational look at the Emotional Stroop phenomenon: A general slowdown, not a Stroop effect. *Journal of Experimental Psychology: General, 133*, 323-338.

Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General, 134*, 258-281.

Atkinson, R. C. & Shiffrin**,** R. M. Human memory: A proposed system and its control processes. In *The psychology of learning and motivation: II*. Spence, Kenneth W.; Spence, Janet T.; Oxford, England: Academic Press, 1968.

Awh, E., & Jonides, J. (2001). Overlapping mechanism of attention and spatial working memory. *Trends in Cognitive Sciences, 5,* 119-126.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory. *Trends in Cognitive Sciences, 4,* 417-423.

Baddeley, A. D. (2002). Is working memory still working? *European Psychologist, 7,* 85-97.

Baddeley, A. D. (2003). Working memory or working attention? In Baddeley, A. D & Weiskrantz, L. (Eds.), *Attention: Selection, awareness, and control: A tribute to Donald Broadbent.* New York, NY: Clarendon Press pp. 152-170.

Baddeley, A. D. & Logie, R. H. Working memory: The multiple-component model. In A. Miyake & P. Shah. (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control*. New York, NY: Cambridge University Press, 1999.

Bianchin, M., Mello-e-Souza, T., Medina, J. H., & Izquierdo, I. (1999). The amygdala is involved in the modulation of long-term memory but not in working or short-term memory. *Neurobiology of Learning and Memory, 71*, 127-1310

Bishop, S., Duncan, J., Brett, M., & Lawrence, A. D. (2004). Prefrontal cortical function and anxiety: controlling attention to fearful faces. *Nature Neuroscience, 7*, 184-188

Broadbent, D. E. (1958). *Perception and Communication*. New York, NY: Pergamon Press.

Brooks, L. R. (1967). The suppression of visualization by reading. *Quarterly Journal of Experimental Psychology, 19,* 289-299.

Buchanon, T. W., Adolphs, R. (2004). The neuroanatomy of emotional memory in humans. In Reisburg, D., & Hertel, P. (Eds.), *Memory and Emotion*. New York: Oxford University Press, pp 42-75.

Canli, T., Zhao, Z., Desmond, J. E., Gross, J. J. & Gabrielli, J. D. E. (2001). An fMRI study of personality influences in brain reactivity to emotional stimuli. *Behavioral Neuroscience, 115,* 33-42.

Chajut, S., Lev, S., & Algom, D (2005). Vicissitudes of a misnomer: Reply to Dalgleish *Journal of Experimental Psychology: General,* 134, 592-595.

Clarkson-Smith, L. & Hartley, A. A. (1990) The game of bridge as an exercise in working memory and reasoning. *Journals of Gerontology, 45*, 233-238.

Conway, A. R.,Cowan, N. & Bunting, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review, 8,* 331-335.

Conway, A. R.,Cowan, N., Bunting, M. F., Therriault, D., & Minkoff, S. (2002). A latent variable analysis of working memory capacity, short term memory capacity, processing speed, and general fluid intelligence. *Intelligence, 30,* 163-183.

Cowan, N (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing. *Psychological Bulletin, 10,* 163-191.

Cowan, N. An embedded-processes model of working memory. In (Eds.), A. Miyake & P. Shah. *Models of working memory: Mechanisms of active maintenance and executive control.* New York, NY: Cambridge University Press, 1999.

Dalgleish, T. (1995). Performance on the emotional Stroop task in groups of anxious, expert, and control subjects: A comparison of computer and card presentation formats. *Cognition and Emotion, 9,* 341-362.

Dalgleish, T. (2005). Putting some feeling into it- The conceptual and empirical relationships between the classic and emotional Stroop tasks: Comment on Algom, Chajut, and Lev (2004), *Journal of Experimental Psychology: General,134,* 585-591.

Daneman, M. & Carpenter, A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19*, 450-466.

Darwin, C. (1999). The expression of the emotions in man and animals. (Introduction by Paul Ekman). London: Harper Collins. (original work published in 1872).

Davidson, R. J. & Irwin, W. (1999). The functional neuroanatomy of emotion and affective style. *Trends in Cognitive Sciences, 3*, 11-21.

D'Esposito, M., Aguirre, G. K., Zarahn, E., Ballard, D., Shin, R. K., & Lease, J. (1998). Functional MRI of spatial and nonspatial working memory. *Cognitive Brain Research, 7*, 11-13.

Dolan, J. (2002). Emotion, Cognition and Behavior. *Science, 298*, 1191-1194.

Dolcos, F., & McCarthy, G. M. (2006). Brain systems mediating cognitive interference by emotional distraction. *Journal of Neuroscience, 26,* 2072-2079.

Duncan, F. (1990). Goal weighting and the choice of behavior in a complex world. *Ergonomics, 33,* 1265-1279.

Ekman, P. Basic emotions. In T. Dalgleish and M. Powers (Eds.), *Handbook of Cognition and Emotion.* Sussex, U. K.: John Wiley & Sons, Ltd., 1999.

Elliman, N. A., Green, M. W., Rogers, P. J., & Finch, G. MJ. (1997). Processing-efficiency theory and the working memory system: Impairments associated with sub-clinical anxiety. *Personality and Individual Differences, 23*, 31-35.

Engle, R. W., Carullo, J. J., Collins, K. W. (1991). Individual differences in working memory for comprehension and following directions. *Journal of Educational Research, 84,* 253-262.

Engle, R. W., Cantor, J., & Carullo, J. J. (1992). Individual differences in working memory and comprehension: A test of four hypotheses. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 972-992.

Engle, R. W., Conway, A. R. A. Tuholski, S. W. & Shisler, R. J. (1995). A resource account of inhibition. *Psychological Science, 6,* 122-125.

Feldman Barrett, L. A. & Gross, J. J. Emotional intelligence: A process model of emotion representation and regulation. In T. J. Mayne & G. A. Bonanno (Eds.), *Emotions: Current Issues and Future Directions*. New York: The Guilford Press, pp. 286-310, 2001.

Gray, J. R. (2001). Emotional modulation of cognitive control: Approach-withdrawal states double dissociate spatial from verbal two-back task performance. *Journal of experimental Psychology: General, 130,* 436-452.

Gray, J. R., Braver, T. S., Raichle, M. E. (2002). Integration of emotion and cognition in the lateral prefrontal cortex. *Proceedings of the National Academy of Sciences, 99*, 4115-4120.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2,* 271-299.

Herrington, J. D. , Mohanty, A., Koven, N. S., Fisher, J. E., Stewart, J. L., Banich, M. T., Webb, A. Miller, A. G., Heller, W. (2005). Emotion-modulated performance and activity in left dorsolateral prefrontal. *Emotion, 5,* 200-207.

Jha, A. P., Fabiani, S. A., & Aguirre, G. K. (2004). The role of the prefrontal cortex in resolving distractor interference. *Cognitive, Affective & Behavioral Neuroscience, 4,* 517-527.

Jonides, J., Reuter-Lorenz, P. A., Smith, E. E., Awh, E., Barnes, L. L. Drain, M., Glass, J., Lauber, E. J., Patalano, A., & Schumacher, E., (1996). Verbal and spatial working memory in humans. In D. L. Medin (Ed.), *The Psychology of Learning and Motivation,* Vol. 35.

Jonides, J., Reuter-Lorenz, P. A., Smith, E. E., Awh, E. Barnes, L. L., Drain, M.,Glass, J., Lauber, E.J., Patalano, A. L., Schumacher, E. H., Verbal and spatial working memory in humans. *The psychology of learning and motivation: Advances in research and theory, Vol. 35.* Medin, Douglas L. (Ed); pp. 43-88. San Diego, CA, US: Academic Press, 1996.

Juth, P., Lundqvist, D., Karlsson, A., Ohman, A. (2005). Looking for foes and friends: Perceptual and emotional factors when finding a face in the crowd. *Emotion, 5*, 379-395.

Kane, M. J. Bleckley, M. K., & Conway, A. R. A. (2001). A controlled-attention view of working memory capacity. *Journal of Experimental Psychology: General,130,*169-183.

Kane, M. J. & Engle, R. W. (2003). Working memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General,* 132, 47-70.

Kane, M. J., Engle, R. W. & Tuholski, S. W. Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence, and functions of the prefrontal cortex. In Miyake, Akira; Shah, Priti (Eds): *Models of working memory: Mechanisms of active maintenance and executive control.* New York, NY, US: Cambridge University Press, 1999. pp. 102-134.

Kane, M. J., Hambrick, D.Z., Tuholski, S. W., Wilhelm, O., Payne, T. W. & Engle, R. W. (2004). The generality of working memory capacity: A latent-variable approach to verbal and visuouspatial memory span and reasoning. *Journal of Experimental Psychology: General,* 133, 189-217.

Keil, A., Bradley, M. M., Hauk, O., Rickstrohl, B., Elbert, T., & Lang, P. J. (2002). Large-scale neural correlates of affective picture processing. *Psychophysiology, 39*, 641-649.

Keil, A., & Ihssen, N. (2004). Identification facilitation for emotionally arousing verbs during the attentional blink. *Emotion, 4*, 23-35.

Kensinger, E. & Corkin, S. (2003). Effect of Negative Emotional Content on Working Memory and Long-Term Memory. *Emotion, 3,* 378-393.

Kesler-West, M. L., Andersen, A. H., Smith, C. D., Avison, M. J., Davis, C. E., Kryscio, R. J., Blonder, L. X., (2001). Neural substrates of facial emotion processing in fMRI. *Cognitive Brain Research, 11*, 213-226

Kiewra, K. A. & Benton, S. L. (1988) The relationship between information-processing ability and notetaking. *Contemporary Educational Psychology, 13,* 33-44.

Keltner, D., & Haidt, J. (2001). Social functions of emotions. In T. J. Mayne & G. A. Bonanno (Eds.), *Emotions: Current Issues and Future Directions*. New York: The Guilford Press, pp. 192-213.

Klein, K., & Fiss, W. H. (1999). The reliability and stability of the Turner and Engle working memory task. *Behavior Research Methods, Instruments and Computers, 31,* 429-432.

Kleinsmith, L. J. & Kaplan, S. (1963). Paired associate learning as a function of arousal and interpolated interval. *Journal of Experimental Psychology 65. 190-193.*

Kleinsmith, L. J. & Kaplan, S. (1964). Interaction of arousal and recall interval in nonsense syllable paired associate learning. *Journal of Experimental Psychology,67, 124-126.*

Kyllonen, P. C. & Cristal, R. E. (1991). Reasoning is (little more than) working memory capacity?! *Intelligence, 14,* 389-433.

Lane, R. (1997). The neuroanatomical correlates of happiness, sadness, and disgust. *American Journal of Psychiatry, 154*, 926-933.

Lane, R., Reiman, E., Bradley, M., Lang, P. J., Ahern, G.L., Davidson, R. J., & Schwartz G.E. (1997). *Neuropsychologia, 35,* 1437-1444.

LaPointe, L. B., & Engle, R.W. (1990). Simple and complex word spans as a measure of working memory capacity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 1118-1133.

Levinger, G., Clark, J.(1961). Emotional factors in the forgetting of word associations. *Journal of Abnormal & Social Psychology, 62*, 99-105.

Mikels, J. A., Larkin, G. R., Reuter-Lorenz, P. A., & Cartensen, L. L. (2005). Divergent trajectories in the aging mind: Changes in working memory for Affective versus visual information with age. *Psychology and Aging, 20,* 542-553.

Mikels, J. A., Reuter-Lorenz, P. A., & Fredrickson, B. L. (2003). Hold on to that feeling: An empirical analysis of affective working memory. Poster presented at the annual meeting of the Psychonomic Society.

Mikels, J. A., Reuter-Lorenz, P. A., & Fredrickson, B. L. (2004). Dissociable orbitofrontal and limbic correlates of affective working memory. Poster presented at the annual meeting for the Society for Neuroscience.

McKenna, F. P.(1986). Effects of unattended emotional stimuli on color-naming performance. *Current Psychological Research & Reviews, 5,* 3-9.

McKenna, F. P., & Sharma, D. (1995). Intrusive cognitions: An investigation of the emotional Stroop task. *Journal of Experimental Psychology: Learning, Memory & Cognition, 21,* 1595-1607.

McKenna, F. P., & Sharma, D. (2004). Reversing the emotional Stroop effect reveals that it is not what it seems: The role of fast and slow components. *Journal of Experimental Psychology, 30,* 382-392.

Northoff, G., Richter, A., Gessner, M., Schlagenhauf, F., Fell, J., Baumgart, F., Kaulisch, T., Kötter, R., Stephan, K., Leschinger, A., Hagner, T., Bargel, B.,Witzel, T., Hinrichs, H., Bogerts, B., Scheich, H., Heinze, H. (2000). Functional dissociation between medial and lateral prefrontal cortical spatiotemporal activation in negative and positive emotions: A combined fMRI/MEG study. *Cerebral Cortex, 10,* 93-107.

Ohman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General. 130*, 466-478.

Ohman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd effect revisited: A threat advantage with schematic faces. *Journal of Personality and Social Psychology, 80,* 381-396.

Packard, M. G. & Teather, L. A. (1998). Amygdala modulation of multiple memory systems, hippocampus and caudate putamen. *Neurobiology of Learning and Memory, 69*, 163-203.

Patrick, C. J., Cuthbert, B. N. & Lang, P. J. (1994). Emotion in the criminal psychopath: Fear image processing. *Journal of Abnormal Psychology, 103,* 523-534.

Petrides, M. & Milner, B. (1982). Deficits on subject-ordered tasks after frontal- and temporal-lobe lesions in man, *Neuropsychologia, 20*, 249-262.

Perlstein, W. M., Elbert, T., & Stenger, A. (2002). Dissociation in human prefrontal cortex of affective influences on working memory-related activity. *Proceedings of the National Academy of Sciences, 99,* 1736-1741.

Perlstein, W. M., Carter, C. S., Barch, D. M., & Baird, J. (1998). The Stroop task and attention deficits in schizophrenia: A critical evaluation of card and single-trial Stroop methodologies. *Neuropsychology, 12,* 414-425.

Pratto, F. & John, O. P. (1991). Automatic vigilance: the attention-grabbing power of negative social information. *Journal of Personality and Social Psychology, 61,* 380-91.

Quevedo, J., Sant, M., Madruga, M., Lovato, I., de-Paris, F., Kapczinkski, F., Izquierdo, I., & Cahill, L. (2003). Differential effects of emotional arousal in short- and long-term memory in healthy adults. *Neurobiology of Learning and Memory, 79,* 132-135.

Schupp, H. T., Junghofer, M., Weike, A. I., & Hamm, A. O. (2003). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science, 14*, 7-13.

Shute, V. J. (1991). Who is likely to acquire programming skills? *Journal of Educational Computing Research, 7*, 1-24.

Simpson, J.R., Öngür, D., Akbudak, E., Conturo, T. E., Ollinger, J.M., Snyder, A. Z., Gusnard, D. A., Raichle, M. E. .(2000). The emotional modulation of cognitive processing: An fMRI study. *Journal of Cognitive Neuroscience, 12*,157-170.

Smith, K. N., Cacioppo, J. T., Larsen, J. T. & Chartrand, T. (2003). May I have your attention, please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia, 41,* 171-183.

Smith, E. E., Patalano, A. L., & Jonides, J. (1998). Alternative strategies for categorization. *Cognition, 65,* 167- 196.

Smith, E. E., & Jonides, J. (1997). Working memory: A view from neuroimaging. *Cognitive Psychology, 33*, 5-42.

Spies¸ K., Hesse, F. W. & Hummitzsch, C. (1996). Mood and capacity in Baddeley’s model of human memory, *Zeitchrift fur Psychologie, 204,* 367-381.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643-662.

Turley-Ames, K. J., & Whitfield,M. M. (2002). *Strategy training and working memory task performance.* Manuscript submitted for publication.

Unsworth, N. & Engle, R., W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review, 114,* 104-132.

Unsworth, N., Heitz, R., P., Schrock, J., C., & Engle, R., W. (2005). An automated version of the operation span task. *Behavior Research Methods, 37*, 498-505.

Williams, J. M.G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin, 120*, 3-24.

Winton, W. C., Clark, D. M. & Edelmann, R. J. (1995). Social anxiety, fear of negative evaluation, and the detection of negative emotion in others. *Behaviour Research and Therapy, 33,* 193-196.

BIOGRAPHICAL SKETCH

Cynthia Elizabeth Kaschub was raised in Connecticut. She did her undergraduate work at Boston College, where she first tasted empirical research methods. After Boston College, she began her graduate studies at Villanova University, where she earned her Master of Science degree in 2004. After completing her Ph.D. at the University of Florida she will serve as a Researcher at the North Atlantic Treaty Organization Naval Undersea Research Centre in La Spezia, Italy for the summer of 2008. Upon returning from Italy, Dr. Kaschub will begin her Cognitive Engineering post-doc Department at the Applied Physics Laboratory at Johns Hopkins University.