COGNITIVE CONTROL OF ATTENTION, EMOTION, AND MEMORY: AN ERP STUDY

by

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ABSTRACT

JOSHUA CAMERON EYER. Cognitive control of attention, emotion, and memory: An ERP study. (Under the direction of DR. MARK FAUST)

Unwanted retrieval of negative memories can be problematic for many clinical populations. The Think/No-Think (T/NT) task (Anderson & Green, 2001) is a new paradigm for studying cognitive control during cued recall. In this task participants view a cue item and are asked to consciously retrieve (think) or interrupt retrieval (no-think) of the associated target item. Eyer (2009) found that self-reported mindfulness was correlated with T/NT cued recall, suggesting a relationship between control of memory retrieval and a general cognitive control skill. The current study measured event-related potentials (ERPs; i.e., electrical brain responses time-locked to cue presentation) for negative and neutral stimuli on the TNT task to assess cognitive control during retrieval.

Method: Participants (N = 35) completed questionnaires (e.g., mindfulness, intrusive thoughts) and cognitive tasks related to cognitive control (e.g., attention, working memory span). Then, ERPs were recorded during the TNT task, followed by a final cued recall test.

Results: Analyses of ERPs found evidence to support somewhat separable neural networks for control of memory retrieval and for processing the emotional content of the target pictures, with some time windows only exhibiting a main effect of strategy or of emotional valence. However, there was widespread evidence for interactions of these subsystems across a range of time latencies post-cue presentation. Of particular note was a significant Strategy x Valence interaction for the early P1 component (125-164 ms).

The overall size of the N2 (250–324 ms) peak was correlated with a wide range of self-report and cognitive test measures of cognitive control at frontal electrode sites.

Discussion: The present study adds to knowledge of the timing of control processes during performance of the TNT task through its use of ERP methodology. The effect of the emotional valence of the to-be-recalled target on the early P1 ERP component suggests surprisingly early emotional processing during memory retrieval. The present results also suggest that at least some of the control processes used during the TNT task are part of a larger general-purpose cognitive control system. These results suggest that individual traits provide important and varying influences on the cognitive control of emotional memories.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANT	Attention Network Task
BC	baseline-corrected
BDI-SF	Beck Depression Inventory–Short Form
EEG	electroencephalogram
ERP	event-related potential
FC3/4	centro-frontal electrodes
FFMQ	Five-Facet Mindfulness Questionnaire
LPP	Late parietal positivity
MCMB	mood-congruent memory bias
MAAS	Mindful Attention Awareness Scale
Neg	negative valence condition
Neu	neutral valence condition
NTk	no-think strategy condition
P3/4	parietal electrodes
PSS	Perceived Stress Scale
RRS	Ruminative Response Scale
SNR	signal-to-noise ratio
SSPAN	Symmetry SPAN task
Tk	think strategy condition
T/NT	think/no-think task
WBSI	White Bear Suppression Inventory

CHAPTER 1: OVERVIEW

From disturbing images to moments of embarrassment to upsetting dreams, we are all troubled by negative memories that we would rather not recall. Important individual differences determine how negative thoughts and memories affect us. Clinical scientists have been studying the role of negative thoughts and memories in psychological disorders for decades (Beck, 1967; Harrington & Blankenship, 2002; Papageorgiou & Wells, 2004) as cognitive scientists have studied memory processes to understand better how memory works. Recently, these two areas of research have found increasing common ground. For example, a concerted effort into the study of the role of inhibitory control over memory retrieval (Anderson & Green, 2001; Depue, Banich, & Curran, 2006) has led to calls for more collaboration across traditional interdisciplinary lines (Levy & Anderson, 2008). Such research has opened new lines of inquiry into the relationship between cognitive memory processes and psychological disorders, particularly by allowing the investigation of how processes involved in the cognitive control of memory adjust to mood states and the perception of emotional stimuli (Depue et al., 2006; Hertel & Gerstle, 2003; Hertel & Mahan, 2008).

Increasingly, cognitive and neuroscience research supports a unified cognitive control system. The concept of cognitive control (i.e., sometimes called executive function) is used to represent an imputed, unitary neural system that functions to regulate a wide range of other neural processes. For example, there is strong evidence to suggest that the brain areas used for cognitive control of memory are the same for cognitive control of behavioral responses (Levy & Anderson, 2002). These findings are consistent with a functional view of memory proposed by Cowan (1999), who suggested that control of memory uses cognitive control of attentional processes to identify relevant material in memory and then shift or maintain focus of that material. Recently, new research has proposed that the neural areas responsible for emotion regulation exert early influence on neural areas involved in cognitive control processes (Banich et al., 2009). Although evidence exists to indicate likely brain areas involved in cognitive control and control of emotion, less evidence exists to elucidate the exact timing and emergence of these networks and their effects, respectively.

Furthermore, it follows that if there is a shared system for cognitive control, then we should see correlations between cognitive control and a range of related constructs. Using recall scores and a self-report measure of mindfulness, a previous study (Eyer, 2009) found a relationship between the ability to maintain mental focus and the operation of cognitive control in memory. Following in this vein, the current study used an innovative new cognitive task, the Think/No-Think (T/NT) task, that allows assessment of cognitive control mechanisms responsible for retrieving and preventing retrieval of recent memories. Furthermore, the study used a multimodal assessment paradigm by assessing the influence of mood and emotional content of memory items on ERP measures of the cognitive control of memory. Specifically, event-related potentials (ERPs; averaged electrical responses of the brain in response to a stimulus event) were recorded during the T/NT task to measure cognitive control processes directly as they occur. Second, cognitive tasks assessing performance on measures of attention and working memory were included to improve understanding of the relationship between attentional focus and cognitive control of memory. Third, self-report measures were administered to investigate the role of dispositional mindfulness (i.e., the expression of mental focus in day-to-day life), intrusive thoughts, rumination, mood, and perceived stress. Using this paradigm, the current study investigated individual differences in cognitive control and replicated and extended previous research on the T/NT task by a number of researchers (Bergstrom, de Fockert, & Richardson-Klavehn, 2009; Depue et al., 2006; Eyer, 2009; Hertel & Mahan, 2008; Nair, 2008)

CHAPTER 2: LITERATURE REVIEW

Negative Thoughts and Control Strategies

We are all plagued by negative thoughts and memories that we would rather not think about, yet despite the fact that we all suffer from such thoughts, large individual differences exist in how those thoughts affect us. Although many people think good memory is the ability to recall information as desired, fewer recognize that an important part of this process is the ability to inhibit irrelevant memories that are unnecessary or undesired. With the purpose of understanding these processes better, clinical scientists have been studying the function of negative thoughts and memories in psychological disorders for decades (Beck, 1967; Harrington & Blankenship, 2002; Papageorgiou & Wells, 2004), while cognitive psychologists have been studying memory to learn more about the processes whereby we remember or forget (e.g., Cowan, 1999). One notable area of research into the difficulty of dealing with negative thoughts comes from the clinical evidence describing reoccurring negative cognitions and methods of coping with them.

Negative Intrusive Thoughts

Cognitive intrusions, more commonly known as intrusive thoughts, are a widespread and difficult symptom of a number of mood and anxiety disorders, from PTSD to major depression to obsessive-compulsive disorder (Carlier, Voerman, & Gersons, 2000; Clark & Rhyno, 2005; Ehlers & Steil, 1995; Reynolds & Brewin, 1998;

Watkins Moulds, & Mackintosh, 2005). Although seen reliably in clinical populations, they are also found in nonclinical populations. In one study of 125 university students, researchers reported that 99% reported experiencing intrusive negative thoughts (Freeston, Ladouceur, Thibodeau, & Gagnon, 1991). Clark and Rhyno offered a general definition of intrusions as "any distinct, identifiable cognitive event that is unwanted, unintended, and recurrent. It interrupts the flow of thought, interferes in task performance, is associated with negative affect, and is difficult to control" (p. 4). Thus, whether arising spontaneously or from obvious triggers, cognitive intrusions are recurring undesirable thoughts that are resistant to attempts to stop thinking about them. Many negative thoughts and memories, therefore, qualify as intrusive thoughts that require effortful cognitive control to inhibit them.

Intrusive thoughts can vary greatly between individuals; however, there seem to be common underlying processes in the way people cope with them. As might be expected, the content of intrusive thoughts varies a great deal person-to-person and may center on almost anything from the thought of a person, place, or thing to a fear or a negative statement (Clark & Purdon, 1995; Freeston, Ladouceur, Thibodeau, & Gagnon, 1992). Generally, clinical and experimental researchers do not make clear distinctions between intrusive thoughts and memories, although a few differences have been discussed (Brewin, Christodoulides, & Hutchinson, 1996). Related to this, Freeston et al. (1991) developed a clinical assessment of individualized cognitive intrusions that records an individual's personalized experience of intrusive thoughts and is also sensitive to preferences in cognitive coping strategies. Their measure has been well received by other clinical researchers for its comprehensiveness and innovation (Clark & Purdon, 1995). However, the wealth of clinical research into assessing intrusive negative thoughts suggests that the content of negative cognitive intrusions is helpful but not sufficient in identifying clinically significant intrusions. Instead, it appears that there are underlying patterns to failures in cognitive control of negative thoughts that are able to be identified as clinically important, such as rumination. The nature of such responses may help indicate the cognitive mechanism at work.

Responses to Persistent Negative Intrusive Thoughts

Common responses

Although they have been linked to a number of disorders from posttraumatic stress and obsessive-compulsive disorders to depression and anxiety (Reynolds & Brewin, 1998; Watkins et al., 2005), the presence of intrusive thoughts alone, given their prevalence, is not sufficient to explain the development of such disorders. In fact, when given enough time, cognitive resources, and opportunity, individuals are usually able to suppress negative thoughts or memories (Freeston et al., 1991; Levy & Anderson, 2008; Reynolds & Brewin, 1998; Wegner, Schneider, Carter, & White, 1987). Consequently, it is likely that a person’s responses to negative thoughts or memories matter more than whether the thoughts occur. Supporting this conclusion, Williams and Moulds (2007) found that, although intrusive negative memories were common in a college student sample, the concurrence of negative appraisals and attempts at cognitive control of the memories were more linked with depressive symptoms. This suggests that the occurrence of intrusive thoughts becomes problematic because of responses to the thoughts more than because of the thoughts themselves. Salkovskis, Westbrook, Davis, Jeavons, and Gledhill (1997) formed a similar conclusion, advancing a set of characteristics to explain how failed suppression can develop into disorder. They suggested that dysfunction related to otherwise-normal intrusive thoughts occurs when they (a) are perceived as personally relevant to the individual, who then takes responsibility for their content and/or occurrence and wishes to take action to prevent them, and (b) result in attempts to neutralize the thought to reduce this perceived responsibility. Consequently, when a person identifies the intrusions as meaningful and attempts to control them, they can trigger dysfunctional patterns of coping, and in fact, a new wave of therapies has shown success at treating a range of disorders by focusing first on reducing the negative appraisals related to the thoughts (Hayes, Strosahl, & Wilson, 2003). Thus, responses to negative intrusive thoughts and memories are likely to lead to problems when a person identifies them as personally troubling and then attempts to control them. Subsequent failures at control appear to be especially problematic in these people.

Control strategies

When negative cognitive intrusions do occur, a range of compensatory responses are used to address them (Freeston et al., 1991; Levy & Anderson, 2008; Reynolds & Brewin, 1998). In fact, a common and distinctive trait in the expression of recurring unwanted intrusive thoughts is that people tend to develop particular control strategies to cope with them and the distress they can produce (Clark & Rhyno, 2005). Freeston et al. (1991) studied a nonclinical sample and found that there were three groups of strategies that people used regularly: effortful escape/avoidance (40%); effortful attentive thinking (34%); and no effortful response (26%). Thus, about a third of individuals sampled from a nonclinical population experiencing intrusive thoughts preferred to try to use inhibitory cognitive control to ignore or suppress them, while a slightly larger group attempted to apply selective attention by bringing some other thought to mind that pushed the unwanted thought from awareness. The remaining minority reported passively waiting, presumably until the intrusive thought was displaced by a resumption of the typical stream of consciousness. Consistent with these findings, an overview of the literature on the cognitive control of memory, Ochsner and Gross (2005) identified two methods of reducing memories: controlling attention for emotionally evocative stimuli and using cognitive methods to change the meaning of such stimuli. That is, they suggest one must either use cognitive control to change the target of attentional processes (distraction) or use effortful cognitive processes to alter the appraisals related to the target (reappraisal).

These categories are also present in a more refined conceptualization of executive thought control. Well and Davies (1994) identified five primary strategies of thought control: reappraisal, attempts at challenging, analyzing, or reinterpreting the thought; distraction, attempts to supplant the intrusive thought with other thoughts or by doing something else; punishment, attempts to punish oneself cognitive or physically for having the thought; social control, attempts to discuss or refrain from discussing the thought with others; and worry, attempts to shift focus to other more or less negative concerns. Furthermore, a recent study has confirmed the assertion of Wells and Davies that three strategies, worry, punishment, and distraction, would be related to more negative outcomes than reappraisal and social control (McKay & Greisberg, 2002).

Thus, according to Salkovskis et al. (1997) and Wells and Davies (1994), control strategies seem to fall into general groupings in which executive cognitive control is used to actively avoid (i.e., distraction, worry, and social control if refraining) or attentively process (i.e., reappraisal, punishment, and social control if discussing) negative thoughts and memories. Furthermore, it appears that attempts at avoidance are more likely to lead to negative outcomes than attempts at direct processing. Although its relative effectiveness is hard to assess, using no effortful strategy is not technically a control strategy, in the same way that doing nothing to move out of the way of a speeding car is not actually a strategy to avoid it. However, Williams and Moulds (2007) suggest that if those choosing this option are not particularly troubled by the negative thought and are unconcerned whether it is maintained in awareness or not, perhaps because they have already successfully used reappraisal to diminish the importance of the thought, then it may be that it passes without negative repercussions for the person. Ultimately, it seems that adaptive strategies of thought control involving active, intentional processes are more likely to lead to positive coping with intrusive thoughts while avoidant strategies seem more likely to result in a loss of control.

Failures in cognitive control

Such failures in the use of control strategies for intrusive negative thoughts (e.g., avoidance, suppression, distraction, neutralization, etc.), whether by a breakdown in one's capacity to use them or by selection of an ineffective strategy, often lead to characteristic patterns of dysfunction. Attempts at cognitive control of negative thoughts have been repeatedly implicated in the development and maintenance of several modes of a cognitive process widely known as rumination (but also called repetitive thought; Langlois, Freeston, & Ladouceur, 2000; Wenzlaff, 2005; Wenzlaff & Luxton, 2003; see Martin & Tesser, 1996, and Watkins, 2008, for reviews). That is, when a negative thought occurs, attempts to control it out of awareness may lead to increased and repeated experiences of the thought. Martin and Tesser have suggested that ruminative thoughts are a common response to a number of situations that involve a discrepancy between reality and a desired goal or outcome, where different contexts result in different content (1996). Several studies report that repetitive thoughts are a shared component in both worry and depressive rumination (Langlois et al.; Harrington & Blankenship, 2002;

Watkins et al., 2005), leading some to observe that intrusive memories tend to be associated with sadness while intrusive thoughts tend to be associated with fear or anxiety, usually about the future (Brewin et al., 1996). These studies describe worry as a cognitive compulsion to think about a fear as a way to address the message of danger the intrusion carries (e.g., "If I think about it enough, I'll figure out a way to avoid it"; Hardy & Brewin, 2005; Watkins et al., 2005). Negative rumination is described as a cognitive compulsion to process negative self-referential intrusive thoughts (e.g., "What have I done to deserve being alone?"; Miranda & Nolen-Hoeksema, 2007; Treynor, Gonzalez, & Nolen-Hoeksema, 2003; Peterson & Seligman, 1984). A number of studies have found that increases in intrusive thinking and rumination are related to increases in negative mood (Wegner & Zanakos, 1994; See Wenzlaff, 2005, for a review). These findings have led to studies of repetitive or ruminative thinking as a common shared mechanism that displays different content in different contexts (Langlois et al., 1991; Segerstrom, Stanton, Alden, & Shortridge, 2003). Taken together, these investigations suggest a proposed mechanism where attempts at coping with intrusive thoughts lead to rumination, paradoxically increasing the frequency of the thoughts and leading to mood disorder.

Summary

From this review of the literature on negative thoughts and control strategies, several ideas emerge with practical implications for studies of memory and emotion. First, while the occurrence of negative thoughts is nearly universal, some people have more trouble than others pushing them out of awareness. However, as shown above in Freeston et al. (1991), the content of negative thoughts only becomes problematic when the cognitive control mechanisms used to minimize them break down. Second, difficulty with negative thoughts appears to arise when a person identifies a negative thought or memory as personally troubling and attempts to use a control strategy to push it out of awareness; however, failures of this control attempt appear to be especially problematic. Third, control strategies for negative thoughts seem to fall into general groupings of active avoidance (i.e., distraction, worry, and social control if refraining) or attentive processing (i.e., reappraisal, punishment, and social control if discussing), for which attempts at avoidance appear less effective than direct processing. The third possibility, not to respond to the thought, may also be adaptive in some situations. Fourth, these investigations suggest a proposed mechanism where attempts at coping with negative thoughts can lead to rumination and an increase in the frequency of the thoughts. However, this seems to occur only when the control strategies fail. Consequently, the sum of this clinical research suggests that meaningful breakdowns in the cognitive control of negative thoughts occur when a person identifies the thought as meaningful and attempts to push it out of awareness but fails. Consequently, cognitive strategies for reducing the occurrence of negative thoughts and memories are likely to be either distract/avoid strategies, as with thought replacement/substitution, or active inhibitory processes. The differences between substituting and inhibiting strategies are likely to also produce differences in brain processes (as supported by Bergstrom et al., 2009), and failures in these strategies are likely to lead to dysfunction at managing negative thoughts and perhaps even psychological disorder. In particular, rumination appears to be related to thought control through these processes, and in fact, a previous study by Nair (2008) found a relationship between rumination and thought control using neurophysiological recordings. Together, these studies produce important implications to research attempting to investigate thought control of negatively valenced cognitive events.

Cognitive Control of Memory: Relevant Theories

Several theories have been proposed by clinical and experimental researchers to help explain the breakdown in cognitive control that occurs when negative intrusive thoughts are not effectively managed. Below three theories will be reviewed for their inputs to a possible mechanism for how intrusive thoughts could lead to disordered thinking.

Ironic Process Theory

Wegner et al. (1987) proposed a cognitive mechanism to explain how active attempts to exclude a thought from consciousness can produce an increase in that target thought. First demonstrated in the White Bear studies, nonclinical participants were encouraged to avoid thinking about a white bear, but experienced a large number of intrusions of this thought (Wegner et al., 1987). To explain this, Wegner et al. proposed ironic process theory, which suggests that cognitive control of negative thoughts, particularly when attempting thought suppression, involves a two-component process: one effortful, control mechanism that requires sufficient cognitive resources to produce the desired outcome, and another automatic, resource-light mechanism that signals the presence of the undesired outcome, such as negative intrusive thoughts requiring suppression (Wegner, 1994; Wegner et al., 1987; see Wenzlaff & Wegner, 2000, for a review). Essentially, it suggests that during periods of cognitive load, attempts to exclude a thought from awareness are accompanied by increases in the experience of the cognition, due to the greater relative activity of the automatic checking process for the undesired target thought over the controlled inhibitory process (Wegner, 1994).

Similarly, in a review of cognitive control processes across three lines of task performance research, Gopher (1996) concluded that effective performance was a combination of automatic processing and successful use of cognitive control (top-down) processes. From this model, then, cognitive control for negative thoughts may function through an automatic identifying mechanism that signals the brain when an undesired thought occurs. Immediately, a second, effortful process begins to act to consciously push the undesired thought out of awareness. A behavioral analogue may be seen in obsessive-compulsive disorder. Salkovskis et al. (1997) indicated that the repetitive behavioral coping responses of reassurance-seeking and compulsions (such as hand-washing) are actually failed attempts at neutralization of intrusive thoughts. That is, when a person experiences an unwanted obsession, the person practices a behavioral compulsion that reduces the anxiety related to the negative thought.

Importantly, ironic process theory also indicates that when a person is under stress, the identifying automatic mechanism continues functioning (bringing attention to the unwanted thoughts) but the control mechanism is unable to suppress or reduce it, resulting in more prominent cognitive intrusions (Wegner et al., 1987; Wenzlaff & Wegner, 2000). There are a number of reasons why this control mechanism might function poorly. The processes responsible for inhibitory control over negative cognitive intrusions seem to require some minimum level of cognitive resources for effective operation (Levy & Anderson, 2008). When intrusive thoughts occur and such resources are not available—such as at times of stress—the suppression is unable to proceed as needed and the negative thoughts are seen to increase in frequency (Wegner, 1994; Wenzlaff & Luxton, 2003; See Wenzlaff & Wegner, 2000, for review). One study sought to confirm the influence of high stress in depleting necessary cognitive resources. After assessing a group on their suppression ability and waiting 10 weeks, those who had scored as high suppressors and who had experienced high levels of stress also reported much higher levels of negative rumination and depressive symptoms, which were significantly greater than before or than those scoring as low suppressors (Wenzlaff & Luxton, 2003).

Executive Deficit Hypothesis

Although cognitive resources are necessary for the effective suppression of a negative memory, there are also individual differences in each person's ability to control intrusive memories. That is, some are very good at cognitive control of intruding memories whereas others are not. As a result, when unwanted intrusive thoughts occur in the absence of cognitive resources needed to inhibit them, successful suppression is unable to proceed. Levy & Anderson (2008) proposed the executive deficit hypothesis to explain these individual differences in the ability to use effortful control of memory retrieval and forgetting. Furthermore, these variations in control also correspond to Wegner's proposed second component. As might be expected, difficulty predictably managing cognitive events due to failures in cognitive control have been linked to a number of dysfunctions and disorders.

Performance Characteristics of Cognitive Control

A third theory describes how variations in the effortful executive process may function. Muraven, Tice, and Baumeister (1998) offered a compelling model for failures in self-regulation that suggests that cognitive control may become fatigued over time or from intense periods of inhibition. Described using the metaphor of a muscle, it explains both how individual differences arise (due to different "strengths" of cognitive control) and how gradual reductions in control occur (as fatigue sets in). However, it also implies that training can "strengthen" cognitive control, increasing its capacity for dealing with decreases in cognitive resources. That is, when undergoing a period of strain such as being required to maintain focus during a long lecture, effective self-regulation is seen to gradually decrease as evidenced by increasing loss of focus. Similarly, a moment of very high self-regulation, such as an exam, can lead to rapid fatigue of self-regulation processes. Notably, repeated exposure to experiences like these allows us to gradually improve our ability to deal with them. That is, executive self-regulatory control appears to develop with exposure to experiences that test it.

Towards a Unitary Theory of Cognitive Control

An integration of these models describes an executive cognitive control mechanism with several characteristics. The proposed mechanism should act as the effortful component process to an automatic process that draws attention to an undesired outcome (e.g., to behave successfully in church, one must recognize not to fidget, not to speak, not to sleep, etc.); should function better in some individuals than others; should decrease in effectiveness with prolonged or intense use; and should demonstrate vulnerability to environmental influences that deplete its resources and decrease its function.

Recently, several models of cognitive control have been proposed, especially in the cognitive psychology literature, and increasingly, these models have demonstrated similar mechanisms of function across domains. Notably, these models have been supported by areas of shared brain activation across cognitive control tasks in multiple domains (see Anderson & Green, 2001, and Naghavi & Nyberg, 2004, for examples), and researchers are now beginning to implicate these consistencies into more unified models of cognitive control (see the Urgency-Gating model by Cisek, Puskas, & El-Murr, 2009 for an excellent example of a model linking action planning with decision making). One such model has been proposed by Posner and colleagues to describe networks associated with the sources of attention, as opposed to areas where attention is exerted (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Posner & Peterson, 1990). Essentially, they propose that there are three attention networks with three functions: one for alerting, one for orienting, and one for executive control. The alerting network produces and maintains an alert state. The orienting network directs attention to the sensory process desired. The executive control network resolves cognitive conflict where discrepancies exist that must be resolved before proceeding, e.g., when an expected result does not occur. Each of these networks has been isolated in function, neuroanatomy, and neurophysiology. Fan et al. (2002) report that the alerting network is associated with norepinephrinergic activity in the right hemispheric frontal and parietal areas. They report that the orienting network is associated with activity in the superior parietal and frontal lobes, and disengaging from one stimulus is hindered by lesions in the temporoparietal junction. Finally, the network for cognitive control of attention activates the anterior cingulate cortex (ACC) and lateral prefrontal cortex (LPFC). To help explore these networks, the researchers have created an attention task that allows assessment of performance characteristics in each of these domains. It is noteworthy that this description of the attention network fits well with the ironic process theory mentioned earlier. That is, both have effortful, cognitive control processes tasked with deciding between alternative strategies, and the alerting network for attention seems to overlap well with the automatic signaling process hypothesized by Wegner and colleagues. Such similarity offers promise for arriving at a broadly explanatory model for cognitive control.

Summary

From these studies, there appears to be growing evidence for a common mechanism of exerting cognitive control across different domains. The work of Posner and colleagues provides interesting new avenues of study for the relationship between cognitive control in other domains, such as emotion or memory, and the cognitive control of attention. For example, the control of memory appears to include an automatic signaling process and a cognitive control process, whereas the ANT networks propose that there are two automatic processes, one for directing awareness and the other for signaling its importance, and an executive controller. Further research should explore the similarities between two networks. If the attention and memory control networks have common or shared components, then the mechanism combining them could have significant implications for the cognitive control of emotional memories, providing rationales and models for why some control efforts fail and some succeed. More research is needed in this area to confirm the networks underlying cognitive control in different domains. Fortunately, work by Anderson and colleagues and Depue and colleagues have created a new method of investigating these processes, utilizing the T/NT task to explore memory function and its interrelations to emotional material.

Mindfulness, Attention, and Related Constructs

Given the model for dealing with negative thoughts described above, cognitive control of memory appears to involve several interrelated cognitive constructs, including dispositional mindfulness (or mental focus), attention, and mood. In a previous study by the author (Eyer, 2009; see “The Pilot Study,” p. 45), self-reported dispositional mindfulness was found to identify a significant difference in the use of cognitive control of memory between participants. This novel finding provides notable implications for the relationship of mindfulness to attention and cognitive control given that each of these constructs requires a sufficient level of effortful mental focus to be used successfully. As a result, mindfulness, attention, and mood should provide a prime area of investigation for identifying the cognitive influences on memory control. We will look at each in more detail below.

Mindfulness

Definition and description

Mindfulness grows out of traditional religious (Buddhist, Yogic, etc.) teachings and is described by Kabat-Zinn as a process of bringing effortful attention to one's moment-by-moment experience (1990). Mindfulness is one of a number of mind-body interventions that include meditation, yoga, and exercise shown to have beneficial cognitive and biological effects (see Kabat-Zinn, 2003 for a review). These therapies have been linked to reliable effects on mental processes, and interventions based on these techniques have been employed to build participants' ability at cognitive control (Hayes et al., 1999; Kabat-Zinn, 1990; Linehan, 1995; Lutz et al., 2009). Essentially, mindfulness interventions instruct a person to sit comfortably in an upright position and attempt to maintain attention on a specific focus, usually somatic sensations such as breathing for concentrative meditation or virtually any identifiable stimulus for mindfulness meditation (Bishop et al., 2004; Kabat-Zinn, 1990; Valentine & Sweet, 1999). Whenever focus is lost, the person is encouraged to take notice of the thought that intruded and then return attention to the breathing, allowing the thought to drift back out of awareness without judging or elaborating on its meaning (Bishop et al., 2004; Kabat-Zinn, 1990). This skill improves with practice, and one goal of treatment is for the use of mindfulness to be integrated into everyday life, allowing one to intentionally exert control when cognitively tested by maintaining mental focus. Bishop et al. (2004) describe a state of mindfulness as “a kind of non-elaborative, non-judgmental, present-centered awareness in which each thought, feeling or sensation that arises in the attentional field is acknowledged and accepted as it is” (p. 8). Most measures of mindfulness, such as the Five Facet Mindfulness Questionnaire (Baer et al., 2008), are self-report and designed to assess how well one is able to develop different facets of this skill.

By contrast, other measures have focused on pre-existing individual differences in day-to-day mental focus, a construct called dispositional mindfulness. Examples of such measures include the Mindful Attention Awareness Scale (Brown & Ryan, 2003). Such measures attempt to identify individual differences in people’s skill at using cognitive control in their everyday lives. In a previous study by the author (Eyer, 2009; see “The Pilot Study,” p. 45), self-reported mindfulness as assessed by the Mindful Attention Awareness Scale was found to identify those who were not able to use cognitive control on memory of negative stimuli. Thus, dispositional mindfulness appears to harness a construct closely related to a trait-like characteristic of someone’s ability to manage their attentional focus in their everyday lives. Although this definition is quite different than the one given above, a recent effort has been made to reconcile the mindfulness literature and produce a guiding operational definition.

In this pursuit, Bishop et al. (2004) have proposed that mindfulness is best described as an evoked state that manages attention towards an internal focus and is therefore a skill that can be learned. Consequently, they define it as having two components: the first is an intentional self-regulation of attention maintained on immediate experience, and the second is a particular orientation focused on one’s experiences in the moment and characterized by curiosity, openness, and acceptance. Mindfulness practice and lead to deeper insight into the nature of one's thoughts by accentuating their subjectivity and transience versus a perception of them as being true or permanent. Although this definition clearly distinguishes the state-like, dual-focused mindfulness here from dispositional mindfulness, it does imply a more precise definition for it. A measure of day-to-day mindfulness fits most closely with a more persistent ability to maintain an intentional self-regulation of attention. Measurement, then, of such a construct should have significant implications for one's ability to direct and maintain attention in other situations as well. Logically, if mindfulness is a skill that can be taught with measurable attentional benefits from prolonged training and mastery (Bishop et al., 2004), such training should produce quantifiable effects on measures of attention and task performance.

Empirical support

As expected, the literature on mindfulness training shows a clear benefit to attentional processes. In a study comparing mindfulness meditators to a control group (Valentine & Sweet, 1999), those who practiced mindfulness regularly showed superior performance over a nonmindful control group on a test of sustained attention. Furthermore, Valentine and Sweet found some differences in the effects of meditation based on the type of meditation practiced. They reported that long-term meditators outperformed newer meditators, and mindful meditators showed a slight advantage in reacting to unanticipated stimuli when compared to concentrative meditators, a group that attempt to focus on a single thought, idea, or sensation. In another study, even a brief meditation training resulted in significant improvements in participants' abilities to focus attention and self-regulate (Tang et al., 2007).

In a study employing the Attention Network Test (ANT; Fan et al., 2002), Jha, Krompinger, & Baime (2007) studied the influence of two types of mindfulness training on ANT attention performance in comparison with a control group of nonmeditators. One group of naïve (new) meditators showed improvements in attentional orienting after attending an 8-week training in Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1990), and another group of experienced meditators trained in MBSR showed improvements in their attentional alerting after attending a month-long, intensive mindfulness retreat. Both of these findings were significant when compared to the other meditation group and the no-training control group. Although the experienced group outperformed both comparison groups on the ANT's measure of executive control/conflict monitoring at the start of the study, the groups did not differ on attentional executive control after the training.

Another study by Lutz et al. (2009) showed a significant improvement in sustained attention following three months of training in meditation. Data collected on behavioral responses and EEG recordings over anterior brain areas showed that improved behavioral responses were related to increased brain-pattern consistency on electroencephalographic recordings, suggesting more efficient cognitive function. The authors concluded that mindfulness resulted in an enhancement of neurophysiological responses to sensory inputs, improving the participants' ability to control their attention. Consequently, mindfulness appears to affect attention in positive ways and may even serve as an indirect measure of attention control. However, other assessments offer more direct measures of individual differences in cognitive control of attention.

Attention

Attention Network Test

Although there are a number of measures of attention, no other researchers have produced the compelling body of evidence for a coherent system of attention than Fan, Posner, and colleagues (Fan et al., 2002; e.g., Posner & Petersen, 1990). They have reported neurobiological and developmental support for three interrelated but separate attention networks with the functions of alerting, orienting, and executive control. After extensive research, they have produced a task capable of measuring performance in each of these three networks called the Attention Network Test (ANT; Fan et al., 2002). No other existing measure of attention is as comprehensive or as minimally time-intensive for the participant while still producing quantitative results on all three subsystems of attention.

Attention and memory

Other research into attention suggests that it plays a key role in memory. Cowen (1999) proposed the Embedded-Processes Model as a functional explanation how the construct of working memory may be attentional processes acting on long-term memory, through both an effortful executive process and an automatic orienting process. Essentially, this model suggests that people use cognitive control of attention to interact with long-term memory stores to hold information in an easily accessible state for the purpose of completing a mental task, whether related to language, problem solving, or decision making. Based on this model, working memory span should be related to general executive control in other areas where attention may be an important influence on cognition. Exploring that idea, a study by Brewin and Beaton (2002) found that higher working memory capacity was linked to higher fluid intelligence (but not crystallized intelligence) and better cognitive control of negative intrusive thoughts, with sizeable implications for cognitive disorders. In a study of the relationship between attention and memory, Redick and Engle (2006) also identified support for such a link. Comparing extreme groups on a span test of working memory capacity, the researchers found significant differences between groups on the ANT's measure of executive control, but not its measures of orienting and alerting. The authors suggested that this supports the idea of individual differences in executive control of attention playing a role in memory performance.

Cognitive control of emotional memory

Despite the growing research into cognitive control of memory, less research has investigated the cognitive control of emotion-related processes. In one study, Depue et al. (2006) found that participants were able to utilize control processes related to emotionally valenced stimuli to remember or forget stimuli as instructed. In a follow-up study using functional magnetic resonance imaging (fMRI) in a memory task, Depue, Curran, & Banich (2007) identified neuroanatomical evidence that failed suppression relied on a network that governs sensory representations to erode recall for items. As retrieval was successfully prevented, a second network became active that overlapped areas commonly associated with cognitive control, including the prefrontal cortex and the hippocampus. Notable, the network also included inputs from the amygdala, presumed to carry the emotional information for integration with other memory attributes. The authors interpreted this to mean that cognitive control of emotional stimuli involves the expected cognitive control systems, but also special emotion inputs that exert influence on the others. In an extensive review of this literature, Banich et al. (2008) used these results and others to call for more research into the effect of cognitive control of emotion for working memory and long-term memory.

Summary

To understand better the nature of the relationship between mindfulness, attention, and cognitive control of memory, a good measure of attention is necessary. Impairments in memory performance may be due to lapses in attention that prevent successful learning and action (Carriere, Cheyne, & Smilek, 2008). Fortunately, Fan and colleagues have created a computer-administered task that accurately assesses participant performance on three separate networks of a hypothesized model for attention function (2002). As described above, this test has been used previously in research on attention and mental focus, contributing valuable information on working memory, mindfulness training, and level of attentional function. Consequently, especially when considering emotionally valenced stimuli that may be reactive to decreases in cognitive resources (Hertel & Mahan, 2008), research into the cognitive control of memory would do well to consider including measures of mindfulness, attention, and/or working memory to assess the influences of individual differences in attention. However, it is also clear that accurate assessment of emotional content in memory requires the assessment of depression-related variables, such as depressive symptoms and rumination.

Depression, Rumination, Intrusive Thoughts, and Stress

Clinical and Psychometric Variables Related to Control of Memory

As discussed below, mood-related variables often play a significant if indirect or even hidden role in studies of memory. Notable among these effects has been the finding that one's level of depressive symptoms may be a predictor of one's memory performance for emotionally valenced stimuli. The phenomenon called mood-congruent memory bias provides an explanation for how these variables affect memory. Similarly, the common cognitive mechanism termed rumination, often identified as a response to negative intrusive thoughts, is a characteristic trait of many presentations of depression and carries implications of its own for research. Furthermore, if it does underlie depressive rumination, a fuller understanding of a person's difficulty managing negative intrusive thoughts should be accessible through measures of intrusive thinking and perceived stress. Consequently, these variables will be examined more closely below.

Depressive Symptoms and Memory Bias

One of the most variable findings in the research on memory is the effect of different levels of depressive symptoms (see Blaney, 1986, & Barry, Naus, & Rehm, 2004). Termed the mood-congruent memory bias (MCMB), most individuals show some level of this phenomenon that appears to function differently with different expressions and intensity of mood (Matt, Vázquez, & Campbell, 1992). Essentially, it indicates that positive stimuli are remembered more easily when one's mood is positive, and negative content is remembered more easily when one's mood is negative or depressed (Matt et al., 1992). In a meta-analysis, Matt et al. (1992) reported that normal, nondepressed people remembered on average 8% more positive than negative stimuli. In contrast, those with subclinical depression remembered equal numbers of positive and negative stimuli, and clinically depressed people remembered 10% more negative stimuli than positive. A number of studies have also reported increased preference among those high in depression for negative autobiographical memories (Lyubomirsky, Caldwell, & Nolen-Hoeksema, 1998; Teasdale, 1983; 1988; See Blaney, 1986, for a review) and for task-irrelevant but mood-congruent information (Frings, Wentura, & Holtz, 2007; Power, Dalgleish, Claudio, Tata, & Kentish, 2000). This individual variability in memory performance has proven so difficult to study that it has left some researchers conspicuously baffled: “The effect seems a will-o’-the-wisp that appears or not in different experiments in capricious ways that I do not understand” (Bower, 1987, p. 451).

However, some researchers have begun to identify consistencies in these variations. For example, Hertel and colleagues have suggested that MCMB varies by whether passive or active memory processes are employed. They suggest that the mood-congruent preference for negative stimuli of those high in depressive symptoms occurs through a passive process in which fewer negative stimuli than positive are forgotten (Hertel & Gerstle, 2003; Hertel & Mahan, 2008; Joorman, Hertel, Brozovich, & Gotlib, 2005). By contrast, more active forgetting paradigms show no mood-congruent preference for negative stimuli and, in some cases, better controlled forgetting of negative memories (Hertel & Mahan, 2008; Joorman et al., 2005). This is quite different than the commonly found result that those with depression appear to show a deficit related to the inhibition of negative emotional material (Joorman, 2004) and to have a characteristically different pattern of performance than those with some level of dysphoria or with none (Matt et al., 1992). From these studies, there appears to be a clear, reliable relationship between one’s level of depressive symptoms and one’s memory function such that high levels of depression lead to greater memory for negative stimuli and low levels of depression lead to greater memory for positive stimuli. However, this may be mostly an effect found in passive recall and forgetting. Further research is needed to identify the exact pattern.

As a result, while this research is inconsistent, it is expected that those with few symptoms of depression should show very different memory recall patterns than those with some or many symptoms. Active memory paradigms may show less of an effect than passive memory tasks, perhaps because they control better for participant effort. Given the decrease in cognitive resources seen in depression, it may be that more symptoms result in reliable patterns of reduced participant performance. This uncertainty notwithstanding, these studies emphasize the importance of adequately assessing depressive symptoms when studying memory of emotional stimuli.

Depression and Rumination

Because of their interrelation, it is difficult to distinguish the relative influences of depression and rumination. Over 40 years of research have provided a compelling association between rumination and major depression (Beck, 1967; Harrington & Blankenship, 2002; Papageorgiou & Wells, 2004). Rumination has been described in a number of ways (see Martin & Tesser, 1996, and Watkins, 2008, for reviews of different modes of ruminative thought). Some researchers have created extensive typologies describing different types of ruminations (Martin & Tesser, 1989) while others have focused on ruminations resulting from specific circumstances or events (Tait & Silver, 1989). Since 1991, many studies have used the definition proposed by Nolen-Hoeksema describing depressive rumination as “repetitively focusing on the fact that one is depressed; on one's symptoms of depression; and on the causes, meanings, and consequences of depressive symptoms” (p. 569). Within this construct, two types of rumination have been distinguished, with one more maladaptive than the other (Treynor et al., 2003). Negative rumination, termed brooding, has been defined as the repeated cognitive processing of the consequences of a negative stimulus, whereas a less negative rumination, termed reflection, was defined as the repeated cognitive attempt to identify the causes for a negative event (Treynor et al., 2003). Several studies have since confirmed the two-factor model of rumination by Treynor et al. (2003) and that reflection appears to have less negative effects than brooding (Joorman, Dkane, & Gotlib, 2006; Lopez, Driscoll, & Kistner, 2009). New research using this definition is providing even stronger connections between depression and rumination (Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002; Treynor et al., 2003; See Nolen-Hoeksema, 2000, and Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008, for reviews), and there is growing evidence that the negative, perseverative style found in depressive rumination may be a characteristic in some people that is resistant to change and related to prolonged difficulties with depression (Davis & Nolen-Hoeksema, 2000).

Rumination and Memory

Based on these measures, research has found direct connections between negative rumination and memory. In one study, depressive rumination was linked to neurophysiological measures of memory suppression (Nair, 2008). In that study, Nair found that brooding, and not reflection, was positively related to brain activity correlated with better control of memory processes (Nair, 2008). However, behavioral measures based on stimulus recall at the end of the study did not show a matching behavioral effect for brooding. Other studies also show inconsistent relationships between rumination and memory control. In a 1998 study of dysphoric people allowed or induced to ruminate while performing a memory task, Hertel found significant impairment in memory performance for both groups compared to a control, and in another study, she found evidence for a rumination-related difficulty in forgetting negative stimuli (Hertel & Gerstle, 2003). However, in a follow-up study similar to Nair (2008), these deficits ceased to be significant with further participant training in successful, active forgetting (Joorman et al., 2005).

When taken together, these studies suggest that depressive rumination is related to cognitive control of memory dysfunction, but the exact relationship is not clear. Similar to the research on mood-congruent bias, it appears to vary in different situations. This is not surprising if rumination underlies or shares the cognitive mechanism producing the mood-congruent bias. It is interesting to note that Nair (2008) apparently found no support for rumination influencing cognitive control behaviorally but did find significant relationships emerge with brain activity. Notably, more research must be done in this area to clarify these findings, particularly combining neurophysiological and behavioral measures.

Intrusive Thoughts

As described above, negative intrusive thoughts are a commonly experienced phenomenon with significant implications for clinical disorders, cognitive processes, and memory. In particular, a strong line of research has characterized depressive rumination as a cognitive response to the experience of unwanted, self-referential, negative intrusive thoughts (Miranda & Nolen-Hoeksema, 2007; Peterson & Seligman, 1984; Treynor et al., 2003; Wenzlaff & Luxton, 2003; Wenzlaff, 2005). In some cases, they have been theorized as the cognitive events that trigger depressive rumination followed by clinical symptoms (Wenzlaff & Luxton, 2003) and have been shown to cause disruptive intrusions during memory tasks of emotional stimuli (Wisco & Nolen-Hoeksema, 2009). For these reasons and the theoretical value presented in the possibility of linking intrusive thoughts to depressive rumination and cognitive control of memory, a study of the effect of emotion on memory should consider assessing a person’s methods of and success at coping with cognitive intrusions.

Stress

Finally, given the requirements for cognitive resources needed in the models described above, stress may be an important source of influence on cognitive control of successive suppression attempts (Levy & Anderson, 2008). Previously, high current stress levels have been found to lead to decreases in cognitive functioning that had significant effects on memory and processing (Cohen & Williamson, 1988). As a result, Hertel and Mahan and others (2008; Joorman et al., 2005) have suggested that, due to the higher demands of managing mood-related cognitive processes, investigations of cognitive control of memory should also include an assessment of stress.

Summary

That there are cognitive deficits in depression is widely known, and these deficits serve as important clinical indictors (APA, 2000; Beck, Steer, & Brown, 1996). There is increasing evidence for a cognitive mechanism underlying these deficits (see Wenzlaff & Wegner, 2000). Research into these deficits has suggested that they may arise as part of negative cognitive cycle that feeds back on itself. Essentially, it appears that we all experience intrusive thoughts, but some can address them better than others, using more adaptive methods. When there is a stress applied to the system that robs it of resources needed to push negative thoughts from awareness, a negative ruminative process begins to occur that increases the occurrence of negative intrusive thoughts and, correspondingly, the cognitive resources needed to control them, intensifying the deficit. Eventually, the continuation of this process may lead to a depressive disorder. However, the exact effect of such a mechanism on memory control is still uncertain.

It can be hypothesized that higher levels of cognitive symptoms of depression (e.g., diminished ability to think, concentrate, or make decisions) should produce quite different patterns of memory control than lower levels, especially showing more mood-congruent bias during passive forgetting procedures. For active memory control paradigms, it may be that low levels of depression indicate someone who has practice dealing with negative intrusive thoughts but who also is relatively high in cognitive resources, leading to rapid, effective reduction in negative thoughts. However, higher levels of depression may lead to insufficient cognitive resources to complete the task, producing patterns that suggest low effort. Future research will need to determine if this model of depressive symptoms and memory performs in this manner.

Researching the Cognitive Control of Memory

The T/NT Task and Memory Suppression.

The recent creation of the T/NT task has allowed researchers to quantify a participant's ability to use cognitive control during retrieval from long-term memory. This task has opened new lines of research into the relationship between cognitive memory processes and psychological disorders (Depue et al., 2006; Hertel & Gerstle, 2003; Hertel & Mahan, 2008), particularly how mood and the emotionality of information to be stored or retrieved results in recruitment of neural regions associated with the cognitive control of emotion processing. To date, there has been insufficient research exploring the relationships between cognitive control processes in different domains. However, there is evidence to suggest some shared processing. For example, cognitive control of memory appears to activate the same network of brain areas as cognitive control of behavioral responses (Levy & Anderson, 2002). Because it requires active halting of stimulus-initiated memory retrieval, the T/NT task provides for direct measurement of brain processes associated with memory control, and for measurement of the influence of memory control on memory performance.

The T/NT Task

One of the primary reasons for the recent increase in knowledge about the relationship between memory and cognitive processes is the creation of the T/NT task. A cognitive extension of the behavioral go/no-go paradigm in which participants are cued by an attribute of the stimulus either to perform or inhibit a learned behavioral response, Anderson and Green (2001) developed the T/NT to provide a behavioral measure of a person's ability to stop a thought even after it has already been triggered. The procedure for the T/NT task employs 3 phases, an initial learning phase in which paired cue-target items are memorized, a middle inhibition/facilitation phase in which participants repeatedly view cue items that signal them to recall some of the previously learned pairings (think condition) and prevent the recall of others (no-think condition), and a final recall phase to record which items were remembered and which were forgotten (Anderson & Green, 2001). Through this design, the T/NT task can assess a participant's ability to use cognitive control to halt automatic, cue-driven retrieval from memory of a previously learned target stimulus, a phenomenon called response override (Levy & Anderson, 2008). Using a portion of the stimuli held aside as a baseline, recall of pairings from the think and the no-think condition can be related to an individual's uninfluenced memory performance. The amount an individual is able to recall think items above baseline or decrease recall for no-think items below baseline identify the effect of the differences in strategy on memory and give a measure of his or her ability to exert cognitive control on remembered stimuli. Notably, these stimuli may be any effective cue-target match and have already been validated with words and images (Depue et al., 2006). Since its creation, this paradigm has been used in a number of studies into the cognitive control of memory.

Individual Differences in Cognitive Control

The T/NT task has proven to be flexible and effective at investigating variations between people in the cognitive control of memory. In a meta-analysis of all their studies, Levy and Anderson (2008) found large individual differences in people's ability to utilize cognitive control to exclude thoughts from conscious awareness. As might be expected, the range in performance is striking. Although the general effect is a modest 6% below-baseline reduction in memory for stimuli presented during the no-think portion of the task, participants show up to 60% below-baseline recall, suggesting excellent cognitive control, while others have shown up to 40% higher above-baseline recall of no-think stimuli. Thus, some participants are able to avoid thinking about the no-think trials successfully, forgetting more than half of the number of pairings remembered in the baseline condition, whereas some show such poor cognitive control that, even though they are asked not to think about them, they actually remember no-think items 40% better than items in the baseline condition. This variability provides strong support for Levy and Anderson's (2008) proposed executive deficit hypothesis (p. 14), which describes how control of memory could be better in some than others.

Cognitive Control of Emotionally Valenced Stimuli

In a study of the effects of valence and arousal on the cognitive control of memory, Marx, Marshall, and Castro (2008) reported a number of findings. Employing the T/NT task on positive and negative word stimuli, they found more effective use of cognitive control of memory for positive stimuli than for negative and as stimuli became more arousing (independent of emotionality). This effect was mostly driven by much better cognitive control for memory of positive stimuli, for both cued recall scores (overall mean approximately 80%) and free recall scores (overall mean approximately

50%). The authors explained this by suggesting that negative but not positive information is elaborated in memory and, as a result, is suppressed with more difficulty, consistent with reports that negative emotional states lead to more effortful processing than positive states. However, this study neglected to assess the depressive symptoms or mood of its participants, tempering the generalizability of these findings.

Another study investigated the valence effects of negative and neutral stimuli on cognitive control of memory recall. Using face-word and face-picture pairs, Depue et al. (2006) varied the emotional valence of the target items as either negative or neutral. They found that neutral items were remembered at a higher level overall and that negative items were both more largely facilitated and inhibited by cognitive control processes than neutral items for both verbal and nonverbal stimuli. That is, participants were better able both to remember and forget negative items when compared to neutral. This study provided additional evidence for the increased importance of cognitive control mechanisms when processing emotional information but, as with the previous study, failed to account for memory affects related to active depressive symptomatology.

Depressive Symptoms

Despite its creation as an experimental cognitive task, the T/NT paradigm has seen increasing use in clinical studies. In one, it was used to explore differences in participant performance related to the presence of depressive symptoms. Joorman et al. (2005) used the T/NT task with word stimuli to investigate stimulus valence in those with depression. They found that nondepressed participants recalled negative and positive stimuli equally well, but among depressed participants recall for negative items was higher than for positive items. Also, while passive memory for unpracticed items indicated evidence for a mood-congruent facilitation effect (depressed participants recalled more unpracticed negative items than positive items; see p. 25), depressed participants showed better cognitive control of memory for negative items than nondepressed participants. In fact, after removing those who acknowledged performing the task poorly, the researchers were able to replicate below-baseline recall for the negative content condition. Together, these results suggest that those with higher levels of depressive symptoms seem to demonstrate passive biases towards remembering negative stimuli, but when using more active control processes, show better performance on memory measures than less depressed individuals.

Rumination

Building on research by Hertel, Joorman, and colleagues and Depue et al. (2006), a recent study (Nair, 2008) used the T/NT task to compare performance on a measure of rumination with memory performance on picture stimuli. As in Depue et al. (2006), participants were asked to memorize matched pairs of photos of faces and images of pictures. Half the picture images were negative and half were neutral, providing the opportunity to assess a person's relative success at controlling memory of emotionally valenced stimuli. However, the current study also included electroencephalographic recordings time-locked to the presentation of stimuli (ERPs) to investigate behavioral scores on the T/NT task in more depth. Overall, the results indicated that neutral items were remembered more than negative items, but negative items were not more largely facilitated and inhibited by cognitive control of memory. However, higher endorsement of rumination was related to greater neurological activity linked to attempts at cognitive control of memory. In other words, higher ruminators showed greater differences in brain activity at parietal sites for think versus no-think conditions. This activity was not linked with behavioral results supporting effective control of memory. Consequently, while the results do not have clear implications, the study indicates a need for future ERP studies of cognitive control of memory using stimuli of varying emotionality.

Event-Related Potentials

ERPs are used to identifying sequential brain activity related to participant performance on a behavioral task. A useful and extensive description of ERPs is given by Luck (2005) and used in this section as a source unless otherwise indicated. ERPs are derived from continuous EEG recordings of electrical brain activity (electroencephalograms or EEGs) recorded through a noninvasive, low-risk procedure in which electrodes are placed on the scalp to collect patterns of electrical activity in cortical neurons. Electrode-gel provides an electrical connection between the electrodes with the skin. These connections with the scalp allow the transference of brain signals to the recording system. The main value of ERP recording is that its temporal resolution is accurate down to thousandths of a second. Because of this ERPs offer significant improvements over other neuroimaging methods like positron-emission topography or magnetic resonance, which have temporal resolutions of only several seconds. As a result, ERPs are the primary method of identifying the timing and sequencing of cognitive activity related to participant responses to a stimulus or on a task.

ERP data is presented as a waveform (see Figures 1, 2, & 3) that charts the activity at each electrode by amplitude and latency. The amplitude is the height of the waveform in microvolts (μV) at any point in time. Latency refers to the amount of time elapsed since the stimulus was presented (zero on the x-axis). As the waveform advances in time, its amplitude swings from baseline (zero on the y-axis) to positive and negative amplitudes. Each maximal point ("peak") and minimum ("trough" or "negative peak") represents important changes in neural activity in the cortex, labeled components.

Notably, because it measures concerted neuronal activity, the higher or lower the amplitude, the more powerful the effect is presumed to be. ERP components follow a simple taxonomy based on polarity and latency. If the polarity of the amplitude is negative, the component is labeled first with an N, and if it is positive, it is labeled with a P. The second part of the label gives the average latency or sequence for that component to arrive at its positive or negative peak. Thus, a P300 represents an ERP component that is positive going and that peaks on or around 300 ms after stimulus presentation, or alternatively, a P3 component is the third positive-going peak in a waveform. These two taxonomies rarely diverge. Some prefer the use of sequential labels (N2) because the common latency labels sometimes do not represent observed latencies (i.e., a P300 may peak 250 ms after stimulus onset).

To process ERPs, recorded EEGs of brain activity are sectioned and then averaged by trial condition within individuals, aligning each section at the exact moment the stimulus was presented. If the number of trials is sufficient, the averaging process removes random noise and leaves only systematic patterns of brain activity related to the condition being studied. Individual averaged ERP waveforms are then averaged across individuals (a nonweighted average) to create a grandaverage waveform representing the average performance of all participants at each condition and removing variation related to noise and individual differences. (From this point, “waveform” or “ERP” will refer to the grandaverage.)

Previous research

ERP research into the T/NT task offers promising results for a greater understanding of cognitive control of emotion and memory. In one study by Bergstrom, Velmans, de Fockert, and Richardson-Klavehn (2007), ERPs were used to identify variations in performance of the T/NT task using word stimuli. The researchers reported a component occurring between 200 and 300 milliseconds that distinguished think trials from no-think trials by latency and amplitude. This component did not vary whether the appropriate paired image had been learned or not. Bergstrom et al. also found a component between 500 and 800 milliseconds that occurred only for remembered think pairs. The authors indicated that this late parietal positivity (LPP) component was indicative of successful conscious recall. In a follow-up study, Bergstrom et al. (2009) found ERP evidence supporting the use of two strategies during no-think trials: direct memory suppression and self-distracting thought substitution. As might be expected, these two strategies produced different ERP waveforms. Direct suppression reduced parietal positivity between 300 and 600 milliseconds that they associated with successful memory recall. Direct suppression, but not distraction, also resulted in inhibitory forgetting that was signaled by an early negativity that they felt might be consistent with a negativity also seen in behavioral motor inhibition (error-related negativity, ERN). In contrast, the distraction memory strategy produced forgetting that did not result from inhibitory processes and, importantly, that had no effect on the late parietal positivity associated with successful recall. Bergstrom et al. interpreted this to mean that there are two types of forgetting, one that uses inhibitory processes and one that does not, suggesting that forgetting can occur through direct control or through substitution, i.e., forming competing, alternative memories.

Similarly, Nair (2008) used ERPs and the T/NT task to investigate the influence of emotion on mental processes. Using emotional pictures from a study by Depue et al. (2006), the results of testing for 23 participants supported the presence of a very early effect (~150 ms) for emotional processing of visible stimuli at parietal sites. Other effects emerged around the P3 component, where Nair found effects for strategy and valence strongest at the right parietal electrode. In the later component, a significant Strategy x Valence interaction emerged, indicating that the effect of strategy was stronger for negative items. These findings supported the contention by Depue et al. (2007) for two memory control networks focused on forgetting: an initial network focused on altering sensory representations to reduce retrieval and a longer memory control process with inputs to the hippocampus and from the amygdala. Activity was generally strongest at right-parietal electrodes. The ERP components identified by Nair also mirrored closely the two primary findings of Bergstrom et al. (2009) for an early suppression-related component and a later, posterior, enduring, lateralized component.

Underlying neural areas

Neuroimaging research into the T/NT task has provided some evidence for the neural networks implicated in task performance. An fMRI study by Anderson et al. (2004) reported a neurobiological model to describe the underlying physiology producing active forgetting on the T/NT using word stimuli. The primary location was found to be the dorsolateral prefrontal cortex, which acted on the hippocampus to reduce recall in the no-think condition. Activity at both areas predicted the magnitude of forgetting. Other areas involved included the anterior cingulated cortex, which was described as a signaling area to indicate the need for control, and premotor areas implicated in behavioral inhibition, including the dorsal premotor cortex, pre-supplementary motor area, and the intreparietal sulcus. Anderson et al. were careful to note that forgetting reflected inhibition of the correct response, not simply extinction of the pairing.

Another fMRI study completed by Depue et al. (2007) was conducted on negative photo images used in the T/NT task. In a previous study, Depue et al. (2006) found that negative pictures produced a significantly greater strategy effect than neutral pictures. Brain areas related to cognitive control of memory (i.e., those found to be more active during attempts to prevent a remembered item from coming to mind than during successful recall) activated right-sided frontal areas. Specifically, activity at two networks appeared to be orchestrated by Brodmann's area 10 in the prefrontal cortex. Activity during early control trials occurring at the right inferior frontal gyrus appeared to represent a "late correction" network that led to decreased activation in the visual cortex (fusiform gyrus) and the pulvinar nucleus of the thalamus, two areas involved in the sensory representations of memory. A later network, also related to activity at Brodmann's area 10, activated the right medial frontal gyrus and resulted in forgetting-related decreases in activity at hippocampal and amygdalar areas. Activity at the right medial frontal gyrus, but not at the earlier network, was related to participant performance at forgetting. Thus, the authors suggest that activity by the early network may serve to decrease prepotent sensory activity and possibly regulate working memory activity through thalamic connections, whereas activity at the later network appears directly related to successful inhibitory control over memory retrieval, replicating the findings of Anderson et al. (2004) for a prefrontal cortex/hippocampus connection responsible for memory control. Furthermore, the authors propose that their largely right-lateralized prefrontal activity is congruent with other research linking right-sided activity with emotion regulation.

Summary

While limited in their breadth, these studies supply a good beginning for continued clinical research into cognitive control of memory using the T/NT task and emotionally valenced stimuli. As demonstrated above, the experimental manipulation of the task is an intervention that allows strong statements to be made about the role of cognitive control processes in memory. Furthermore, experimental manipulations of the emotion valence of stimuli allow newly precise insights into the cognitive processing of emotional content. Emerging patterns show that neutral items tend to be remembered at higher levels than negative items, but this finding may provide some helpful stability to a remarkably inconsistent literature, as other studies have found no valence differences (Bradley, Greenwald, & Lang, 1992) or a stronger negative (Joorman et al., 2005) and sometimes positive memory bias (see Matt et al., 1992 for a meta-analysis). One reason for this variability is that studies of memory and mood must account for the level of clinically significant depressive symptomology that carries with it a well known negative bias (see “Depressive Symptoms and Memory Bias,” p. 25). Similarly, the importance of the relative arousal of the stimuli is another facet of stimulus valence that is beginning to be recognized and addressed. Of particular note, ERP research has begun to produce findings with significant implications for the understanding of cognitive control of memory processes. Specifically, Bergstrom et al. (2009) found neurophysiological evidence supporting inhibitory processes as a successful method of negative memory control. Both fMRI studies demonstrated activation in similar areas. However, Depue et al. (2007) found amygdalar activity for negative stimuli that was related to hippocampal activity and behavioral recall and that was not present in non-valenced stimuli used in Anderson et al. (2004). Nair (2008) found brain activation with significant valence and strategy effects that occurred at right-sided posterior sites during time windows at 150 and 350 ms that appear to represent the onset and results of conscious cognitive control processes.

Given these findings, the use of ERPs affords opportunities to develop a better understanding of the timing of underlying neurophysiological processes, to identify time periods of importance in the use of cognitive control, and to provide a purer measure of strategy effects that can be used to identify relationships with other constructs related to cognitive control, such as mindfulness or rumination.

CHAPTER 3: SUMMARY AND PILOT STUDY

Summary of the Literature Review

Negative intrusive thoughts are a widespread and common phenomenon, but in some people, present significant problems. Although many are able to manage them with seemingly little effort, others have considerable difficulty and may even develop related psychological disorders. Given how widespread they are, it is like that problems arise not from the thoughts themselves but rather from failures in attempts to control them. These failures appear to be particularly troublesome when a person identifies the thoughts as personally troubling and acts on a desire to control them. Strategies employed to reduce such thoughts generally include avoiding them (e.g., distraction), attentively processing them (e.g., reappraisal), or simply waiting for them to go away. However, failures in one's control strategies can increase the frequency of such negative thoughts and can lead to cognitive processes such as depressive rumination, anxious rumination, or obsessions that have been linked with a number of common psychological disorders. It has been hypothesized that this occurs at least in part due to the activity of a two-component cognitive process, featuring an early, automatic control mechanism and an effortful, later control mechanism.

The physiology underlying cognitive control networks used to reduce negative thoughts appears to share many brain areas found in other applications of cognitive control, such as inhibition of motor movements. Two groups of researchers, Depue et al.

(2007) and Anderson et al. (2004), proposed similar brain areas for the cognitive control of emotional memories that may involve an initial network responsible for reducing sensory representations of the memory and a second network that leads to more stable forgetting as indexed by reduced activity in the hippocampus. Depue et al. (2007) also reported concurrent decrease in activity at the amygdala for negative stimuli.

As these studies indicate, the creation of the T/NT task by Anderson and Green (2001) has provided a new method of investigating the processes related to cognitive control of memory due to its novel task requiring two different cognitive responses to memory cues. The use of emotional stimuli with the T/NT task further increases the possibilities for elucidating control processes involved in emotional memory. Notably, the T/NT task also allows simultaneous recording of neurological activity that can provide additional information about the cognitive processes underlying observed memory results.

Such impairments in memory performance may be related to a number of variables with hypothesized links to cognitive control, and research into cognitive control calls for a multifaceted assessment for the identification of individual differences. Aside from recall scores generated on the memory test, ERP brain recordings offer significant opportunities for elaborating the link between brain activity and other variables. The allocation of attention seems to be an important element of cognitive control of memory, and work by Posner and colleagues suggests that there are three attention-related processes, one for directing attention, one for signaling importance, and one for resolving attentional conflicts. As suggested by Cowan (1999) and others, memory itself may function by the allocation of attentional focus to long-term memory traces. Consequently, actual performance tests of attention and working memory span can provide reliable measures of cognitive activity. Finally, a few psychometric constructs appear to be important to understanding the inconsistencies in cognitive control of memory. In particular, self-report measures assessing mindfulness, failures at cognitive control (i.e., depressive rumination, suppression of intrusive thoughts), and clinically relevant measures (such as depressive symptoms and perceived stress) could identify those who have difficulty handling negative memories. Together, these measures may illuminate patterns of individual differences in the efficiency and function of cognitive control. To establish this possibility, a pilot study was conducted to explore the relation between mindfulness and cognitive control of memory.

The Pilot Study

An initial study investigating the effects of emotional stimuli on memory control was completed in 2009 (Eyer). It included self-report measures of depressive symptoms, rumination, intrusive thoughts, dispositional mindfulness, and perceived stress. It did not include a direct assessment of attention. The primary measure was behavioral performance on the cognitive T/NT task, which included a memory task involving both negative and neutral stimuli. The pattern of resulting recall scores indicated that participants remembered 63.1% (*SD* = 15.5%) of stimuli. Stimuli held aside after the final training session and only seen again during the final recall task were used to identify the baseline memory performance. The overall rate was 53.5%. Main effects on baseline-corrected recall scores were identified for strategy, think (M = 19, 15.80) > no-think (M = 5, SD = 15.20), $F(1,24) = 29.07$, $p < .001$, $\eta_p^2 = .55$, and for valence, neutral stimuli (M = 15.25, SD = 15.97) > negative stimuli (M = 8.75, SD = 13.44), $F(1,24) = 13.53$, $p = .001$, $\eta_p^2 = .36$. A significant interaction was obtained, $F(1,24) = 20.02$, $p < .001$, $\eta_p^2 = .46$, indicating that the effect of strategy was stronger for neutral items than negative items. Analyses by condition indicated that the two think conditions (negative and neutral), but not the no-think conditions, were significantly different than zero (representing performance at baseline), suggesting the presence of a memory facilitation effect but no evidence of memory suppression.

The key finding implicated the role of self-reported mindfulness in the modulation of attentional control. Scores on the MAAS, a self-report measure of dispositional mindfulness, were significantly correlated with total recall scores ($r = .56$, $p = .004$). An extreme-groups analysis, using a median split (median = 4.13) to separate participants into low controllers ($n = 10$, $M = 3.45$, $SD = 0.48$) and high controllers ($n = 9$, $M = 4.70$, $SD = 0.39$), explored the effect of mindfulness on recall and found that low versus high controllers produced characteristically different patterns of memory recall when attempting to exert cognitive control over stimuli with negative content. Specifically, those reporting low day-to-day mindfulness yielded reduced cognitive control effects for negative versus emotionally neutral items, whereas high controllers yielded statistically equivalent cognitive control effects for both item types. This finding was indicated as control-related phenomenon suggesting that mindfulness may represent a behavioral expression of automatic cognitive control processes.

The Current Study

Based on the results of the pilot study and the literature presented, the current study sought to investigate performance on the T/NT task in relation to measures of attention, mindfulness, rumination, depression, intrusive thoughts, and stress. Several key changes from the pilot study were implemented. The most important was the addition of electrophysiological recordings during the experimental phase of the T/NT task. A second change added two comprehensive, rich tests of attention and working memory span performance to supply new information on three networks believed to form the attention system. These measures provided useful information for identification of the role of attention and working memory in cognitive control of memory. A third change increased the rigor of the initial training phase of the T/NT task. After three training cycles, a recognition test given during the fourth cycle of training was increased in difficulty to strengthen learned pairs and improve assessment of training. The fourth change sought to include an additional measure of mindfulness. The Five Factor Mindfulness Questionnaire assesses mindfulness on five domains.

CHAPTER 4: HYPOTHESES

The current study is an extension of research into cognitive control of memory processes. Specifically, it used the T/NT task created by Anderson and Green (2001) to investigate individual differences in cognitive control of memory. Furthermore, the study built off the work of Depue et al. (2006) who used negative and neutral face-image pairs as stimuli in the T/NT task. Bergstrom et al. (2007) used word stimuli in an ERP study of the T/NT task, and Nair (2008) followed up with a study integrating these methodologies to investigate the influence of emotionally valenced stimuli on ERP results recorded during the T/NT task. To prepare for the study, a pilot study (Eyer, 2009) was conducted that investigated behavioral results on the T/NT task with negative and neutral stimuli in relation to a number of theoretically associated psychometric variables, including measures of mindfulness, attention, and rumination. The current study sought extends the literature by investigating the following hypotheses.

Hypothesis 1: Primary Analysis

Analyses employed a 2 Strategy (think or no-think) x 2 Valence (negative or neutral) repeated-measures ANOVA design using baseline-corrected recall scores to investigate the effect of stimulus emotionality on the use of cognitive control strategies with memory. In three previous studies of emotional stimuli in the T/NT task (Depue et al., 2006; Nair, 2008; and Eyer, 2009), three different overall patterns of recall were identified. Consistent with the pilot study described above, the following predictions were made.

Main Effect for Strategy

As found in Anderson and Green (2001), Bergstrom et al. (2007; 2009), Depue et al. (2006; 2007), Nair (2008), and the pilot study, recall was anticipated to be higher in think trials than no-think trials.

Main Effect for Valence

Consistent with Depue et al. (2006) and Nair (2008), recall was anticipated to be higher in the neutral condition than the negative condition.

Interaction Effect

Consistent with the pilot study, an interaction was anticipated in which the effect of cognitive control (think > no-think) was larger for neutral stimuli than negative stimuli. However, other studies have found different patterns (Depue et al., 2006; Nair, 2008).

Hypothesis 2: ERP Results

Using data generated from ERP recordings during the experimental portion of the T/NT task, a separate 2 Strategy x 2 Valence repeated-measures MANOVA performed on four electrode sites for each time window of interest are expected to produce the following effects.

200-300 ms Strategy Difference

Consistent with the results of Bergstrom et al. (2007; 2009) and Nair (2008), an early main effect for strategy was anticipated between 200 and 500 milliseconds. Nair (2008) found early differences based on stimulus emotion, suggesting automatic emotion regulation processes. Furthermore, according to Bergstrom et al. (2009), the difference in

ERP amplitude at later lateral, parietal electrode sites occurring represents cognitive control processes related to initiating inhibitory processes for the no-think condition.

300-600 ms Memory Difference

Also consistent with Bergstrom et al. (2009), accurate think trials were expected to produce a later ERP component that represented cognitive activity associated with the successful recall of remembered items. Consequently, it was not anticipated on no-think trials. Nair (2008) also found later separation related to the emotionality of the stimuli, supporting the results of Depue et al. (2007) who proposed emotion-related neural inputs to the cognitive control areas.

Exploratory Effects

ERP results were included in correlational analyses with measures of attention, rumination, and mood. Consistent with Nair (2008), the current study explored a relationship between higher rumination scores and neural activity related to better cognitive control of memory. Based on research by Cowan (1999) and others, attention and working memory span scores generated from performance on the ANT and SSPAN were expected to be related to better cognitive control and better overall performance on the memory tasks.

Hypothesis 3: Clinical Measures Analysis

Previous research suggested that mood (Matt et al., 1992) and attention (Redick & Engle, 2006) play significant roles in memory processes. Mindfulness is defined as having a major component of attention training (Bishop et al., 2004), suggesting that those higher in mindfulness may differ substantively in their attentional abilities from those who do not. This relationship has been confirmed in a number of studies (Jha et al., 2007; Lutz et al., 2009; Tang et al., 2007; Valentine & Sweet, 1999). Consequently, clinical and cognitive measures administered during testing were anticipated to correlate with memory performance variables, both recall and ERP data. Significant relationships were anticipated with mindfulness, depressive ideation, rumination, attention, and working memory span.

CHAPTER 5: METHOD

Participants

A total of 57 participants were initially recruited from the university subject pool and participated in an initial pretesting session. All met inclusion criteria that they be 18 years-old or older, native speakers of English (although they could also have spoken another language from birth), and right-hand dominant (laterality quotient > +70) with no underlying neurological or vision problems that could preclude performance. In addition, each endorsed sufficient normal vision or corrected-to-normal vision to view a computer screen presenting images for an extended period of time and denied a history of negative reactions to similar situations (i.e., headaches or seizures). During pretesting, 3 students met a safety exclusion criterion by endorsing current suicidal ideation on the Beck Depression Inventory-Short Form (BDI-SF), a measure of depressive symptoms. In general, these participants scored highly, two meeting the diagnostic cutoff for depression ($M = 13.7$), although total BDI-SF score was not considered for exclusion. These participants were immediately referred to the on-campus counseling center and exempted from further participation with full credit. No participants were excluded for existing visual, learning, or attention problems that would render them unable to safely and effectively participate. Nevertheless, the necessity of breaking the study into two sessions to reduce participant fatigue resulted in a fair amount of attrition between pretesting and the primary testing session. In all, 12 participants (21%) either did not attend or were unable to schedule a follow-up appointment within one week of pretesting. Anecdotal reports indicated that participant loss was due primarily to students choosing not to participate after having met departmental research requirements and, secondly, to difficulty scheduling a follow-up session within one week of pretesting.

Thus, 42 participants were enrolled in the primary stage of the study. Three participants failed to complete data collection. Mechanical failure resulted in the loss of one participant’s data. One participant withdrew due to scalp irritation during the initial step of the primary task. Another participant withdrew prior to the primary task because she realized she had an appointment and would be unable to finish the study. Of the 39 remaining participants, an additional four failed preliminary data review. This included an analysis of memory recall to assess fundamental task compliance. Two participants were outliers, obtaining total recall percentages of 5% and 14%, and were dropped from further analyses. Electroencephalographic (EEG) data was also reviewed for task compliance. Two participants demonstrated excessive artifact in their recordings that precluded their inclusion in analyses. One participant demonstrated eye-blink and movement artifact such that fewer than 200 trials were acceptable for analysis (n = 115). A minimum of 200 trials were deemed necessary to form four reliable individual waveforms from averaged trials. A second participant was rejected for excessive somnolence-related artifact (alpha waves) that resulted in a signal-to-noise ratio (SNR) that was an outlier when compared to other participants. High SNR is an indication of excessive noise that dilutes sought-after brain activity.

An exploratory analysis on demographic variables was completed on participants who were included in the study versus those who were not included. The two groups did not differ significantly on gender, ethnicity, age, or year in school. Due to the low size of the rejected sample and potential for a Type II Error, a qualitative review was conducted. Results suggested that participants not included in analyses were somewhat more often African American (n_{AA} = 8, 36%), younger (M_{age} = 21.7 years, SD_{age} = 6.1), and lowerclassmen (n_{class} = 18, 82%) than those whose data were included (n_{AA} = 6, 17%; M_{age} = 23.8 years, SD_{age} = 6.1; n_{class} = 19, 56%). In addition, a brief comparison between the 21 of the 22 participants who did not complete the study and the 35 who did conducted on measures completed by all participants at the pretesting session produced only one significant difference on the WBSI after accounting for unequal variances, $t(50.12) = -2.15$, $p = .036$, 95% CI[-10.58, -0.36]. The means indicated that excluded participants scored approximately 5.5 points higher than included participants on average. Another comparison suggested a trend for included participants to endorse less judging of their internal experiences than excluded participants, $t(54) = 1.78$, $p = .078$, 95% CI[-0.40, 7.23]. Together, these measures suggest that excluded participants may have experienced somewhat worse difficulty reducing negative self-judgments. Given these findings, the current study appeared to have initially recruited a larger proportion of minority students, although the excess was lost to attrition. Otherwise, group differences appear to suggest that desirable variability in mood-related cognitive control was removed from the sample, perhaps biasing the results towards a null finding. However, there is no evidence of any bias that would render further analysis invalid.

The final sample comprised 35 students who approximated the general student population (see Table 1 for participant demographics). They were evenly male and female (n = 17; 49%), average aged (M = 23.84, SD = 6.14), and representative of the racial distribution of the university in 2009 [$\chi^2(3, N = 17{,}646) = 0.47$, $p = 0.926$, Cramer's $\varphi = 0.00$, when compared across the four groups represented in this sample]. Several participants reported mild discomfort during the ERP data collection, but only one participant (see above) reported more than momentary discomfort.

Measures

The following self-report measures were administered to assess participants on their level of mindfulness, both dispositional and multifaceted, intrusive thoughts, rumination, depressive symptoms, and current stress level (see Appendix B for all measures). In addition, a simple biographical information form was administered to record basic demographic information and to identify those with existing conditions that would limit their ability to participate in the study. The measures were given in two stages, a pretesting session and a primary testing session. Composition of the packets is described in the Procedure.

Demographic and Descriptive Measures

Biographical information form

A basic two-part demographic form was administered at the start of each session that included elements relevant to EEG recordings. Data collected included self-reports of basic descriptive or demographic information, prior exposure to foreign languages, self-report of handedness, vision, and learning difficulties, neurological problems, head traumas, losses of consciousness, seizures, or medications likely to affect participation. This information was used to elicit information relevant to possible concerns of participating but did not serve as defined exclusion criteria. The measure took approximately 4 minutes to administer. Additional questions asked at the beginning of the primary session recorded participant estimates of the amount of sleep obtained the night before and time since the last food eaten to record conditions at testing. This information will be used to record experiment conditions, not for exclusion purposes. It took approximately 2 minutes to administer.

Handedness

Consistent with research showing hand-dominance-related laterality differences in functional neuroanatomy that can affect ERP recordings (Alexander & Polich, 1995), a modified version of the Edinburgh Handedness Inventory (EHI) was administered at pretesting to quantify the degree of right handedness reported by participants. Originally published by Oldfield (1971) and updated by Dragovic (2004) to improve its statistical properties and ease of administration (Williams, 2008), the current version is an 8-item self-report measure of actual handedness behaviors on a number of common tasks. Scores were recorded using a 5-point Likert-type scale from -2 (always left) to +2 (always right). A laterality quotient (LQ) to categorize hand preference was computed by adding all scores together, dividing them by the sum of the absolute values of all scores, and multiplying by 100 $[(\Sigma x/\Sigma |x|) * 100]$. Scores range from -100 to +100, and those scoring lower than +70 have been suggested as having biologically different physiology than those who score +100 (Schacter, 2000). Thus, LQ scores lower than +70 resulted in exclusion for the present study. The measure took approximately 3 minutes to administer.

Mindfulness Measures

Dispositional mindfulness

To record aspects of participant exposure to and practice of mindfulness-related qualities, two mindfulness questionnaires were given at pretesting and during the primary testing session. To identify participants' levels of day-to-day mental focus or mindfulness, the current study included the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003), a 15-item, self-report scale assessing a single factor related to one's ability to stay mindful in the moment instead of becoming distracted or losing focus on the task at hand. Because it assesses more stable traits, it has been described as a measure of dispositional mindfulness. Items were scored on a 6-point Likert scale from 1 "Almost Always" to 6 "Almost Never" giving a range of total scores from 6–36 and include text such as "I tend to walk quickly to get where I'm going without paying attention to what I experience along the way" and "I do jobs or tasks automatically, without being aware of what I'm doing." Brown and Ryan reported internal consistencies of .82 for college students and .87 in adults, and a four-week test-retest reliability of .81 (2003). Administration took approximately 5 minutes.

Multifaceted mindfulness measure

The Five-Facet Mindfulness Questionnaire (FFMQ) is a 39-item, self-report measure of one's experience with five different elements of mindfulness, each corresponding to its own subscale (Baer et al., 2008). These are Observing, Describing, Acting with Awareness, Nonjudging of Inner Experience, and Nonreactivity to Inner Experience. Items are scored on five-point Likert-type scale from 1 (never or very rarely true) to 5 (very often or always true). Possible scores range from 8–40 (7–35 for nonreactivity). The authors have reported adequate to good internal consistencies in multiple types of samples (*r* = .67–.92). To respond to the items, participants are asked to choose the answer "that best described your own opinion of what is generally true for you." Sample items include "I watch my feelings without getting lost in them" and "I notice the smells and aromas of things." The measure has been validated in a number of types of participants, including undergraduates, meditators, and nonmeditators. The questionnaire took approximately 15 minutes to complete.

Control over Intrusive Thoughts

Rumination Measure

To quantify a person's tendency towards ruminative cognitive patterns, particularly depressive rumination, the current study administered the Ruminative Responses Scale (RRS; Nolen-Hoeksema & Morrow, 1991), a 22-item, self-report measure of rumination that assesses persistent thinking about the possible causes, meaning, or consequences of dysphoric mood. This scale was the first administered during the primary data collection session. Items were rated on a Likert scale from 1 (almost never) to 4 (almost always) and possible scores range from 22–88. The scale has reported Cronbach alphas of .89 (Nolen-Hoeksema & Morrow, 1991) and .90 with a reported test-retest reliability of .67 (Treynor et al., 2003). All items are prefaced by the phrase "How often do you" and include content related to depression such as "Think about how passive and unmotivated you feel" and "Think about all your shortcomings, failings, faults, mistakes." Additional analyses provided scores on two 5-item subscales. Treynor et al. described the Reflection subscale as indicating a more adaptive focus on mood-related cognitive problem-solving (sample item: "Analyze recent events to try to understand why you are depressed?") while the Brooding subscale represents a more passive, negative focus on the causes for one's negative mood (sample item: "Think "What am I doing to deserve this?"). Both scales show adequate internal consistency with Cronbach alphas of .71 and .77, respectively (Miranda & Nolen-Hoeksema, 2007). The measure took 4–6 minutes to administer

Thought Suppression

To help identify failed attempts at cognitive control through thought suppression, the current study administered a widely used questionnaire assessing suppression of intrusive thoughts. The White Bear Suppression Inventory (WBSI; Wegner & Zanakos, 1994) is a 15-item, self-report measure with item scores ranging from 1 "Strongly Disagree" to 5 "Strongly Agree" and total scores that range from 15–75. Internal consistency was reported at alpha = .89, and one-week test-retest reliability was .92. Items have content such as "I have thoughts that I cannot stop" and "Sometimes I really wish I could stop thinking." Although this measure has been widely used in research into intrusive thoughts, some have criticized it as being too narrowly focused and a measure of only failed attempts at suppressing intrusive thoughts (Rassin, 2003). The measure took about 5 minutes to complete

Attention and Working Memory

Attention

The Attention Network Test-Short Form (ANT; Fan, 2003; Fan et al., 2002) is a computer-administered cognitive test of attention that quantifies participants' attentional abilities in three domains: Alerting, Orienting, and Conflict. Using a unique integration of two cognitive tasks built off extended research into attention by Posner, Fan, and others, the ANT assesses attention performance on three interrelated, empirically-derived networks based on established neuroanatomical pathways. The Alerting domain assesses one's ability to achieve and maintain an alert state when needed. Orienting quantifies how well one applies directional focus to a selected sensory input, and Conflict quantifies one's effectiveness at using cognitive control to resolve attentional conflicts. The task involves variations on two simple and widely used cognitive tasks: a cuing task and a flanker task (see Figure 4). A trial consists of a fixation cross appearing on a gray screen for a variable period of time (400-1600 ms), followed by a warning cue (an asterisk *) presented above or below the center cross for 100 ms. After a fixation period of 400 ms, a string of five arrows is presented above or below the fixation cross. The center arrow is presented at the exact position of the warning cue pointed in either the same or opposite direction as four neighboring arrows (two on each side) pointing to the left or to the right. The participant's task is simply to press the left- or right-arrow key within 1700 ms if the center, cued arrow is pointing left or right. Scores produced include mean accuracy and reaction time for each domain. The target and distracter arrow directions and cued position vary by condition. The entire task took approximately 15 minutes to complete.

The current study used the short form of the ANT (Fan, 2003), which reduces administration time by eliminating the neutral flanker condition (dashes instead of arrows) and double-cued condition (both above and below). Three composite scores are still generated from means of median reaction time scores generated during the task. Alerting scores are formed by subtracting the mean of median scores for all center cued trials (providing a temporal cue but not a spatial cue) from the average median scores for all uncued stimuli (no temporal or spatial cue). Higher Alerting scores indicate lower benefit from temporal cueing. Orienting scores are formed by subtracting the average of spatial and temporal cues provided above and below the fixation cross from the central cue, which provides temporal cueing without spatial cueing. Higher Orienting scores suggest lower ability to use spatial cueing. Conflict scores are formed by subtracting the mean of median reaction time scores to all congruent trials from the mean of median scores for all incongruent trials. Higher Conflict scores indicate greater disruption of cognitive processes when required to process incongruent stimuli.

Working Memory

The automated symmetry span task (SSPAN) is a computer-administered working memory task that uses images instead of text to test a person's ability to maintain an idea in active memory while simultaneously completing another type of processing task. One of a number of automated working memory span tasks created by Unsworth, Heitz, Schrock, and Engle (2005), it provides a visual/spatial paradigm for assessing working memory capacity and efficiency that appears to represent a consistent mechanism across multiple stimulus types (Unsworth, Redick, Heitz, Broadway, & Engle, 2009). To begin, participants were trained to remember the spatial placement of red boxes presented sequentially on a 4 x 4 grid of 16 white boxes. Each red box was shown for 650 ms with a 500 ms inter-trial interval (see Figure 5). Participants were then asked to recall the red boxes and use a mouse to click sequentially on the matrix where the boxes were displayed. Feedback on performance was provided. For the next part of the task, participants were presented with black and white boxes laid out on an 8 x 8 grid with varying spatial compositions and were asked to decide if the figures were symmetrical about the vertical centerline or not. Feedback was provided and reaction time was recorded for each trial. Finally, the two tasks were combined such that participants were to recall sequences of 2-5 red boxes presented randomly after completing the symmetry decision task. Each red box in sequence was counted for accuracy with three trials for each length for a total of 42 possible correct responses. Response time for this portion of the task was limited to the participant's mean reaction time to the symmetry task alone plus 2.5 SDs. Scores provided include absolute accuracy score, a sum of the set lengths for which the participant had perfect performance (range: 2–42); total recall score, a sum of all correct responses; and error scores for the symmetry task, composed of two scores: failures to respond during the time allowed (speed errors) and failures to correctly determine whether the image was symmetrical (accuracy). Cronbach α's are .80 for recall scores (red boxes), .84 for processing accuracy (symmetry task), and .99 for processing time (duration errors), and test-retest reliability was reported as $r_{139} = 0.77$ (Unsworth et al, 2008). The entire task took 20-25 minutes to complete and was followed after a short break by the T/NT task (described below).

Clinically Relevant Measures

Depression Symptoms

To assess participants' levels of current depressive symptomatology, a special short form of the Beck Depression Inventory was used that eliminates some questions which load primarily on somatic, physical, or performance-related symptoms of depression (BDI-SF; Beck & Beck, 1972; Beck, Steer, & Brown, 1996). Based on the 21-item, empirically validated, clinical self-report measure of depressive symptoms and severity that was created to assess DSM criteria for depressive disorders (APA, 2000), the BDI-SF is composed of the 13 cognitive-affective items with a recommended cutoff of 10 for the identification of moderate to severe depressive syndromes (Beck, Steer, et al.). More recent research by Furlanetto, Mendlowicz, and Bueno (2004) has indicated that a cutoff of 10 is effective for screening purposes (sensitivity = 100%) and 13 for diagnosis (specificity = 96%). Consequently, the BDI-SF is effective in environments, such as primary care, where somatic symptoms may be prominent and in research which focuses on cognitive aspects of depressive dysfunction. Item scores range from 0–3, and total scores range from 0–39. Beck and Beck reported that the short form correlated with the long form at .96. Cronbach's α for the short form has been reported at .87 (Sheier, Carver, & Bridges, 1994). Scale norms have been validated in both genders and in multiple ethnic populations. Items are given as domains for which test-takers must choose the statement with which they best agree based on how they have felt over the last two weeks. For Sadness, the items are "I do not feel sad" (0 pts), "I feel sad much of the time" (1 pt), "I am sad all the time" (2 pts), and "I am so sad or unhappy that I can't stand it." The measure took approximately 5 minutes to complete.

Perceived stress measure

To identify and quantify the effects of stress on cognitive performance, as described by Hertel and colleagues (Hertel & Calcaterra, 2005; Hertel & Gerstle, 2003; Hertel & Mahan, 2008), the study administered the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983; Cohen & Williamson, 1988), a self-report questionnaire of stress from situations arising in the past month. In particular, it identifies the extent to which participants perceive their lives as unpredictable, uncontrollable, and overloaded. Item scores are on a 5-point Likert scale and range from 0 "never" to 4 "very often" for a range of total scores from 0–56. The 10-item version produced an internal consistency of

.78 and a two-day test-retest reliability of .85. Sample items include: "In the last month, how often have you been upset because of something that happened unexpectedly?" and "In the last month, how often have you found that you could not cope with all the things that you had to do?" The scale took approximately 3 minutes to administer.

Debriefing measure

At the end of the study, participants were administered a short debriefing questionnaire. First, questions covered information about memory strategies employed, control strategies used to prevent recall of a memory, stimulus characteristics, distractions during the task, their perceived performance on the task, reasons they might have done well or poorly, and previous exposure to mindfulness or meditation. Participants responded on a single Likert scale giving a self-assessment of their performance on the task. Then, participants were given a brief description of the study, verbally and in writing, including a rationale for its components. The information sheet included the IRB number and contact information for the principal investigator. Questions were solicited and answered if possible. This portion of the study took approximately 10 minutes.

T/NT Memory Suppression Task

The main component of this study is a computer-administered cognitive task that quantified participant ability to use cognitive control processes to facilitate or inhibit memory retrieval of images on demand. Termed the think/no-think task (T/NT), it requires the participant to selectively inhibit the recall of some learned pairings while actively trying to remember others. Rather than words, the stimuli in this study were the same images as those used in the Depue et al. (2006) adaptation of the T/NT task: 80

neutral faces (40 males and 40 females) that were paired with 80 pictures (40 with negative content and 40 with positive) from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). See Figure 6 and Figure 7 for example images. The IAPS is a standardized collection of affectively ranked pictures available for use in research. Each picture is assigned a valence score based on the average of rater reactions to the image on a 9-point scale from 1 “very negative” to 9 “very positive.” Negative images were used to help identify the effects of negatively valenced stimuli on memory. Neutral images provided the comparison condition. No positive images were included. As reported by Depue et al. (2006), the full set of negative images has a mean rating of 2.4 (*SD* = 0.51), while the neutral images have a mean rating of 4.4 (*SD* = 0.23).

Training Phase

The three stages to the task are an initial training phase, the experimental phase, and a final recall phase. During the training phase, all 80 face photos were paired with a picture image and displayed in pairs on a screen with a black background for 3.5 seconds (see Figure 8). The two pictures appeared side-by-side. Face photos appeared centered vertically and were aligned to the edge of the screen on the left side and to the vertical centerline on their right side. Picture images were centered vertically and aligned to the vertical centerline on their left side and the edge of the screen on their right side. All pictures are the same size (225 x 225 pixels). Each presentation was followed by a 0.5-second intertrial interval featuring a medium gray fixation cross in the center of the screen. All pairings were presented in a random order in blocks of 20 and cycled three times. To ensure high memory for stimulus pairs, a final fourth cycle of training was administered in one continuous task that randomly displayed all stimuli, using a harder recognition testing paradigm to improve memory of paired stimuli. On all cycles, all blocks were balanced by photo gender and image valence. At the end of each block, a recognition test reinforced learned pairings and generated a measure of initial learning.

During the recognition test administered after each subset of 20 stimuli in the first three training cycles, participants were shown one face photo from the subset as a memory cue stimulus centered vertically on the left half of the screen. On the right half, two picture images were shown, one above the other, in a randomized position (see Figure 9). One was the correct match (target) for the face-cue photo while the other was a matched distracter image chosen at random without replacement from the pool of 20 picture images. The distracter varied across cue-faces but not across subsets. Using a standard response box, the participant's task was to press the button clearly labeled "T" (the left button) if the correct target image was on top or to press the "B" (the right button) if the correct target image was on the bottom. Following each response was a 0.5-second inter-trial interval that displayed a medium gray cross in the center of the screen. This continued until the participant saw each of the 80 pairings three times. This method was previously shown to produce competent learning of the pairings (Nair, 2008) and previous research suggests effective learning of face-picture pairings after three presentations (Depue et al., 2006).

For the fourth cycle, a new training paradigm was used that was designed to produce better learning of the stimulus pairings. Instead of four blocks of 20 stimuli, participants were shown all 80 stimuli in one block. As before, the participant was asked to choose between two images. However, the distractor image on this task came from any of the other 79 images available without replacement. The increased difficulty of this task should have produced better learning in the participants.

Experimental Phase

The experimental portion of the task used 64 of the 80 pairings, 32 neutral pairs and 32 negative pairs. The remaining pairings (16) were reserved as baseline stimuli for the final memory recall portion of the task. All of the stimuli in each valence condition (neutral or negative) were randomly assigned to the think condition or no-think condition. Each trial consisted of a face photo presented as a memory cue for 3.5 seconds on a black screen (see Figure 10). The photo was centered both vertically and horizontally. The stimulus was followed by a 0.5-second inter-trial interval that displayed a medium gray fixation cross in the center of the screen. For each photo cue (image size: 225 x 225), a 30-mm border was extended from it on all four sides. The color of the border varied based on the condition of the trial: a green border indicated a think trial, and a red border indicated a no-think trial. For trials with a green border, participants were instructed to make an effort to think consciously about the picture target that was learned with the face cue. For trials with a red border, participants were instructed to make an effort to let the previously learned picture target come into conscious awareness. Each of the 64 stimuli was viewed 10 times. After every two cycles, a short, one-minute break was given to allow participants to rest their eyes. If necessary, this break was extended to allow the participants more time if requested.

Recall Phase

The final phase of the task was a memory recall test. The task tested participant memory for all 80 faces learned during the T/NT task. Each cue face was presented for 8 seconds (see Figure 11), giving the participant time to form a two-to-five-word response describing the face's matching picture. After completing a response, the participant was able to push a button to advance immediately to the next stimulus if desired. Most participants found it unnecessary to proceed more rapidly. Between each cue, an inter-trial interval of 0.5 seconds displayed a medium gray fixation cross in the center of the screen. Each participant response was recorded verbatim on a response sheet that replicated the photo cues being displayed to ensure accurate pairing of responses with the photo cue.

ERP Recording

During the experimental phase, continuous electroencephalograms (EEGs) were recorded from 38 sintered Ag/AgCl electrodes. Electrodes were embedded on a Neuroscan Quick-Cap (Compumedics USA, Charlotte, NC) consistent with the International 10-20 system and situated over the midline central site at the center of the scalp. Bipolar ocular activity was recorded from the supra-orbital and infra-orbital areas above and below the left eye (VEOG) and the left and right canthi (HEOG) on the outside of the right and left eyes. Electrode impedances were reduced to 5 kOhms or less. The activity at a single electrode, placed on the bridge of the nose near the tip and isolated from most brain activity, was used as the reference channel and subtracted from all other channels. The signal was digitized in 32-bit acquisition by a Neuroscan NuAmps amplifier from DC to 300 Hz at a rate of 500 points per second. No notch filter was applied. Offline, the data was band-pass filtered from .01–30 Hz and visually inspected. Channels experiencing poor performance and sections displaying extensive artifact were manually rejected. EEG data was then sectioned into 1200-ms, stimulus-locked epochs, from -200 ms before the stimulus to 1000 ms after, each having 601 samples. A spline fit was applied to allow analyses in the frequency domain. After baseline correction, all epochs were automatically rejected if voltage amplitudes exceed +/- 70 µV. A sample of accepted trials was confirmed not to contain significant eye artifact, and rejected trials were verified as containing an inappropriate level of eye artifact. No artifact reduction was used. Individual averages of epochs were formed for each experimental condition by participant. Participants amassing fewer than 200 accepted trials (~ 50 per condition) for were rejected. Grand averages were then computed overall for each condition using all accepted participant data.

Procedure

The current study was reviewed thoroughly by the university's Institutional Review Board (IRB) and approved with some recommendations. Due to the negative content in the photos used, the IRB required some alterations to the design. Among these was the exclusion of any participants experiencing current suicidal ideation. Such results were to be discussed immediately with the participants by the author, an advanced doctoral student in clinical psychology. Information on free counseling services available on campus was provided and the participant was accompanied to the on-campus counseling center if desired. Although three subjects were excluded from further participation due to suicidal ideation, none requested an escort to the counseling center or indicated active suicidal ideation. Another requirement of the IRB was to provide participants with credit completed through pretesting rather than provide all credit at one time upon study completion.

Participants were recruited from the psychology department participant pool and received research credit to meet departmental requirements. All researchers were provided and used a detailed script (see Appendix A) describing the study to ensure consistency in study presentation across researchers. Participants initially registered for participation in a group pretesting appointment, which began with a detailed disclosure of risks to participation. Risks included a negative reaction to introspection or from assessment of depressive symptomatology, lowering of self-confidence if participant had difficulty completing tasks, and cognitive and/or emotional fatigue due to testing. Because the current study included pictures with negative emotional material, there was also a slightly increased risk for a negative reaction to these materials. Consequently, the precautions described above were taken to avoid any negative result from the use of negatively-themed stimuli. However, the severity of the negative content was no worse than images shown on the evening news. Such risks are common to psychological research, and any negative occurrences led to immediate referral to the counseling center, including accompaniment to the counseling center if desired. The consent procedure took approximately 10 minutes.

If participants provided consent, they were assigned a number and administered a pretest packet. Measures were organized into two packets and administered in a consistent sequence for all participants. The pretest packet was composed of a biographical information form, the EHI-R, the BDI-SF, the FFMQ, the WBSI, and the PSS. Each measure was explained to the participant separately to promote attention to the task, and each response form was reviewed with the participant to ensure that it was completed in good faith and to identify any unintentionally skipped items or errors. Each participant was met with privately to review their responses and schedule their timeslot for the primary session. At this time and thus before exposure to negative stimuli, scores on the BDI-SF item assessing suicidal ideation were reviewed and appropriate referrals were made to the counseling center if suicidal ideation had been endorsed. Participants endorsing this item were exempted from further participation with full research credit. Other participants received credit for the time they invested with additional credit available upon completion of the primary session. Pretesting time varied from 20-45 minutes.

Despite requiring another visit, the majority of participants returned for the second and primary testing session. Upon arrival, they were reminded again of the study risks and verbal consent was obtained to continue. Participants then completed a short information form asking about their sleep, diet, vision, and medicine usage for the previous 24 hours, the RRS, and the MAAS. If participants had not eaten for a number of hours, they were provided a short break and invited to have a snack. If they did not have one or could not obtain one, a small snack was provided for them. Most participants were provided with a soft drink from a nearby vending machine. After a brief break, participants were seated at the testing computer, and their distance from the screen was measured to ensure they were approximately 60 cm away, following recommendations for the ANT. Once comfortable, the computer-administered tasks were started.

Instructions for the first task, a short measure of attention known as the ANT, were presented on the screen, and participants were given an opportunity to discuss these instructions before starting. The ANT has a 2-minute practice and 5–7-minute testing period. Most participants completed the task in less than 15 minutes. After completion, the SSPAN task, a short measure of working memory span, was begun, and again, participants were given the opportunity to ask questions about the task, which took approximately 20 minutes including questions.

After completion of the ANT and SSPAN tasks and a short break but prior to starting the final cognitive task, participants were fitted with a 40-channel electrode cap. Five points on the scalp and face were swabbed with alcohol, and then cleaned with a slight facial abrasive and a sterile cotton swab. To these spots, a small amount of water-soluble, hypoallergenic, electro-conductive gel was applied to improve conductance between the skin and five electrodes that were taped (with standard medical tape) to sites on the head. The remaining electrodes in the cap also received conductive gel to complete the preparation of the subject. This procedure took around 30 minutes per participant. Approximately 10 minutes into the cap application, the participant began the cognitive task.

The computer-administered task was presented using E-Prime stimulus software (Version 1.1-SP3, Psychology Software Tools, Inc., Pittsburgh, PA) on a Dell Optiplex GX280 desktop computer connected to a 17-inch, flat-screen Dell monitor. The participant was seated comfortably in a lighted room approximately 60 cm from the screen. The initial training block of the T/NT task took approximately 45 minutes, during which time, research assistants completed cap application by ensuring that all electrodes were recording at low impedances (< 5 kOhms). The experimental portion of the task took approximately 50 minutes, during which time the participant regarded cue images and attempted to recall or avoid recalling the paired image. Continous EEG recordings were saved throughout the experimental portion of the test. Unless the participant expressed discomfort or requested a break, the QuikCap remained on the participant during the final recall portion of the experiment, when participants described recalled images when provided with a face cue. The recall phase took approximately 15 minutes. Participants produced a recall score for each of 80 stimuli, ranging from 0–80. Recall data was scored 1 for a correct trial or 0 for an incorrect trial or no response. Upon completion of the T/NT task, the cap was removed, and the participant was provided materials to assist in cleaning off electrode gel, if desired. During this time, debriefing occurred, and any participant questions were answered. The total primary testing session duration ran 2.5 hours, including breaks.

CHAPTER 6: RESULTS

Data Preparation and Preliminary Analyses

Demographic Analysis

Participant characteristics for the 35 participants included in this study are presented in Table 1. The participants were evenly male (*n* = 18; 51%) and female (*n* = 17; 49%), χ^2 (1, *N* = 35) = 0.03, *p* = 0.866, φ = .03); aged 18–45 years old (*M* = 23.8 yrs; *SD* = 6.14); and racially representative of the student body and mostly freshman. Most (77%) fell in the age range between 18–25 yrs, while 5 (14%) were in their 30s and 1 (3%) in his/her 40s. The students were White (*n* = 23; 66%), Black (*n* = 6; 17%), Latino/a (*n* = 2; 6%), and Asian American (*n* = 4; 11%). In addition, the largest number of participants were Freshman (*n* = 12, 35%), followed by Juniors (*n* = 8; 24%), Sophomores (*n* = 7, 21%), Seniors (*n* = 6; 18%), and Post-baccalaureate students (*n* = 1; 3%). Students did not vary significantly across years, χ2 (4, *N* = 35) = 4.02, *p* = .404, φ = .34).

By self-report, all participants claimed to be right-hand dominant. LQ scores generated from responses on the EHI-R indicated that only one participant endorsed mixed handedness (LQ = 75), which did not meet the exclusion criteria of an LQ < +70. All other participants (97%) had an LQ = 100, achieving a mean of 99.3 (*SD* = 4.23). Thus, no participants were excluded for mixed handedness.

All participants were native speakers of English and denied a history of seizures or any medical condition that might affect their performance. Three (9%) reported taking medication that could potentially affect their performance (e.g., antidepressants, antipsychotics, stimulants, and allergy medicine), but no obvious performance effects were noted in their scores. Of 11 participants (31%) who reported needing glasses to read text on a computer screen, 8 (23%) wore contacts and 3 (9%) wore glasses for the duration of the study.

Debriefing Questionnaire Data

A qualitative review of questions posed on the debriefing questionnaire provided useful information about participant performance on the cognitive control aspects of the T/NT. However, no participants were excluded based on their responses. Participants endorsed two distinct types of strategies to remember pairings, sometimes using both at the same time. One strategy was to associate features of the photo cue with the image itself. A second strategy was to create a story that integrated the cue photo person into a story that explained the image shown to the participant. Although not quantitative, anecdotal reports suggest that the use of the second strategy produced more robust memory for the paired stimuli. Similarly, suppression strategies included a range of techniques. Participants generally endorsed a variation on a substitution strategy, such as thinking about a new thought or remembering just a simple detail of the cue. However, some endorsed self-distraction by, for example, singing a song to themselves while others endorsed direct suppression attempts. Participants generally stated that they found it somewhat more difficult to suppress negative images than neutral images, although some reported an opposite pattern. Participants reported some mild discomfort and fatigue as distracting during the task, but denied any major problems. Using a five-point Likert-type scale from 1 (really well) to 5 (really poorly), most participants endorsed doing well on the task (M = 2.54, SD = 0.76). No participants endorsed very poor effort, and none were excluded on the basis of this item. Finally, students endorsed varying levels of exposure to mindfulness or meditation training, but none endorsed competence, regular practice, or advanced exposure to mindfulness techniques.

Data Preparation

Scales were computed according to published procedures for each test. All data were entered into a database using SPSS for Windows (Release 16, Chicago, IL: SPSS Inc). Resulting data were the following.

- Mindfulness: MAAS (mean score for all items) and FFMQ (total scores for each subscale: observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience);
- Control over Intrusive Thoughts: WBSI (total score) and RRS (total and subscale scores for brooding and reflection);
- Attention/Working Memory: ANT (alerting, orienting, and conflict scores) and SSPAN (scores representing absolute span performance, accuracy score, and total symmetry errors, which sums errors on duration and accuracy).
- Clinically Relevant Measures: Depressive symptoms and perceived stress level were assessed using BDI-SF (total score) and PSS (total score).

Descriptive Analysis of Self-Report Psychometric Measures

Preliminary analyses reviewed the descriptive information for psychometric measures administered (see Table 2 for descriptive information and correlations).

Mindfulness

On the MAAS, a measure of dispositional mindfulness or one's awareness in day-to-day life (possible range: 1–6), participants tended to endorse the presence of traits related to poor mindfulness as occurring "somewhat infrequently" with an average score (M = 4.08, SD = 0.78). These scores did not differ significantly from the scores obtained in the pilot study (N = 24, Mdn = 4.13, M = 4.06, SD = 0.68), $t(57) = 0.26$, $p = .797$, 95% CI[-0.44, 0.37].

On the FFMQ, a measure assessing mindfulness-related attributes, participants scored in roughly the same pattern on all scales. They were most likely to endorse items related to their daily experience of mindfulness-related attributes in the positive direction of "sometimes true" to "often true" (possible range: 8–40). First, participants recorded a mean of 27.40 (SD = 5.11) on the FFMQ-Observe, a measure of their ability to engage in mindful observation. For the FFMQ-Describe, a measure of how well people are able to describe their environment, participants obtained a mean score of 27.23 (SD =5.42). On the FFMQ-Awareness, participants obtained a mean of 26.69 (SD = 5.99), suggesting that most participants were fairly ambivalent about their tendency to notice things going on around them. On the FFMQ-Nonjudging factor, participants obtained a mean score of 29.37 (SD = 6.96), suggesting a tendency away from evaluating their inner experience. On the final factor FFMQ-Nonreact (with a smaller range from 7-35), participants obtained a score of 23.20 (*SD* = 3.43), suggesting they tend slightly towards endorsing a more reflective posture about themselves.

Control over intrusive thoughts

On the RRS, a measure that identifies and quantifies ruminative style (possible range: 22-88), participants endorsed symptoms of rumination averaging between responses of "Never" and "Sometimes" (*M* = 39.00, *SD* = 9.90). On two important 5-item subscales (range: 5-20), participants endorsed experiencing somewhat more brooding or depressive rumination (*M* = 9.17, *SD* = 2.56) than the more positive reflection (*M* = 8.54, *SD* = 3.24).

On the WBSI (possible range: 15–75), a measure of attempts to control negative intrusive thoughts, participants endorsed total scores suggesting that they feel fairly unsure or neutral about their experience with intrusive thoughts (*M* = 47.03, *SD* = 10.93).

Clinically relevant measures

Results of the BDI-SF (possible range: 0–39) indicated that most participants were experiencing few symptoms of depression (*M* = 3.66, *SD* = 3.35). Using established cutoffs designed to screen for and assist in diagnosing depression to describe this sample (Furlanetto, Mendlowicz, & Bueno, 2005), only 1 participant (3%) exceeded the diagnostic cutoff with a 14. Three other participants (10%) placed just below the screening cutoffs with scores of 9. Of those excused from participation for endorsing some suicidal ideation on Item I, two met diagnostic cutoffs and the third scored a 13. Despite the use of the suicide item to exclude some participants, it is not without precedent to continue to use the measure in later analyses (e.g., Hertel & Mahan, 2008).

However, it should be noted that no participants were excluded due to their total scores and that a range of total scores was still obtained (0-14).

On the PSS, a subjective assessment of stress experienced in the last month (possible range: 0–40), participants endorsed relatively low levels of stress (*M* = 17.17, *SD* = 7.82), suggesting that, in general, they experienced given stressors from “Almost Never” to “Sometimes.”

Descriptive Data on Cognitive Measures

Working memory

Preliminary analyses reviewed the descriptive information for cognitive measures administered (see Table 3 for complete data). Mean performance for the total score correct was 26.37 (*SD* = 8.89), and the range was from 5–42, nearly the entire possible range. On absolute score correct, a sum of the sizes of entire sets successfully recalled, participants obtained a mean score of 16.46 (*SD* = 8.61), with the scores covering the entire possible range of positive scores (0–42). These scores suggest that, for example, the average participant may have successfully remembered 2 sets of the 2 red-box sequences, all 3 sets of the 3 red-box sequences, and 1 set of the 4 red-box sequences for an absolute score of 17 while the lowest performing participant did not successfully recall any complete sets. However, participants made few errors on the symmetry task (*M* = 3.14, *SD* = 3.77), with few speed errors (*M* = 0.11, *SD* = 0.40) and several accuracy errors on average (*M* = 3.03, *SD* = 3.74).

Attention

On the ANT, which provides mean of median RT difference scores where higher scores indicate worse performance on each of three related, anatomically-derived attention networks, participants obtained the following scores. For the Alerting network, a measure of participant failure to use cueing well, the mean score was 19.90 ms (*SD* = 26.93). This score suggests that participants responded approximately 20 ms slower to a stimulus when not cued to its presentation, which was considerably better (*Z* = -1.51) than the normative sample reported by Fan et al. (2002). (Note that a negative *Z* score represents lower error scores and, thus, better performance.) For the Orienting network, participants obtained a mean score of 45.66 (*SD* = 46.77). Thus, participants responded approximately 46 ms slower to a stimulus when not cued spatially to its future location. This score was slightly better (*Z* = -0.25) than the normative sample (Fan et al.). For the Conflict network assessing cognitive control, participants obtained a mean score of 105.51 (*SD* = 36.97). This score indicates that participants had somewhat more difficulty (*Z* = 0.86) than the normative sample at resolving cognitive conflicts produced by incongruent trials.

Intercorrelation of cognitive measures

Cognitive measures were analyzed for expected correlated activity (see Table 3). Within scales, the ANT network scores showed significant intercorrelation. The largest relationship was a negative correlation between Conflict and Orienting, while Conflict also had a large positive relationship with Alerting. Orienting and Alerting were also negatively related, indicating that these networks must be interrelated.

SSPAN Absolute and Total scores were significantly related and both were negatively related to symmetry errors. The symmetry errors score is composed of errors from both speed and accuracy. Speed errors were not significant related to any other SSPAN measure.

Between measures, several significant correlations were identified. The ANT Conflict scale produced a significant negative relationships with SSPAN Total score, r = -.34, p = .05, r^2 = .12, and a large positive correlation with SSPAN symmetry errors, r = .64, p < .001, r^2 = .40. These relationships suggest that higher ANT Conflict scores, which represent more difficulty at resolving conflicting inputs using cognitive control, are linked to worse maintenance of a memory item while performing another task and more errors on that task. The only other significant relationship was a negative correlation between the Orienting network and Symmetry errors.

Primary Analyses

Type I Error Caution

The analyses in the following sections include a family of repeated-measures ANOVAs and correlational analyses. No attempt was made to adjust α to control for familywise error rate or experimentwise error rate in these groups of analyses. The decision was made to prioritize identifying relationships for future research over reducing the possibility of spurious findings. However, these results should be taken with some caution, particularly those with significant effects that approach α = .05.

Hypothesis 1

Recall scores were hypothesized to show main effects for strategy (think > no-think) and valence (neutral > negative). An interaction was anticipated in which the effect of strategy was greater in the neutral condition than the negative condition.

Data preparation

Recall responses (2-5 word descriptions) obtained during the T/NT task were scored for accuracy by two raters, and all disagreements were adjudicated by a third judge. The author served as the first rater and was blind to the condition each picture was in for a particular participant (i.e., think vs. no-think) but not to hypotheses. A second rater was naïve to all stimuli, the hypotheses being tested, and the manipulation of recall strategy or picture valence in the study. Initial inter-rater agreement was 98% across all trials (*N* = 3,120) for all subjects scored (*N* = 39) and 96% across all valid responses (*N* = 1,954). A 3rd rater blind to the strategy condition of each picture was used to adjudicate the small number (*n* = 73) of conflicting ratings. Total percent-correct free recall across all conditions and subjects was 51.36% (*SD* = 18.04). Percent recall scores for the experimental conditions, 2 Strategy x 2 Valence design, were baseline-corrected as recommended by Anderson and Green (2001) and Depue et al. (2006). The baseline correction procedure subtracts off each participant's percent-recall for items learned during training but not included in the T/NT task. Unlike Depue et al. (2006), recall of baseline items in the negative condition (*M* = 38.9%; *SD* = 24.6%) did not differ significantly from recall of baseline items in the neutral condition (*M* = 39.3%; *SD* = 25.9%), *t*(34) = -.10, *p* = .918, 95% CI[-7.38, 6.67]. Consequently, an overall mean baseline recall score was used instead of separate scores for negative and neutral items. The overall mean baseline recall was 39.1% (*SD* = 23.11). Continued learning due to retrieval practice would result in positive means for think condition pairs due to higher recall than baseline. Conversely, negative means for no-think condition pairs would indicate successful memory retrieval at a lower rate than baseline. Anderson and Green (2001) have argued that negative scores represent a memory suppression effect due to repeated interruption of the retrieval process for pictures in the no-think condition.

To identify predicted patterns of recall, baseline-corrected recall scores were prepared as reported above and entered into a 2 Strategy (think vs. no-think) x 2 Valence (negative vs. neutral) repeated-measures ANOVA. The main effect for strategy showed that the think condition produced significantly higher recall (*M* = 23.7%, *SD* = 13.2%) than the no-think condition (*M* = 7.0%, *SD* = 12.0%), $F(1, 34) = 64.11$, $p < .001$, $\eta_p^2 = .65$. The main effect for valence indicated that significantly more neutral items were recalled (*M* = 18.4%, *SD* = 12.1%) than negative items (*M* = 12.2%, *SD* = 12.8%), $F(1, 34) = 9.70$, $p = .004$, $\eta_p^2 = .22$. The interaction of Strategy x Valence, however, failed to reach statistical significance, $F(1, 34) = 3.02$, $p = .091$, $\eta_p^2 = .08$, observed power = .39. These main effects for the strategy and valence are consistent with prior research using these stimuli in the T/NT task (Depue et al., 2006) and two master's theses in our lab (Dykstra, 2009; Nair, 2008). However, the interaction found in Depue et al. (2006) failed to emerge. A review of means indicated that think items had a higher mean percent-correct than no-think items for both negative, $t(34) = 4.37$, $p < .001$, 95% CI[6.98, 19.1], and neutral items, $t(34) = 6.91$, $p < .001$, 95% CI[14.4, 26.3]. The interaction term above, then, represented a non-significant trend for the think advantage to be greater (*M* = +20.4%) for neutral items than for negative items (*M* = +13.0 %). This pattern of a greater strategy effect for neutral than for negative items conflicts with the results of Depue et al. (2006) using these same stimuli, who found the effect of strategy significantly greater in negative items rather than neutral items. In addition, post-hoc analyses of each of the 4 baseline-corrected means indicated that all means were significantly greater than 0 (all *p*s < .026 for one-sample t-tests). Thus, these data again failed to produce significant below baseline forgetting as reported in Anderson and Green

(2001) and Depue et al. (2006; 2007). However, it is consistent with two previous studies completed in the same lab as the present dissertation project that also failed to find a significant memory suppression effect (Dykstra, 2010; Nair, 2008).

Hypothesis 2

ERP data was expected to conform to standard topography, with only experiment-related variation. ERP data was prepared and then analyzed for ERP-related hypotheses reviewed below.

Overview of Standard Visual ERPs

As we expected, the ERP waveforms observed in response to visual presentation of face cues conformed to standard waveform topography. The typical visual perception waveform, as described by Luck (2005), is observed across a variety of tasks and is composed of a sequence of positive (P) and negative (N) components that appear in a predictable order: C1, P1, N1, P2, N2, P3 (sometimes called the P300), and others, such as the N400. C1, the first deflection (i.e., large change in amplitude), occurs at approximately 50 ms post-stimulus presentation, may be either positive or negative depending on the location of the visual object, and is most pronounced at occipital and parietal sites (see Figure 1 for negative C1s at P3 and P4 sites). Following C1 is a succession of peaks in the 100-300 ms range that reflect sensory responses to visual stimuli, often termed exogenous components for this reason and referred to as visual evoked potentials (Luck, 2005). The waveforms presented in Figure 1 depict typical ERP patterns for a visual task and the peaks P1, N1, P2, N2, and P3 are visible on the posterior waveform. Frontocentral ERP waveforms presented in Figure 2, however, show an expected variation in component sequence in that only N1, P2, N2, and P3 are visible (see “100–200 ms period . . .” for explanation). The early P1–N2 components are reliably linked to a number of aspects of attention and cognitive control processing (Luck, Woodman, & Vogel, 2000). Following N2, the P3 component with an onset around 300 ms at anterior and posterior sites is generally considered the first endogenous component in that it represents internally generated cognitive activity linked to categorization processes (Luck, 2005). Following the P3, several prolonged effects can be identified. Bergstrom et al. (2007) identified a late, left-sided positivity from ~500-800 ms known as the Explicit Memory effect or Late Positive Component that has been linked to successful conscious recollection. Similarly, Schupp et al. (2000) describe a Late Parietal Positivity (LPP), which is related to affective categorization tasks and maximal over right or central parietal areas.

ERP Data Preparation

Using the same basic procedure as other similar studies (e.g., Bergstrom et al., 2007; Dykstra, 2010; Nair, 2008), electrophysiological recordings were reviewed, filtered, segmented and averaged for each participant, producing a waveform for each electrode for each experimental condition of the 2 Strategy x 2 Valence design (see Method for more detail). Previous research identified four electrodes as indicators of lateralized (left and right, respectively) frontal activity (F3 & F4) and parietal activity (P3 & P4). See Figure 12 for diagram of electrode locations. In a departure from previous studies, the decision was made to use frontocentral electrodes FC3 and FC4 in place of F3 and F4. This was determined as the best method of addressing significant perspiration-related electrode artifact occurring at F3 and F4 for a small number of participants. The F# and FC# electrodes are spatially quite proximal (~ 1 inch more posterior), and this change in electrode site is not expected to produce any change in the resulting ERP data.

Using a standard procedure for identifying ERP topography (Luck, 2005), grand average waveforms were visually reviewed for each condition to identify the onset and offset of alternating peaks and troughs representing separate neural ERP components. Data generated from ERP waveforms is an area measure representing the space between the curve and the origin within the time window specified. No attempt was made to balance variation in component latency between anterior and posterior window sites. Area-under-the-curve values were computed separately for each experimental condition (i.e., 2 Strategy x 2 Valence) at each window (anterior vs. posterior) for two electrode sites (left vs. right of midline). Anterior windows used FC3 and FC4 and posterior sites used P3 and P4. Previous research identified F3/F4 and P3/P4 as desirable choices due to their position directly over frontal and parietal sites, respectively, regions of interest in this paradigm (Bergstrom et al., 2009; Dykstra, 2010; Nair, 2008). In place of F3/F4, this study opted to use the electrodes in the row immediately behind, FC3/FC4, because of notably cleaner recordings and the low likelihood of differential effects between these adjacent electrodes. Analyses entered ERP area-under-the-curve values at each window in a 2 Strategy x 2 Valence x 2 Laterality repeated-measures ANOVA. Scores were used from either the 2 anterior (FC3 & FC4) or 2 posterior (P3 & P4) electrodes.

Hypotheses

At exogenous components (i.e., P1, N1, P2, N2), I expected activity at each component to follow a basic pattern where early activity was primarily related to visual processing of stimulus features while later activity demonstrated automatic task- and emotion-related aspects of the stimuli. Finally, endogenous late components should demonstrate conscious integration of task aspects consistent with successful performance of the T/NT task. In addition, I expected to replicate the finding by Nair (2008) that posterior activity at the earliest components, P1 and N1, was associated with control processes involved in retrieval versus inhibited retrieval strategies on the T/NT task and the differential emotional valence of the target pictures (i.e., negative vs. neutral).While P1 and N1 are primarily concerned with processing attributes of visual stimuli, P2 and N2 components should be modulated at both the frontal and posterior sites, consistent with control processes associated with attention and the onset of memory retrieval (Anderson et al., 2004; Depue et al., 2007; Nair, 2008). Based on previous results reported by Nair (2008), I expected to find evidence for the involvement of emotion- and retrieval-strategy-based neural networks that can operate independently in some time windows (i.e., main effects of strategy and/or valence in the absence of interaction). As these inputs were integrated through cognitive processes, I expected a later emergence of interactive Strategy x Valence effects. Finally, I expected to find a long duration parietal laterality effect that represents successful recall (Bergstrom et al., 2007; Schupp e al., 2000).

P1 and N1 Peaks: 100–200 ms Period Peaks at Posterior Electrodes

Waveform patterns at P1. Early ERP components indicated successful processing of the visual features of the face-cue stimuli. As can be seen in Figure 3, there are P1 and N1 positive and negative peaks, respectively, in the 100-200 ms time window at P3/P4 (left/right parietal sites; see Figure 12 for a diagram of electrode site placement). There are also anterior P1 and N1 deflections barely discernable on Figure 2. The anterior P1 is actually negative-going and represents only the negative pole of visual responses present in posterior occipital areas, reflecting the fact that frontal control of posterior visual processing does not appear until later in the time-course of perceptual processing. Consequently, it is only a small amplitude shift that overlaps significantly with the subsequent N1 component, which is also very small in amplitude. The small size and overlapping nature of these components rendered them inaccessible to analysis.

Posterior P1 (125–164 ms). A 2 Strategy x 2 Valence x 2 Laterality ANOVA was used to analyze the posterior P1 ERP areas in the 125-164 ms time window (see Table 4). There was a significant Strategy x Valence interaction, $F(1, 34) = 6.08$, $p = .019$, $\eta p2 = .15$, in which the P1 amplitude is greater for negative ($M = 149.26$, $SEM = 17.87$) than for neutral images ($M = 135.31$, $SEM = 18.32$) on think trials but greater for neutral ($M = 145.39$, $SEM = 16.73$) than negative items ($M = 128.40$, $SEM = 18.11$) on the no-think trials (see Figure 13). There is also a significant Strategy x Valence x Laterality interaction, $F(1, 34) = 8.57$, $p = .006$, $\eta p2 = .20$, where the previously described Strategy x Valence interaction is stronger at the left (P3) than the right (P4) parietal sites. This pattern suggests automatic processing of stimulus characteristics that appears to favor neutral stimuli over negative stimuli when encoding no-think stimuli but, when encoding think stimuli, appears to favor neutral over negative stimuli.

Posterior N1 (165–204 ms). The same ANOVA was conducted for the N1 negative peaks in the 165-204 ms time window (see Table 4). There was a significant main effect for strategy, $F(1, 34) = 7.74$, $p = .009$, $\eta p2 = .19$, with think trials ($M = 107.79$, $SEM = 21.06$) yielding a more negative N1 peak than no-think trials ($M = 124.56$, $SEM = 20.97$). Luck (2005) indicates that the N1 is an exogenous component that varies based on attributes of the stimuli being perceived and can respond greater in occipital areas to discrimination tasks. This suggests that even at 165 ms, participants were already correctly allocating more attentional resources to think stimuli than no-think stimuli.

P2 and N2 Peaks: 175-325 ms Period at Anterior and Posterior (P3 & P4) Sites

Anterior P2 (170–249 ms). Later exogenous components exhibited activity related to cognitive processing of the T/NT stimuli (see Table 4). Because of the higher resolution and more defined topography at posterior sites, the anterior P2 ERP peak starts sooner at the frontal (FC3 & FC4) sites. The overall time period of the anterior P2 and N2 analyses overlap by 30 ms with the preceding N1. The P2 component, an attention-modulated measure of higher-order perceptual processing, is usually maximal over frontal regions. Areas of the P2 peak at the frontal (FC3 & FC4) sites were submitted to a 2 Strategy x 2 Valence x 2 Laterality ANOVA for the 170-249 ms time window. The analysis yielded only a significant main effect for strategy, $F(1, 34) = 4.40$, $p = .043$, $\eta p2 = .12$, where the mean P2 component was larger for think ($M = 143.47$, $SEM = 31.77$) than for no-think trials ($M = 125.16$, $SEM = 32.04$).

Posterior P2 (205–254 ms). A similar ANOVA was conducted for areas under the P2 peak at the posterior (P3 & P4) sites in the 205-254 ms time window (see Table 4). There were no significant effects in the analysis of areas for the P2 waveform at the posterior electrode sites. According to Luck (2005), the P2 component is a primarily frontal component that is sometimes larger for target stimuli when the stimuli are easily distinguishable or infrequent, which represents the influence of attention on higher-order perceptual processing. Thus, the main effect for strategy at frontal sites suggests that the colored border identifying think and no-think items was likely prominent during this period and appears sufficient for rapid discrimination between conditions.

Anterior N2 (250–324 ms). Areas for the N2 at the frontal (FC3 & FC4) electrode sites in the 250-324 ms time window yielded a different pattern than posterior sites (see Table 4). Anterior electrodes produced only a significant Valence x Strategy interaction, $F(1, 34) = 4.54$, $p = .040$, $\eta p2 = .12$, for which the negative condition produced an inhibition effect where no-think trials ($M = -8.89$, $SEM = 33.47$) had a more negative-going peak than think trials ($M = 21.72$, $SEM = 33.01$). See Figure 14. However, for neutral stimuli, the pattern was reversed such that no-think stimuli ($M = 14.94$, $SEM = 34.87$) showed only a small deflection while the think/neutral ($M = -11.69$, $SEM = 35.75$) showed a large, unexpected negative deflection.

Posterior N2 (255–324 ms). For posterior windows, a main effect emerged for strategy and a significant interaction was identified for Strategy x Valence (see Table 4). A review of these means indicated that think items ($M = 192.53$, $SEM = 30.35$) produced significantly lower negative deflection than no-think items ($M = 240.57$, $SEM = 27.85$), $F(1, 34) = 13.67$, $p = .001$, $\eta p2 = .29$. In the interaction, this negative deflection for strategy was larger for neutral items, think ($M = 176.58$, $SD = 32.68$) > no-think ($M = 254.18$, $SD = 31.77$) than for negative items, think ($M = 208.47$, $SD = 30.26$) > no-think ($M = 226.95$, $SD = 26.71$), $F(1, 34) = 4.43$, $p = .043$, $\eta p2 = .12$; see Figure 15). These results are consistent with two subcomponents of the N2 described by Luck (2005) that have been linked specifically with go/no-go behavioral tasks, a similar experimental paradigm to the T/NT task that has participants respond behaviorally instead of cognitively. Thus, the N2 represents a transitory component from exogenous or evoked potentials to endogenous components that are related to cognitive control processes, in this case responsible for inhibition. These results are congruent with a characteristic caudality effect for N2 components where anterior regions are involved primarily in inhibition (termed N2b component) and posterior regions respond more to visual discrimination of target stimuli (the N2c component). Thus, the emergence of valence effects in both N2 peaks suggest that cognitive control processes related to emotional content have already been invoked. Notably, the presence of the posterior N2c component is often linked with the appearance of a significant P3 component across the entire scalp.

P3 Peaks: 300-600 ms Period

Anterior P3 (325–449). Data from the P3 components indicated evidence for significant activity related to conscious control processes (see Table 4). Anterior ERP activity from 325-449 milliseconds showed a positive component that peaked between 350–400 ms and resulted in significant main effects for strategy and laterality, but no significant interactions. The patterns of marginal means indicated that think items (M = 284.39, SEM = 66.59) generated a larger positive deflection than no-think items (M = 219.77, SEM = 61.88), F(1, 34) = 6.04, p = .019, ηp2 = .15. Similarly, FC4 (M = 268.13, SEM = 64.86) produced a larger P3 than FC3 (M = 236.04, SEM = 62.88), F(1, 34) = 11.46, p = .002, ηp2 = .25.

Posterior early P3 (325–389 ms). At posterior sites, a P3 waveform was identified with two peaks, the first occurring between 325–374 ms and the second occurring between 400–449 ms (see Table 4). Visual inspection of the waveforms suggested that qualitatively different patterns of brain activity were occurring in the two peaks, so analyses addressed them separately. The results for the first posterior P3 peak produced significant main effects for valence and laterality, and a nonsignificant trend towards a three-way interaction between Strategy x Valence x Laterality (*p* = .051). The main effects for valence and laterality showed a greater positive deflection for negative items (M = 299.13, SEM = 30.73) than neutral items (M = 273.67 , SEM = 31.37), F(1, 34) = 5.29, p = .028, ηp2 = .14, and the emergence of a trend for greater positive deflection in the right-sided electrodes FC4 & P4 (M = 305.54, SEM = 32.42), than the left-sided electrodes FC3 & P3 (M = 267.26, SEM = 30.06), F(1, 34) = 8.40, p = .007, ηp2 = .20. A review of the means suggest that valence differences in the no-think condition showed a contrasting pattern at P4 (negative < neutral) when compared to P3 (negative > neutral).

Posterior main P3 (390–474 ms). The results for the second posterior peak also produced significant main effects for strategy and laterality, but no interactions (see Table 4). The effect of strategy showed greater positive deflection for think items (M = 418.13, SEM = 43.24) than no-think items (M = 353.04, SEM = 37.99), F(1, 34) = 7.39, p = .010, ηp2 = .18. The laterality effect was a continuation of the pattern for right-sided parietal electrodes (M = 418.38, SEM = 43.89) to produce a larger positive peak than left-sided electrodes (M = 352.78, SEM = 36.03), F(1, 34) = 10.86, p = .002, ηp2 = .24.

The main effects for strategy, valence, and laterality appearing in frontal and/or parietal sites are congruent with information on the P3 provided by Luck (2005) that it tends to be larger on more complex tasks, especially when participants are expected to attend to and evaluate stimuli or when affective stimuli are manipulated by the participant. The P3 is considered the first fully endogenous ERP component in that it is the first component that is a measure of internally generated rather than externally evoked phenomena. As a result, the effects of strategy and valence suggest the appearance of brain activity directly related to the use of cognitive control on memory processes. Furthermore, the laterality effect is likely an early expression of a long-enduring, effortful component termed the late parietal positivity (LPP; Schupp et al., 2000), which appears on tasks that involve memorizing and recalling of correct responses.

Late ERP Effects

Anterior late ERP activity (450–824 ms). Late components revealed significant activity related to participant performance on the T/NT task (see Table 4). To further investigate the emergence of strategy, valence, and late positivity effects, analyses were completed on ERP data from 450–824 ms at anterior sites and 475-849 ms at posterior sites. Both anterior and posterior windows produced significant Strategy x Valence x Laterality interactions. Anterior sites also produced a main effect for laterality in which the right-sided FC4 electrode ($M = 854.66$, $SEM = 166.79$) showed significantly greater ERP positivity than the left-sided FC3 electrode ($M = 666.45$, $SEM = 163.29$), $F(1, 34) = 6.39$, $p = .016$, $\eta p2 = .16$. The 3-way interaction produced a pattern where the effect of strategy on negative items (think > no-think) was greater than on neutral items, and this pattern was more pronounced at FC4 than at FC3, $F(1, 34) = 4.98$, $p = .032$, $\eta p2 = .13$; see Figure 16).

Posterior late ERP activity (475–849). Posterior sites produced a large main effect for strategy where think items ($M = 1148.11$, $SEM = 139.44$) produced a larger ERP response than no-think items ($M = 728.10$, $SEM = 143.63$), $F(1, 34) = 20.38$, $p < .001$, $\eta p2 = .38$ (see Table 4). The significant 3-way interaction demonstrated a contrasting effect of valence on strategy at the P4 electrode where negative items showed a greater strategy effect (think > no-think) when compared to P3 electrode where neutral items showed a larger strategy difference (think > no-think), $F(1, 34) = 5.71$, $p = .023$, $\eta p2 = .14$; see Figure 17).

Together, these late windows provide strong evidence for the presence of a late potential representing a large P3 response to the cognitive task of selectively recalling or inhibiting recall of recently formed memory traces. Frontal sites in the late window show a significant amplitude difference favoring the right side, and anterior sites demonstrate a large strategy difference generated on the right side that was maintained for the duration of the window (see Figures 2 & 3).

Hypothesis 3

To identify important relationships between ERP activity, cognitive performance, and psychometric variables, correlation analyses were performed on recall scores and ERP variables from periods of interest (see Table 4). Cued recall test performance following the T/NT task and ERP data were anticipated to relate significantly with psychometric and cognitive variables theoretical or empirically related to cognitive control, including measures of mindfulness, control over ruminative thoughts, attention, working memory capacity, and depression/stress. From previous research by Nair (2008), ERP activity at parietal sites during P1 and N1 were expected to relate significantly with measures of cognitive control. Similarly, Nair (2008) identified the N2 components appearing late in the 200–300 ms window as important in the expression of emotional control processes. Consequently, significant correlations were anticipated for ERP effect variables generated for these windows.

Percent Recall Correlations

Relationships with memory recall were examined first. Recall scores were computed to represent total recall percent and general strategy and valence effects for each participant. This was done by taking mean percent-correct recall scores for all think trials for each individual and subtracting the mean percent-correct recall on all no-think trials for each individual to generate the strategy effect variable. Similarly, mean percent correct scores for all neutral items for each individual were subtracted from mean recall scores for all negative items for each individual to generate the valence effect variable. These variables were then entered with mean percent-correct recall scores for each condition of the 2 Strategy x 2 Valence design into a correlational analysis assessing their relatedness to mindfulness measures (MAAS and FFMQ), control of intrusive thought measures (RRS and WBSI), attention/working memory measures (SSPAN and ANT), and clinically relevant measures (BDI and PSS). Results are reported in Table 5. Aside from a significant negative relationship between the strategy variable and the FFMQ-Observe, $r = -.38$, $p = .023$, $r^2 = .15$, that indicated an inverse relationship between recall and paying attention to one's perceptions, thoughts, and feelings (perhaps identifying a trait related to internal distraction), a significant pattern of direct relationships emerged between two of the condition-related recall scores. Overall performance on a measure of working memory span was significantly related to recall performance on both negative but neither neutral recall conditions: Think/Negative, $r = .40$, $p = .018$, $r^2 = .16$, and No-Think/Negative, $r = .48$, $p = .004$, $r^2 = .23$. These relationships suggest that better performance at working memory is related to better recall of negative items, regardless of strategy condition.

Preparation of ERP Variables.

To investigate the hypothesized relationships between cognitive-control-related ERP activity and psychometric and cognitive measures, summary ERP variables were computed for early posterior components, P1 and N1, and for both anterior and posterior N2 components previously identified by Nair (2008). No laterality effects were considered so all variables were averaged across laterality. The variables were: a) a mean ERP score across all four 2 Strategy x 2 Valence conditions; b) an ERP strategy score which averaged think trials and subtracted the average of no-think trials; and c) an ERP valence scores that averaged all negative condition scores and subtracted neutral condition scores. These variables were entered into a correlation analysis with the other measures of interest listed above. Results are reported in Table 6.

Correlations for Posterior P1

Results for the three ERP variables at posterior P1 produced only two significant correlations. The strategy ERP variable was negatively correlated with the FFMQ-Nonjudging subscale, $r = -.35$, $p = .039$, $r^2 = .12$, and positively correlated with the RRS-Total score, $r = .35$, $p = .044$, $r^2 = .12$. This strategy-related activity occurring at the earliest time window analyzed suggest that traits related to increased self-judgment and higher rumination are positively related to higher ERP/brain activity in the think over the no-think difference.

Correlations for Posterior N1

Results for the three ERP variables at the posterior visual N1 component produced a significant direct correlation between the ERP strategy variable and the FFMQ-Observe, $r = .41$, $p = .016$, $r^2 = .17$. This relationship suggests that as a participant endorsed higher levels of attending to their sensations, perceptions, thoughts, and feelings, they produced a less negative shift (or weaker response) in ERP activity on think items when compared to no-think items.

Correlations for Posterior N2

Results for the three ERP variables at the posterior N2, a component chosen *a priori* as a window of particular interest, identified two significant relationships with the valence ERP variable: a negative correlation with the BDI-SF, $r = .53$, $p = .001$, $r^2 = .28$, and a positive correlation with the FFMQ-Describe, $r = .35$, $p = .041$, $r^2 = .12$. These are the first relationships identified with valence effects. The first correlation suggests that higher scores on a measure of depressive symptomatology are related to a significantly more negative difference for ERP activity on negative trials subtracting out neutral activity. Conversely, the relationship with the FFMQ-Describe, a measure of a participant's tendency to label/categorize their experiences, suggests that as their Describe scores increase, they produce a significantly smaller negative difference for ERP activity in negative trials minus neutral trials.

Correlations for Anterior N2

Results for the three ERP variables at the anterior N2 indicate a number of significant effects. Mirroring activity in posterior areas, FFMQ-Describe produced a significant positive relationship with the ERP valence variable, $r = .48$, $p = .004$, $r^2 = .23$. The presence of the same effect at anterior sites as posterior sites suggests a widespread valence-related control mechanism active at N2. Notably, the Total ERP activity variable resulted in a five significant relationships with measures related to effective cognitive control: the FFMQ-Aware, the WBSI, the MAAS mean score, SSPAN Total score, and the ANT Conflict network. The significant negative correlation with the FFMQ-Aware, a measure of how well a participant acts with awareness in his or her day-to-day life, r = -.40, p = .034, r^2 = .16, and the MAAS, a dispositional mindfulness measure, r = -.38, p = .025, r^2 = .14, suggest that as participants endorse higher levels of mental control, they produce significantly stronger negative ERP effects at N2. Similarly, a significant negative relationship emerged with an actual performance-related variable measuring working memory span, the SSPAN Total score, r = -.46, p = .006, r^2 = .21. The final two significant relationships were with the WBSI, a measure of failures at controlling negative intrusive thoughts, r = .34, p = .048, r^2 = .11, and with the ANT Conflict network, a performance-based assessment of an attention network related to executive function (where higher scores = worse performance), r = .39, p = .022, r^2 = .15. These relationships suggest that as scores on the measures increase, representing poorer cognitive control, ERP activity related to general recall memory also shows significantly weaker negative-going amplitudes. Together, the significant congruent correlations of these five variables theoretically and empirically related to cognitive control demonstrate strong evidence for the action of cognitive control processes at anterior N2.

DISCUSSION

Review and Rationale

The effective use of cognitive control on mental processes is a crucial skill needed in day-to-day life. The ability to selectively promote or inhibit specific cognitive events is required for normal function, and deficits in cognitive control can often lead to negative outcomes, from depression to absentmindedness. Mounting evidence suggests that control of cognitive events, including memories, uses the same neural network as control of behavioral responses (Anderson et al., 2004), leading some researchers to propose a unitary cognitive control network active across multiple domains (Anderson & Green, 2001). According to other researchers, this network likely functions using two processes (Gopher, 1996; Wegner et al., 1987), a rapid, automatic control process followed by a slower, effortful process that is able to counteract or sustain the first. Because it is effortful, it may respond poorly to a number of internal and external conditions, including individual difference in the functioning of executive control (Levy & Anderson, 2008) or fatigue from extended or intense usage (Muraven et al., 1998). One researcher has noted the presence of automatic patterns in cognitive control of memory that may underlie mood-congruent biases (e.g., the MCMB), which were also counteracted by invoking conscious, effortful processes (Hertel & Mahan, 2008). Another has suggested that rumination functions by automatically flagging a negative thought and then failing to reduce the thought using an effortful process (Wegner et al., 1987). Thus, this group of studies provides evidence for what appears to be a single, generic, two-component cognitive process for exerting control over multiple domains that is subject to failure, and such failures can lead to severe consequences.

One primary reflection of cognitive control performance is attention, as control processes are largely responsible for the effective directing of attention. While memory is known to be managed by cognitive control, the exact method is still unknown. Cowan (1999) and Engle (Reddick & Engle, 2006) have suggested a mechanism for cognitive control of memory through working memory. They proposed that working memory is the temporary direction of attention on long-term memory traces. If true, the cognitive control of attention and memory would be closely associated. However, this process is complicated by the inclusion of emotion. Recent research has suggested that emotional inputs function relatively separately from early cognitive control but can influence control processes. Depue et al. (2007) and Nair (2008) found evidence to support this early component, using the T/NT, ERP, photo images for stimuli, and negative and neutrally valenced stimuli to elicit emotion-related effects on cognitive control.

The study by Nair (2008), completed in the same lab as this dissertation and modeled on research by Depue et al. (2006) studied the effects of emotion on cognitive control using the T/NT task. This innovative cognitive task, related to the go/no-go task, renders accessible processes of selective facilitation or inhibition that are not available from more traditional tests of memory. Nair related ERP recordings during completion of the T/NT task to a measure of depressive rumination, a hypothesized sign of a breakdown in cognitive control. Nair’s results supported her hypothesis that rumination was related to emotion control processes found to be at work in a 200-300 ms window post-stimulus. Furthermore, she found early activity at P1 and N1 in posterior areas that was connected to better performance on the T/NT task and activity after 500 ms related to successful recall of memory. Building off this study, a pilot study was conducted by the author. Seeking to link cognitive control on the T/NT task with several variables related to successful or failed control (e.g., mindfulness, intrusive thoughts, rumination), the results indicated that low scores on a measure of dispositional mindfulness were able to identify participants that showed a deficit in the cognitive control of negative memories. As a result, the current study sought to extend these findings by adding ERP collection and analysis to the design in the hope of providing stronger evidence for the role of mindfulness and other variables in the cognitive control of emotional memories.

Summary of Main Results

The current study was designed to elicit and assess cognitive control of emotional memories on a cued recall task. Secondarily, it sought to identify neural activity recorded during completion of the T/NT task. Thirdly, it sought to associate neural activity and memory recall with clinical and cognitive measures hypothesized to influence or express cognitive control. Using this process, it was hoped that this study would provide new information about individual differences in cognitive control of emotional memory. As predicted, recall scores were greater for neutral vs. negative items and for items in the think vs. no-think condition that emphasized conscious facilitation of a memory trace. Unlike previous studies in other labs (Bergstrom et al., 2007; Depue et al., 2007) but consistent with a previous study in this lab (Nair, 2008), no interaction was found. However, given its low power (.39) to find a small effect ($\eta_p^2 = .08$), a larger *N* study may find the current pattern rise to the level of statistical significance, where strategy effects were greater in the neutral condition than the negative condition, as was found in the pilot study (Eyer, 2009).

Secondary analyses reviewed neural ERP recordings taken during the T/NT task for evidence of emotion-related cognitive control processes. Several ERP findings were especially noteworthy. At the posterior P1 component occurring at only 125-164 ms, significant variability in ERP activity was seen related to integrated stimulus characteristics that were both visible (i.e., strategy effects represented by colored borders) and associated (i.e., valence effects resulting from previous pairings with negative and neutral images) and appeared stronger on the left side. In addition, integrated valence effects did re-emerge at both anterior and posterior sites in the N2 component at 250–325 ms, although no stand-alone main effects for valence were identified in early components. Strategy-related effects were observed very early in the waveforms and continued until 800 ms. A late ERP component, starting at 300 ms in both anterior and posterior sites, represented a second period related to conscious cognitive control. Laterality effects also emerged around 300 ms indicating the presence of late parietal positivity (LPP) that was maximal over posterior sites and lateralized in this study to the right-side. It also included a significant, prolonged Strategy x Valence x Laterality interaction. Together, these effects suggest two distinct periods of cognitive control, one rapid and relatively automatic around 200 ms and one more effortful and enduring occurring around 300 ms, with both featuring integrated valence and strategy information.

Tertiary analyses explored general, strategy-, and valence-related ERP activity with psychometric and cognitive measures. A sequence of findings emerged at very early components, mostly associated with sensory perception, which show evidence of relationships to working memory and executive function. A significant pattern of relationships emerged at N2 strongly suggesting that the period from 200–300 ms, identified *a priori* as important, represents a period of active automatic cognitive control. Activity at posterior sites during this period, usually related to accurate recall of target stimuli, was associated in opposite directions with depressive rumination and a mindfulness-related trait. Furthermore, activity at anterior sites during N2, usually associated with inhibiting responses, was broadly correlated with measures that reflect individual differences in cognitive control, including self-reported mindfulness, working memory, failures at managing intrusive thoughts, and attention-related executive functioning. These correlations provide strong evidence that ERP activity at P1, N1, and P2/N2 represents the electrical signature of cognitive control processes.

Interpretation

The results of the current study provide intriguing information to elucidate the influences of emotion and attention on the cognitive control of memory. The study produced three significant findings: (a) evidence for a remarkably early stimulus response that carries information about valence and strategy at posterior P1; (b) timing evidence for the neural networks proposed in Depue et al. (2007) and Anderson et al. (2004); and (c) significant links between general brain activity at N2 and a number of cognitive control-related variables.

The first finding for an integrated cognitive response to stimuli at P1 is notable as this period is generally considered to only represent the parsing and recombination of visual stimuli. This effect suggests either the presence of a novel, nearly instantaneous endogenous influence on P1 or the pairing of the emotional content of the target stimulus directly onto the cue image. It is important to note that the cue images presented to the participants did not have any inherent emotional attributes. Rather, the valence effects are a result of memorized emotional content that was immediately accessed upon stimulus presentation before conscious awareness. Whether endogenous or paired, the emergence of an effect at this early period would seem to diverge from widely accepted views of early visual processing as one of stimulus attributes alone. Early valence effects were also found by Nair (2008), but no other evidence of such an early effect was found outside this lab. If validated, this effect suggests early perceptual processes may be capable of eliciting or recognizing more complex stimulus characteristics than previously thought.

The second primary finding in this study was the identification of periods of cognitive control that appear related to the neural networks proposed by Depue et al. (2007) and Anderson et al. (2004). Depue et al. proposed two networks, one occurring when first attempting to exert cognitive control on memories and another when that control begins working and memory retrieval is avoided. Consequently, these two networks may well overlap in their timing. Nevertheless, the emergence of a significant main effect for brain activity at P2 to be related to the strategy condition, followed immediately by the emergence of Strategy x Valence interactions at N2 provides reasonable overlap with the prefrontal connections that lead to greater frontal strategy effects, and according to Depue et al., integrated with valence effects proceeding from the amygdala. Thus, it appears likely, at least, that the neural networks identified by Depue and Anderson and colleagues commence their primary activity at N2.

The third primary finding of this study is the compelling group of cognitive control variables correlated to general brain activity at the anterior N2. General brain activity was not related to any measure at any other time window examined. This provides strong evidence to suggest the primary activity represented at N2 is the action of cognitive control processes. Furthermore, the nature of the relationships (negative correlations with MAAS, FFMQ-Awareness, and working memory SSPAN Total, and positive correlations with WBSI and the Conflict subscale of the ANT) suggest that greater magnitude effects at N2 (negative-going) are related to better cognitive control.

Implications & Conclusions

These findings suggest that cognitive control processes linked to memory begin in earnest at anterior N2, approximately ~250 ms after stimulus onset, and appear to represent neural activity identified by others. Frontal sites are implicated strongly in fMRI research by Depue et al. (2007) and Anderson et al. (2004), including prefrontal cortex, dorsolateral and mediallateral prefrontal cortex, and anterior cingulate cortex. These structures have been implicated in a number of paradigms invoking cognitive control and attention, for example linking the anterior cingulate to conflict-monitoring/resolving control processes (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999). Similarly, Lang and colleagues have proposed a "motivated attention" model of emotional perception occurring at N2 that represents the influence of control-modulated motivational inputs on attention and which are linked to the parallel activation of areas in the inferotemporal visual cortex and the amygdala (Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005). Thus, this study provides some assistance by establishing the likely temporal distribution of the neural networks confirmed in these studies.

Similarly, correlational measures and other data indicate that working memory and attention are intimately intertwined, particularly soon after stimulus presentation. These data support the embedded-processes model proposed by Cowan (1999) that working memory is the product of cognitive control of attention focused on long-term memory stores. In the current study, attention and working memory span measures presented in Table 3 were highly correlated, and early brain activity associated with cognitive control of remembered items was also related to working memory span. Thus, it seems likely that working memory features a close relationship with attention that well may be best described by the theory proposed by Cowan and elaborated by Engle.

These results also seem to support several models proposing a two-component process of control, one automatic and fast and another slow and effortful, such as ironic process theory outlined by Wegner and colleagues. We identified an early automatic cognitive control component located during N2 around 275 ms post-stimulus, and a later long-enduring change in ERP topography that was related to effortful control of memory on the T/NT task. Notably, these early components showed relationships with variables such as depressive rumination, mindfulness, and Wegner's WBSI. These relationships provide further support for the rapid, automatic signaling process proposed by Wegner and followed by a long, effortful control process. However, the indirect association of these patterns of early activity with ultimate recall suggests that individual variation in executive function may provide important variability in the effectiveness of these networks, as was proposed in the executive-deficit hypothesis by Anderson and colleagues. Indeed, despite the presence of early automatic processes, there was a large range in recall scores, suggesting that both automatic and effortful control processes demonstrate variability between persons, as posited by Anderson, and within persons, as suggested by Baumeister and colleagues. Given this pattern of control, the variation in expression of the mood-congruent memory bias makes more sense. When effortful conscious cognitive control is exerted on negative memories, as described by Hertel, even depressed participants are able to intentionally forget them. However, when effortful control is not invoked, Hertel found evidence to support a mood-congruent effect for greater negative recall. It may be that this earlier automatic process up-regulates mood-congruent negative material in those with depressive symptoms, producing a bias for negative material that a person may not consciously recognize because it uses mechanisms that operate immediately before conscious control steps in.

However, evidence for separate emotion-related neural inputs posited by Nair (2008) given her finding for the presence of separate main effects for valence and strategy were not supported. Nair suggested the presence of two mechanisms at work to identify and inhibit certain stimuli and separately to process emotional aspects of the associated memory trace. The current study only found interactions suggesting an integrated representation of valence and strategy aspects of the stimuli, consistent with the co-occurring changes in the hippocampus and amygdala reported by Depue et al. (2007). Thus, differential emotion-related ERP effects at periods of pre-conscious processing implicate an automatic emotional input. It is noteworthy—though congruent with common experience—that such influences occur before conscious control processes are able to influence them. Consequently, these inputs likely exert initial influences beneath the level of conscious awareness.

Similarly noteworthy for clinical psychologists are the early relationships identified between emotion-related activity at early windows and the clinical variables of rumination, depression, and mindfulness. As reported above, theories for a cognitive cause of depression go back to at least the early 60s (Beck, 1967), and one proposed mechanism is through ruminative thought (Miranda & Nolen-Hoeksema, 2007). Our finding that early anterior activity was related to depressive symptoms and mindfulness traits suggests the presence of a possible underlying trait that can result in depression if effortful control processes are not invoked. One attractive candidate for such a process is mindfulness. It should be noted that the measure of self-reported dispositional mindfulness emerged as significantly related with ERP activity prior to the onset of conscious or effortful cognitive-control processes. This activity supports suggestions by proponents of the clinical use of mindfulness (e.g., Kabat-Zinn, 2003) that mindfulness may serve to prevent the expression or development of negative cognitive patterns. However, none of the students in this study regularly practiced mindfulness, so it is likely that these results represent untrained or base-level trait mindfulness. Although some researchers are finding compelling physiological changes in brain activity after only brief mindfulness training (Zeidan et al., 2011), it remains to be seen if it can produce such early changes in neural responses.

Given these relationships to theory, possibilities exist for future research. If emotional memory does indeed occur before conscious processing of the image, a study involving a priming paradigm, where an image is displayed only long enough to be encoded visually but where the participant is immediately asked to complete another task, should produce a result where emotional inputs are activated but conscious awareness of the emotional content is not activated. Thus, mood effects may be triggered or transferred without the participant's conscious awareness. For example, if the priming paradigm pairs previously learned cue images for negative content consistently with an image of a neutral stimulus, subjective participant ratings for the neutral stimulus may become more negative without the participant being consciously aware of the new emotional link. A subsequent sorting task may allow the researchers to indirectly assess the participant's emotional connection to a stimulus.

Similarly, additional research into the emotional control of negative intrusive thoughts suggests some areas for additional research. For example, given the postulated two-component structure of ironic process theory, negative emotional content may be automatically triggered by any number of stimuli without a person's conscious awareness of these links. If a person begins to attempt effortful cognitive control to down-regulate negative emotional stimuli but has little idea which stimuli are triggering the emotion, errors in sourcing could produce patterns often seen in clinical conditions such as anxiety disorders.

Study Weaknesses

As described above, the current study produced a range of findings that offer strong support for some theories about cognitive control of emotional memory and more speculative evidence for others. It was able to produce these results despite a number of weaknesses. Most notably, significant participant loss to attrition was experienced. The use of two separate testing sessions was implemented to reduce participant fatigue during the rather long primary testing session (~2.5 hrs). Initially, participants were to sign up for the entire study and receive all credit upon completion. However, the IRB requested that intermediate credit be given for completion of Part 1. As a result, many students obtained the credit they needed and opted not to complete the study, despite asserting their total participation before agreeing to participate. Although methods of reducing this attrition were discussed, none were implemented to ensure continued congruence with IRB requests and protection of student participants. Given the high number of variables and relationships explored across a range of ERP components, the current study also runs significant risk for a Type I Error. Given the newness of this information and the limited power to find effects given the low *N*, it was decided to investigate relationships and effects without controlling for experimentwise error to help present information that could lead to future research. However, the findings reported here need to be replicated before stronger statements can be made about their implications. More confidence may be afforded to the patterns of effects that emerged with some consistency than to any individual effect or correlation. Another weakness of the current study is the long duration of the second testing session. One reason for this duration is the overtraining that was used to ensure high levels of initial memory for stimulus pairs. However, the resulting recognition scores suggest that the use of a fourth training cycle may have induced participant fatigue that negatively affected recall. Future studies using this paradigm should reduce this training time by at least one cycle. In the same vein, although the T/NT task requires nearly two hours to complete with the current stimulus set, it is possible that all other assessments (i.e., RRS, MAAS, ANT, and SSPAN) could have been given at an initial session. The decision was made to use the current design to avoid time-related variation in participant characteristics and performance between testing sessions. Perhaps related to this, the current study fails to find expected relationships between performance variables and clinical measures. For example, relationships between MAAS and memory recall and between ERP variables and Brooding subscale of the RRS failed to emerge despite robust relationships seen in previous studies in the same lab. Similarly, a number of secondary measures could have been cut from the current design, reducing its duration.

In other areas, the design and results suggest some shortcomings as well. Most notably, many studies using the T/NT fail to find the significant memory suppression effect as found by others (Anderson et al., 2004; Bergstrom et al., 2007; 2009; Depue et al., 2006; 2007). One possible explanation for this deficit is the current task is longer with a somewhat different training process than other studies. It is possible that our research suffers more from passive forgetting than others due to these factors. Consistently lower baseline recall scores in this study, Eyer (2009), Dykstra (2010), and Nair (2008) would support this supposition. If baseline score were to rise, the chances of finding a memory suppression effect would increase. On a smaller scale, ERP waveforms demonstrated a strong slope during the pre-stimulus period. Investigation of this effect resulted in the identification of a prolonged LPP that endures for up to two seconds after a stimulus is presented, depending on the length of stimulus presentation. Although this EEG activity is unlikely to produce significant effects on ERP data, future studies should prolong and vary the length of the intertrial interval to reduce the risk of ERP contamination. Finally, participant strategies for thought suppression on the T/NT task can vary widely. If these patterns are unsystematic, then any related activity will be averaged out during processing. However, as reported by Bergstrom et al. (2009) and found in our study, participant responses coalesce to two primary strategies: thought substitution and simple suppression. When thought substitution is chosen, ERP results mimic those of successfully recalled pairs. Consequently, desired strategy-related differences are reduced, perhaps significantly. To address this, Bergstrom et al. (2009) used a simple prompt "You should accomplish this by trying to block thinking of the Response word, but not by replacing it with any other thoughts. To repeat: do not think of anything else than the Hint word while you are blocking the response, just keep paying attention to, and looking at, the Hint word the entire time" (p. 729). Future studies using this paradigm should include such a brief statement.

Study Strengths & Conclusion

Despite the weaknesses described above and its failure to replicate the pilot study's effect for mindfulness, the current study exhibits a number of strengths. Most notably, it conducted a broad-based investigation of cognitive-control-related variables for comparison with direct measures of brain activity. ERPs were collected during performance of an innovative new paradigm, the T/NT task, which provides explicit measures of cognitive control success or failure, as well as behavioral recall scores. In the interest of improving its translation to other branches of psychology, it also included two cognitive tasks on attention and working memory and a number of psychometric self-report measures to establish a context for the cognitive results. The benefits of this approach include the use of direct measures of brain activity representing automatic emotion-related control process for association with widely used psychometric and clinical measures. Accordingly, the results of this combined clinical/cognitive psychology study provide unique new material for scientists. Most notably, it suggests the presence of an automatic cognitive processing component that occurs at stimulus presentation and contains relatively complex information. It also provides important temporal patterns for relating to neural networks generated by other studies. Specifically, it appears that early activity in the prefrontal cortex leads to activation of multiple frontal areas and subsequent posterior and limbic system areas that are related to down-regulation of sensory representations in memory and actual emotional memory as represented by hippocampus and amygdala activity. Finally, it provides compelling evidence for the role of N2 in the onset of cognitive control processes. To a lesser extent, the concurrent emergence of early emotion-related valence effects and significant relationships with measures of depression, rumination, and mindfulness provide cognitive psychologists with new data about an emotionally valenced attention-control process and clinical psychologists with new information about how mindfulness may function to reduce clinical disorders, such as anxiety. Furthermore, this unique paradigm has allowed us to make connections with features inside Skinners "black box." That is, the use of the T/NT and ERP recordings allows noninvasive exploration of actual thought processes. These insights have produced new evidence supporting Cowan's embedded-process theory and Gopher's dual process model for executive function. It validates Hertel's contention that mood-congruent passive forgetting can be overcome by conscious effort and provides support for Anderson's executive-deficit hypothesis, suggesting individual differences in cognitive control function. As such, the current study provided new data outlining the sequencing and interaction of strategy and mood processes during the performance of a cued-recall cognitive task and advances the literature on the mechanisms underlying the cognitive control processes governing recall of emotional memories.

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TABLE 1

Demographic and Descriptive Data for Participants

	Male		Female		Statistics			
Variable	*N*	%	*N*	%	*df*	χ^2	*p*	*ES*
Gender	18	51.4	17	48.6	1	0.03	.866	–
Age[a]	24.2	(5.66)	23.5	(6.78)	34	0.13	.723	.00
Race[b]	–	–	–	–	3	4.69	.196	.37
White	11	31.4	12	34.3	–	–	–	–
Black	2	5.7	4	11.4	–	–	–	–
Latino/a	1	2.9	1	2.9	–	–	–	–
Asian	4	11.4	0	0.0	–	–	–	–
Class[c]	–	–	–	–	4	4.02	.404	.34
Freshman	8	23.5	4	11.8	–	–	–	–
Sophomore	2	5.9	5	14.7	–	–	–	–
Junior	5	14.7	3	8.8	–	–	–	–
Senior	3	8.8	3	8.8	–	–	–	–
Other	0	0.0	1	2.9	–	–	–	–
Handedness								
Self-Report	18	100.0	17	100.0	–	–	–	–
EHI-LQ	98.6	(5.89)	100	(0.00)	34	.94	.339	.03
Native Speaker	18	100.0	17	100.0	–	–	–	–

Note. Total *N* = 35. *ES* = effect size, either φ or η^2, as appropriate; & EHI-LQ = the Edinburgh Handedness Inventory–Laterality Quotient.

[a] Age and EHI-LQ report means, standard deviations, *F* statistics. [b] Other and Mixed categories were dropped from table (*n*s = 0). [C] One female declined to give class information.

TABLE 2

Descriptive Information and Correlations for Psychometric Measures and Recall Percent Correct x Experimental Condition

			Correlations[a]											
Measure	*M* (*SD*)	95% CI	1	2	3	4	5	6	7	8	9	10	11	12
1. MAAS	4.08 (0.78)	[3.81, 4.35]	(.85)	.06	.12	.66**	.60**	.38*	-.64**	-.61**	-.43**	-.64**	-.38*	-.61**
2. FFMQ-OB	27.40 (5.11)	[24.64, 29.16]		(.73)	.09	.15	-.12	-.18	.32	.20	.41*	.21	-.13	.22
3. FFMQ-DE	27.23 (5.42)	[25.37, 29.09]			(.88)	.32	.18	.08	-.28	-.23	-.10	-.31	-.52**	-.12
4. FFMQ-AW	26.69 (5.99)	[24.63, 28.75]				(.89)	.51**	.34*	-.40 *	-.44**	-.12	-.49**	-.50**	-.55**
5. FFMQ-NJ	29.37 (6.96)	[26.98, 31.76]					(.92)	.35*	-.66**	-.66**	-.38*	-.80**	-.49**	-.66**
6. FFMQ-NR	23.20 (3.43)	[22.02, 24.38]						(.66)	-.27	-.24	-.25	-.47**	-.35*	-.62**
7. RRS [b]	39.00 (9.90)	[35.55, 42.45]							(.91)	.80**	.80**	.76**	.55**	.54**
8. RRS-BRD	9.17 (2.56)	[8.29, 10.05]								(.70)	.39*	.72**	.46**	.65**
9. RRS-REF	8.54 (3.24)	[7.43, 9.66]									(.83)	.55**	.37*	.26
10. WBSI	47.03 (10.93)	[43.28, 50.78]										(.88)	.46**	.75**
11. BDI-SF	3.66 (3.35)	[2.51, 4.81]											(.74)	.40*
12. PSS	17.17 (7.82)	[14.48, 19.86]												(.92)
Condition[c, d]														
Baseline	39.11 (23.11)	[31.17, 47.04]	.04	-.10	.010	.11	.02	.14	-.09	-.07	.05	-.12	-.20	-.28
BC TkNeg	18.75 (16.54)	[13.07, 24.43]	.09	-.30	-.08	.03	.02	-.05	.07	.02	.02	-.01	.39*	-.07
BC TkNeu	28.57 (15.18)	[23.36, 33.79]	-.09	-.12	-.14	.03	-.02	-.14	.09	.09	.09	-.09	.27	.03
BC NTkNeg	5.71 (14.49)	[0.74, 10.69]	.07	.10	-.13	-.13	-.03	.10	.08	.06	.11	.06	.26	.05
BC NTkNeu	8.21 (14.68)	[3.17, 13.26]	.13	.08	-.23	.01	.16	-.10	.10	.15	-.10	-.07	.24	.09

Note. N = 35. M = mean; SD = standard deviation; CI = confidence interval; MAAS = Mindful Attention Awareness Scale; FFMQ = Five Facet Mindfulness Questionnaire; OB = Observe; DE = Describe; AW = Awareness; NJ = Nonjudging; NR = Nonreacting; RSS = Ruminative Responses Scale; BRD = Brooding; REF = Reflection; WBSI = White Bear Suppression Inventory; BDI-SF = Beck Depression Inventory–Short Form, ; PSS = Perceived Stress Scale; Tk = Think; NTk = No-Think; Neg = Negative; & Neu = Neutral.

[a] Observed Cronbach alphas reported in parentheses. [b] n = 34. [c] Data for each condition is composed of baseline-corrected, percent correct scores generated during the final recall portion of the study.
[d] Main effects were found for strategy, $F(1, 34) = 64.11$, $p < .001$, ηp2 = .65, and valence, $F(1, 34) = 9.70$, $p = .004$, $\eta_p^2 = .22$, but the interaction was not significant, $F(1,24) = 3.02$, $p = .091$, $\eta_p^2 = .08$.

*$p < .05$ (2-tailed). ** $p < .01$ (2-tailed).

TABLE 3

Descriptive Information and Correlations for Cognitive Measures and Recall Percent Correct x Experimental Condition

				Correlations							
Measure[a]	N	*M* (*SD*)	95% CI	1	2	3	4	5	6	7	8
1. ANT-AL	35	19.90 (4.55)	[10.65, 29.15]	—	-.55**	.58**	.06	.05	.30	-.18	.33
2. ANT-OR	35	45.66 (49.77)	[28.56, 62.75]		—	-.67**	.18	.15	-.56**	.11	-.57**
3. ANT-CO	35	105.51 (36.97)	[92.81, 118.21]			—	-.30	-.34*	.64**	-.15	.66**
4. SSPAN-ABS	35	16.46 (8.61)	[13.50, 19.51]				—	.92**	-.55**	.10	-.56**
5. SSPAN-TOT	35	26.37 (8.89)	[23.32, 29.42]					—	-.50**	.19	-.52**
6. SSPAN-ERR	35	3.14 (3.77)	[1.85, 4.44]						—	.12	.99**
7. SSPAN-SPD	35	0.11 (0.40)	[-0.02, 0.25]							—	.02
8. SSPAN-ACC	35	3.03 (3.74)	[1.74, 4.31]								—
Condition[b]											
Baseline	35	39.11 (23.11)	[31.17, 47.04]	-.32	.10	-.20	.15	.30	-.27	.24	-.32
BC TkNeg	35	18.75 (16.54)	[13.07, 24.43]	.34*	-.22	.19	.10	.13	.17	-.19	.19
BC TkNeu	35	28.57 (15.18)	[23.36, 33.79]	.04	-.07	-.08	.12	-.01	-.05	-.25	-.02
BC NTkNeg	35	5.71 (14.49)	[0.74, 10.69]	.35*	-.17	.10	.15	.05	.11	-.30	.14
BC NTkNeu	35	8.21 (14.68)	[3.17, 13.26]	.17	-.04	.09	-.01	-.08	.03	-.23	.06

Note. N = the sample size; *M* = mean; *SD* = standard deviation; CI = confidence interval; ANT = Attention Network Test; AL = Alerting domain; OR = Orienting domain; CO = Conflict domain; SSPAN = automated Symmetry Span task; ABS = Absolute score; TOT = Total score; ERR = Symmetry Error sum; SPD = Speed Error cont; ACC = Accuracy error count; BC = baseline-corrected; Tk = Think; NTk = No-Think; Neg = Negative; & Neu = Neutral.

[a] Measures are performance scores generated on cognitive tasks. [b] Except for the Baseline condition, which is composed of simple percent-correct scores, data for each condition is composed of baseline-corrected, percent-correct scores generated during the final recall portion of the study.

*$p < .05$ (2-tailed). ** $p < .01$ (2-tailed).

TABLE 4

Significant repeated-measures ANOVA effects at each ERP component using area-under-the-curve scores.

	Window (ms)	Effect	F^b	p	η_p^2
P1[a]					
Posterior	125–164	Strategy x Valence,	6.08	.019	.15
		Strategy x Valence x Laterality	8.57	.006	.20
N1[a]					
Posterior	165–204	Strategy	7.74	.009	.19
P2					
Anterior	170–249	Strategy	4.40	.043	.12
Posterior	205–254	NS	—	—	—
N2					
Anterior	250–324	Strategy x Valence	4.54	.040	.12
Posterior	255–324	Strategy	13.67	.001	.29
		Strategy x Valence	4.43	.043	.12
Early P3[a]					
Posterior	325–389	Valence	5.29	.028	.14
		Laterality	8.40	.007	.20
P3					
Anterior	325–449	Strategy	6.04	.019	.12
		Laterality	11.46	.002	.25
Posterior	390–474	Strategy	7.39	.010	.18
		Laterality	10.86	.002	.24
Late ERPs					
Anterior	450–824	Laterality	6.39	.016	.16
		Strategy x Valence x Laterality	4.98	.032	.13
Posterior	475–849	Strategy	20.38	.001	.38
		Strategy x Valence x Laterality	5.71	.023	.14

Note. $N = 35$. NS = none significant. Anterior indicates electrodes FC3 and FC4. Posterior represents the activity at electrodes P3 and P4. Strategy represents the activity at think trials compared to no-think trials. Valence represents the activity for negative compared to neutral items. Laterality represents the activity at FC3 versus FC4 at anterior sites or P3 versus P4 at posterior sites.

[a] Analyses were not conducted on corresponding anterior windows. [b] *df*s for all ANOVAs were (1, 34).

TABLE 5

Correlations between Recall Percent-Correct x Experimental Condition and Effect Scores with Psychometric and Cognitive Measures

	Correlations													
Measures	MAAS	FFMQ-Observe	FFMQ-Describe	FFMQ-Awareness	FFMQ-Nonjudging	FFMQ-Nonreactve	RRS[a]	WBSI	BDI-SF	PSS	SSPAN Total Score	ANT-Alerting	ANT-Orienting	AND-Conflict
Recall Scores[b]														
TkNeg	.04	-.26	.09	.12	.01	.10	-.06	-.09	-.03	-.28	.40*	-.07	-.06	-.07
TkNeu	-.05	-.13	.07	.13	-.02	.05	-.06	-.15	-.15	-.23	.33	-.32	.06	-.28
NTkNeg	.08	.04	.10	.02	.02	.29	-.09	-.06	-.21	-.29	.48**	-.14	-.01	-.20
NTkNeu	.10	.02	.01	.11	.11	.08	-.06	-.14	-.18	-.20	.29	-.24	.09	-.17
Effect Scores[c]														
Strategy	-.15	-.38*	.07	.11	-.11	-.11	-.00	-.06	.13	-.11	.10	-.05	-.07	-.03
Valence	.05	-.13	.09	-.08	-.05	.18	-.02	.13	.11	-.10	.17	.32	-.20	.20

Note. N = 35. MAAS = Mindful Attention Awareness Scale; FFMQ = Five Facet Mindfulness Questionnaire; RSS = Ruminative Responses Scale; WBSI = White Bear Suppression Inventory; BDI-SF = Beck Depression Inventory–Short Form, ; PSS = Perceived Stress Scale; SSPAN = automated Symmetry Span task; ANT = Attention Network Test; Tk = Think; NTk = No-Think; Neg = Negative; & Neu = Neutral.

[a] $n = 34$. [b] Data for each condition is composed of total percent-correct recall for each condition. [c] Effect scores: Strategy is formed by taking mean percent-correct recall scores across all think trials and subtracting mean scores for no-think trials. Valence is formed by taking mean percent-correct recall scores across all negative trials and subtracting mean scores for neutral trials..

*$p < .05$ (2-tailed). ** $p < .01$ (2-tailed).

TABLE 6

Correlations for Computed ERP Scores and Psychometric and Cognitive Measures

ERP Measures[b]	MAAS	FFMQ-Observe	FFMQ-Describe	FFMQ-Awareness	FFMQ-Nonjudging	FFMQ-Nonreactve	RRS[a]	WBSI	BDI-SF	PSS	SSPAN Total Score	ANT-Alerting	ANT-Orienting	ANT-Conflict
Posterior P1														
Total	-.09	.11	.18	-.18	.04	-.08	.20	-.01	.08	.10	-.13	-.05	.03	-.02
Strategy	-.14	.20	-.10	.07	-.35*	-.12	.35*	.31	.12	.17	-.07	.09	-.29	.30
Valence	-.06	.17	.04	.10	-.13	.07	.12	.16	-.27	.06	-.19	.03	-.26	.31
Posterior N1														
Total	-.11	.25	.21	-.08	.23	-.22	-.05	-.06	-.15	.17	-.15	-.32	.18	-.24
Strategy	.09	.41*	-.06	.12	-.25	-.07	.07	.19	.00	.13	.02	.28	-.07	.08
Valence	-.14	.03	.14	.05	-.15	-.06	.06	.14	-.27	.16	-.12	.00	.07	.09
Anterior N2														
Total	-.38*	-.06	-.33	-.36*	-.18	-.13	.32	.34*	.28	.26	-.46**	.16	-.13	.39*
Strategy	.07	-.06	-.04	.20	-.03	.11	.04	-.01	.13	-.11	-.07	.21	-.08	-.08
Valence	-.13	.04	.48**	.11	-.17	.09	-.08	-.00	-.35*	.03	.04	-.16	-.00	-.06
Posterior N2														
Total	-.14	-.04	-.13	-.18	.12	-.13	.12	.09	-.00	.07	-.13	.08	-.06	.20
Strategy	-.11	.15	.13	.14	-.11	-.09	.10	.12	-.05	.13	-.17	.17	-.17	.10
Valence	-.05	.00	.35*	.24	-.03	.17	-.14	-.02	-.53**	-.07	.09	-.13	-.01	-.03

Note. N = 35. MAAS = Mindful Attention Awareness Scale; FFMQ = Five Facet Mindfulness Questionnaire; RSS = Ruminative Responses Scale; WBSI = White Bear Suppression Inventory; BDI-SF = Beck Depression Inventory–Short Form, ; PSS = Perceived Stress Scale; SSPAN = automated Symmetry Span task; ANT = Attention Network Test; & P1, N1, and N2 = ERP components.

[a] n = 34. [b] ERP scores: Total score is formed by averaging ERP activity across all conditions. Strategy is formed by taking mean ERP think values and subtracting mean ERP no-think values. Valence is formed by taking mean ERP negative values and subtracting mean ERP neutral values.

*p < .05 (2-tailed). ** p < .01 (2-tailed).

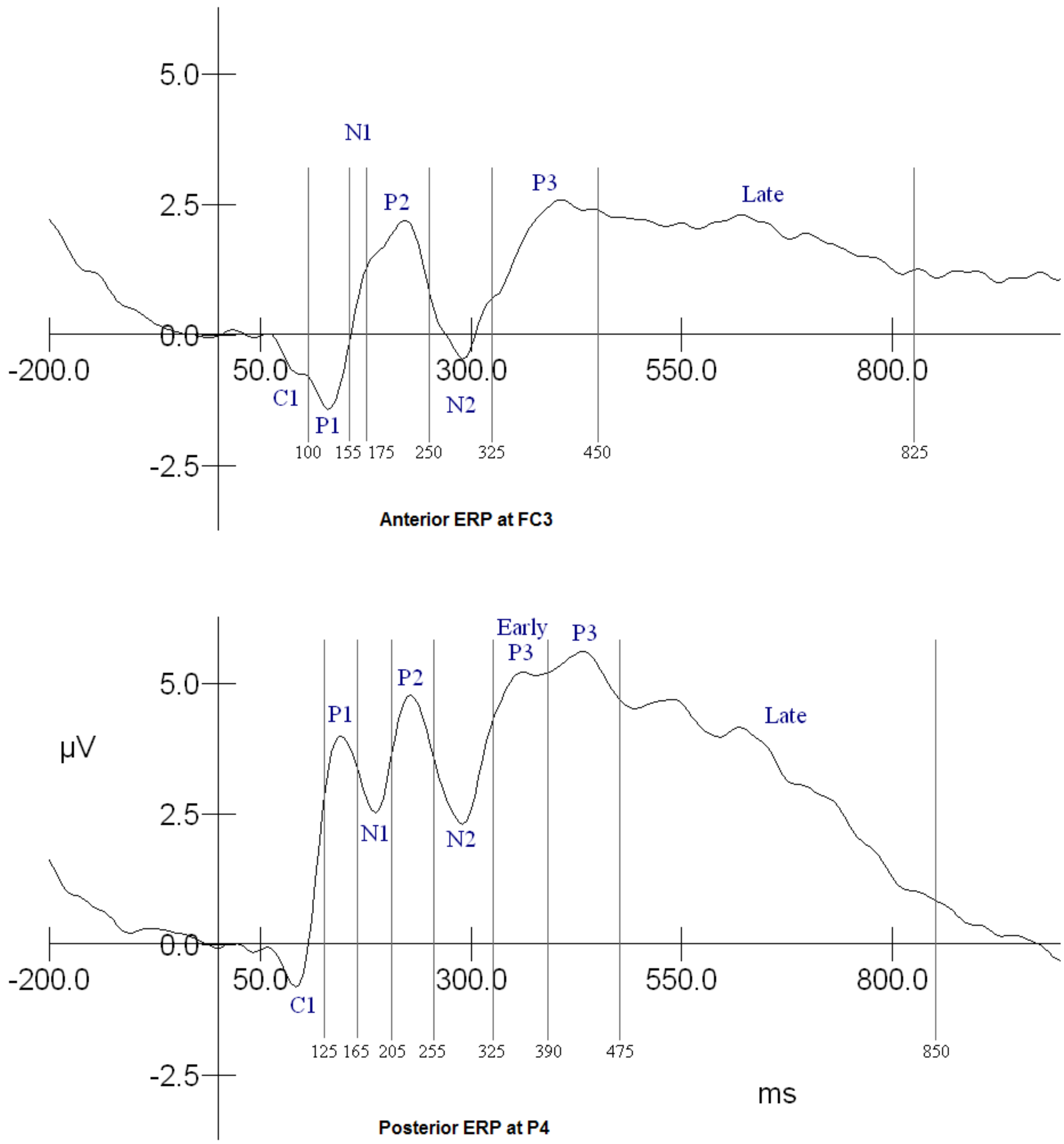

FIGURE 1: Anterior left-sided (top) and posterior right-sided (bottom) ERP waveforms averaged across all conditions and all participants. ERP components are labeled in blue.

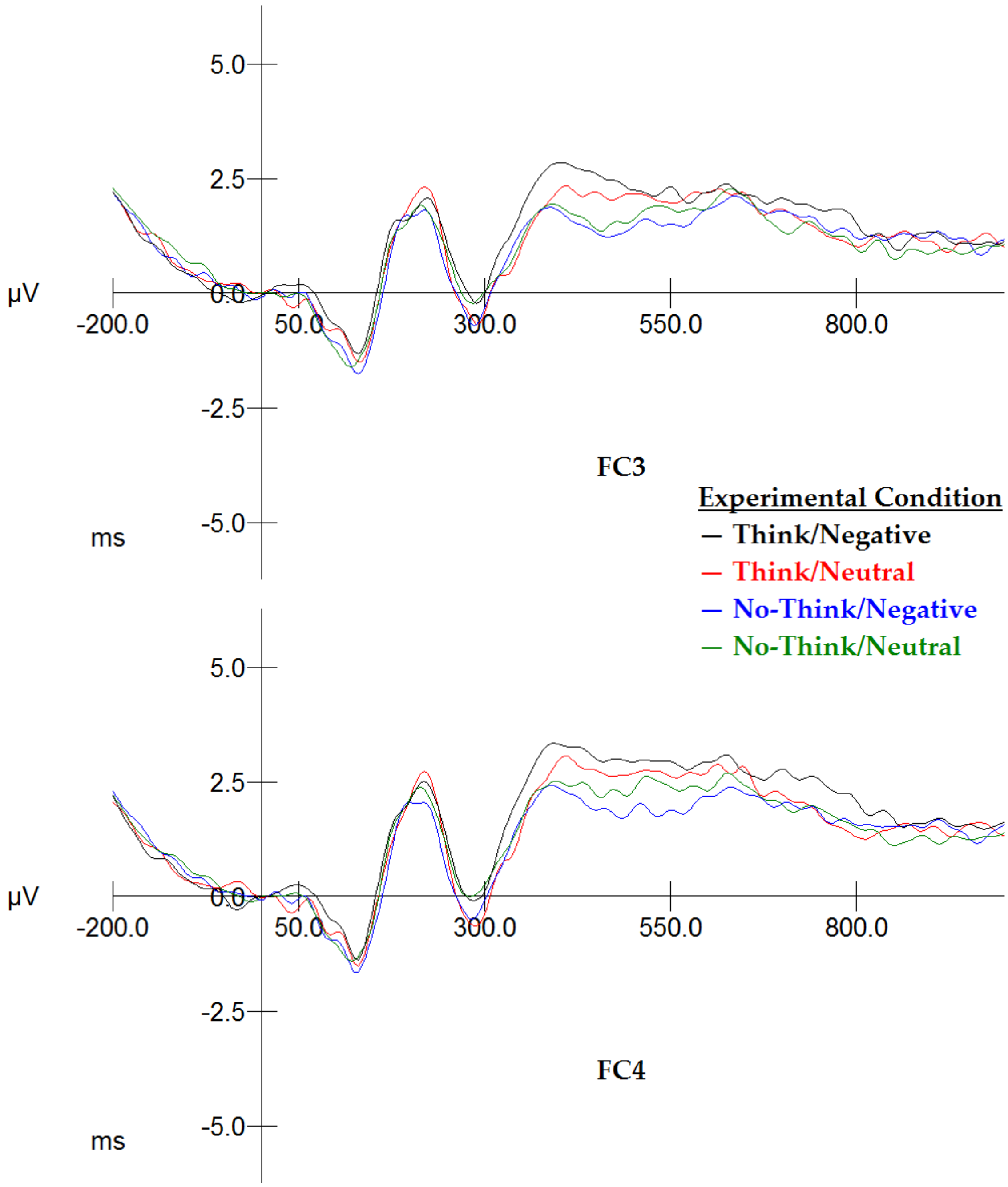

FIGURE 2: ERP waveforms for anterior electrodes, FC3 (top) and FC4 (bottom), showing four lines representing the activity occurring in each of four experimental conditions (i.e., 2 Strategy x 2 Valence).

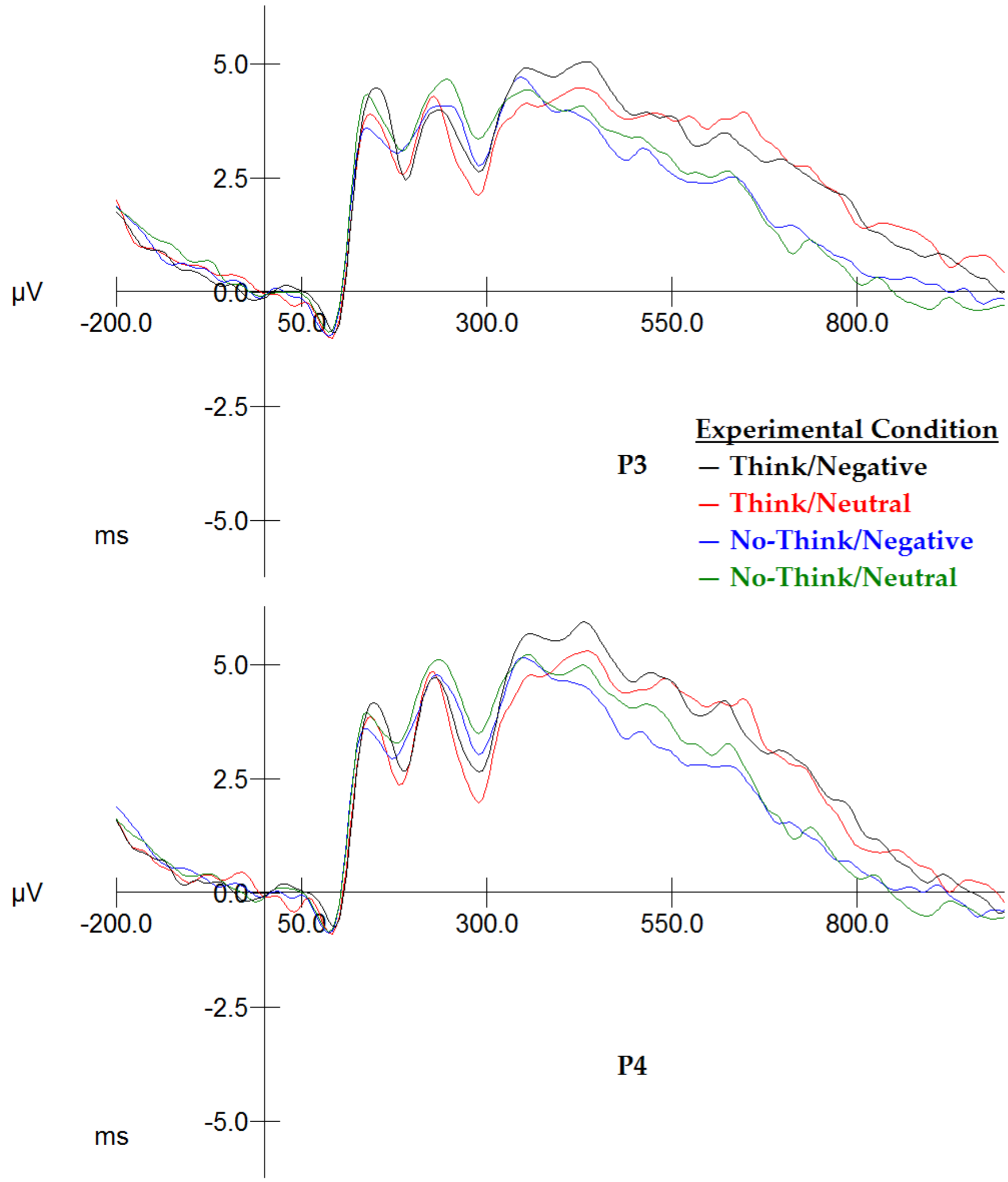

FIGURE 3: ERP waveforms for posterior electrodes, P3 (top) and P4 (bottom), showing four lines representing the activity occurring in each of four experimental conditions (i.e, 2 Strategy x 2 Valence).

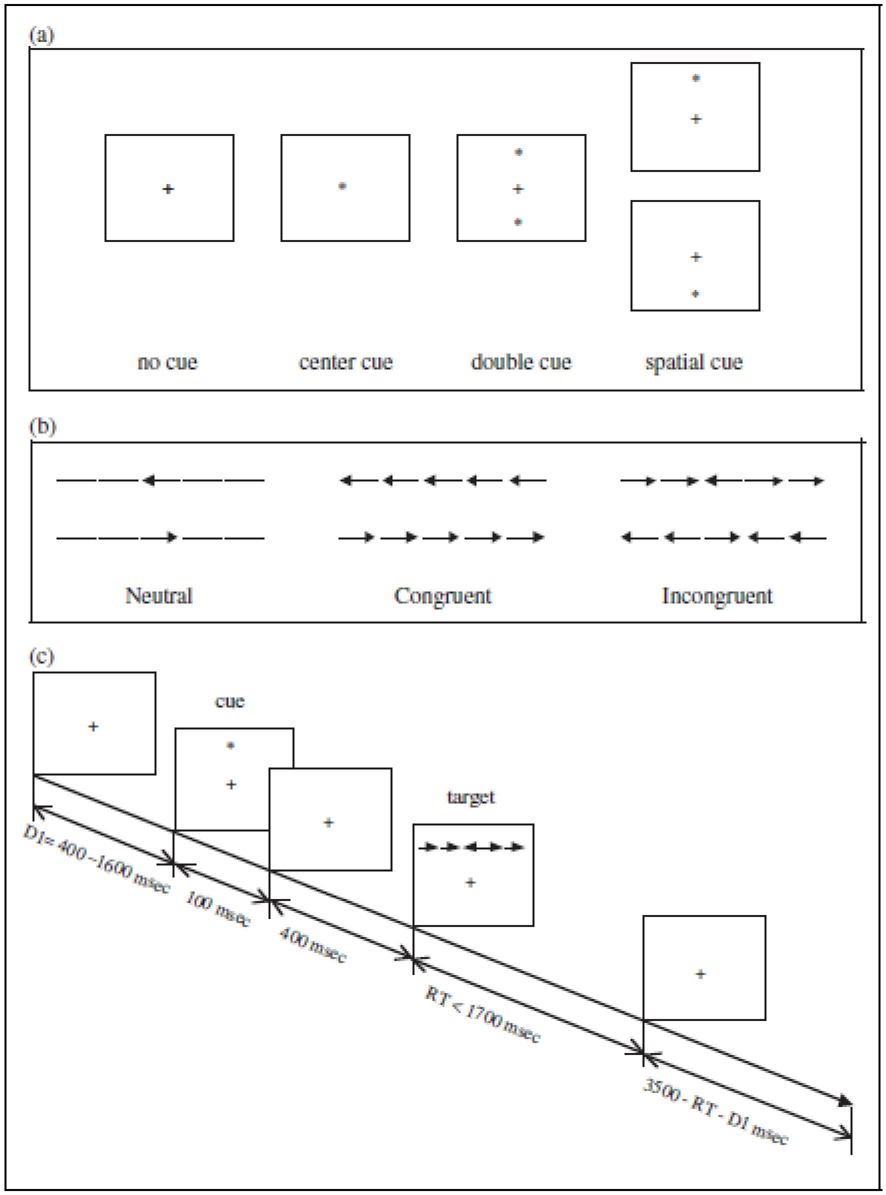

FIGURE 4: Experimental procedure from the Attention Network Test. The four cue conditions are presented in (a). The six stimuli are presented in (b), and the procedure is displayed in (c). The double cue condition and neutral stimuli were not included in this study. Adapted from Fan, McCandliss, Sommer, Raz, and Posner (2002).

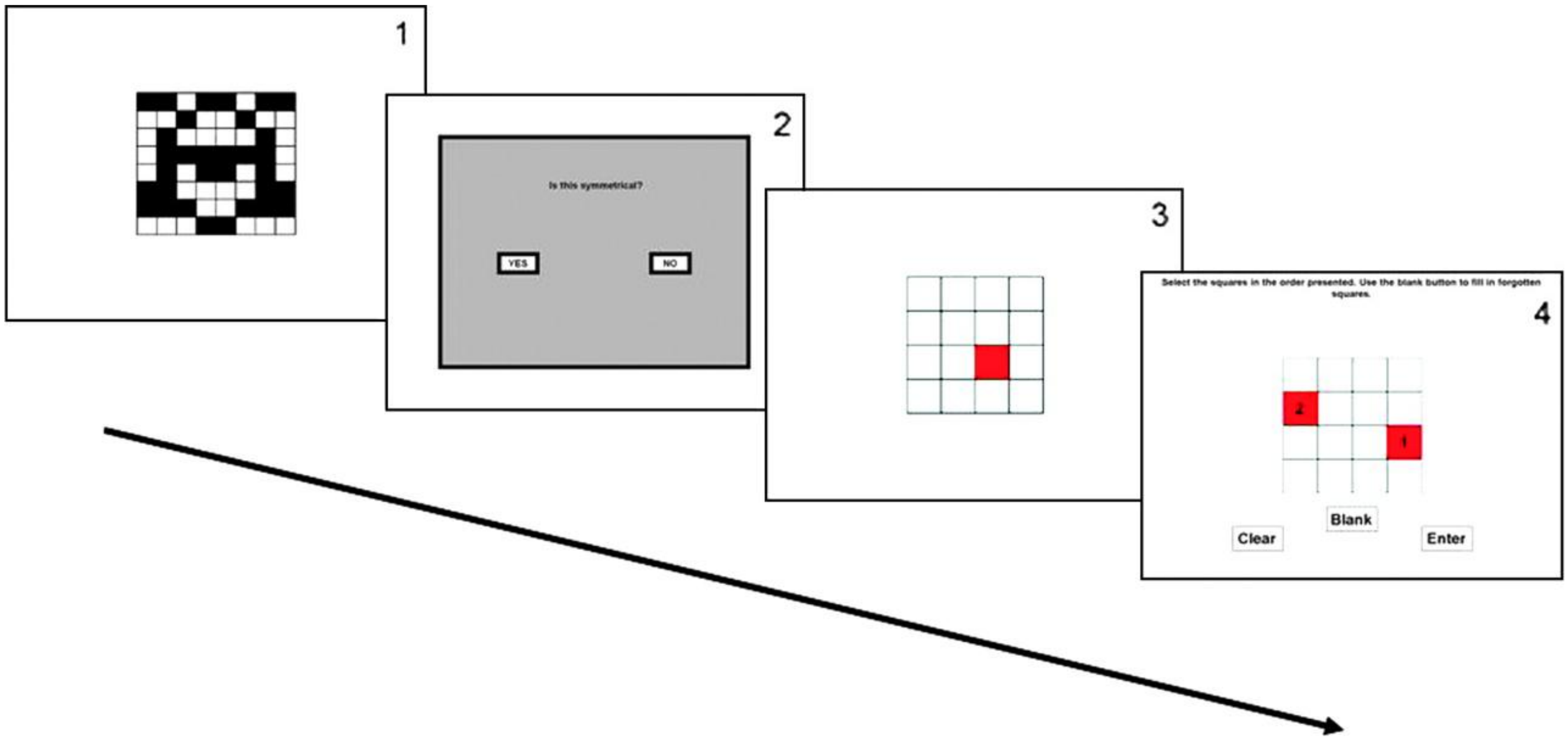

FIGURE 5: Stimuli and procedure from Automated Symmetry Span task. Screens are presented in the order indicated by the number in the top right corner of each panel. In a single trial, participants are asked to determine whether a black-and-white image is symmetrical around the vertical centerline. On each trial they are presented with a red box on a grid. Finally, after a variable number of trials (2–5), participants are asked to recall the position of each red box in the order presented. Adapted from Barch et al. (2009).

FIGURE 6: Examples of neutral (top) and negative images (bottom) like those found in the International Affective Picture System (Lange et al., 2008). (Obtained Getty Images at http://www.gettyimages.com.)

FIGURE 7: Example neutral female (top) and male (bottom) faces (2 of 80) from Depue et al., 2006.

FIGURE 8: This is a screenshot of photo-cue (left) and example image-target (right) during the learning parts of the training phase. In this case, the photo is male, and the target is a negative stimulus. Participants are instructed to memorize these two stimuli as a pair.

FIGURE 9: This is a screenshot during the recognition test portion of the training phase. In this case, the photo-cue (left) is male, and the correct image-target (right) is in the top position. The bottom position has another image as a distractor. Participants are instructed to select the correct image-target by pressing a button corresponding to the top or bottom positions. (Target images are copyrighted to Getty Images.)

FIGURE 10: This is a screenshot during the experimental phase. In this case, the photo-cue is male, and the photo is surrounded by a colored border. A border indicates that it is a no-think condition. Participants are instructed to attempt actively to prevent the paired image from coming into awareness. When the border is green (think condition), participants are instructed to attempt actively to recall the paired image.

FIGURE 11: This is a screenshot during the final recall phase. In this case, the photo-cue is male. When they see a photo-cue as shown above, participants are instructed to describe the image-target in 2-5 words.

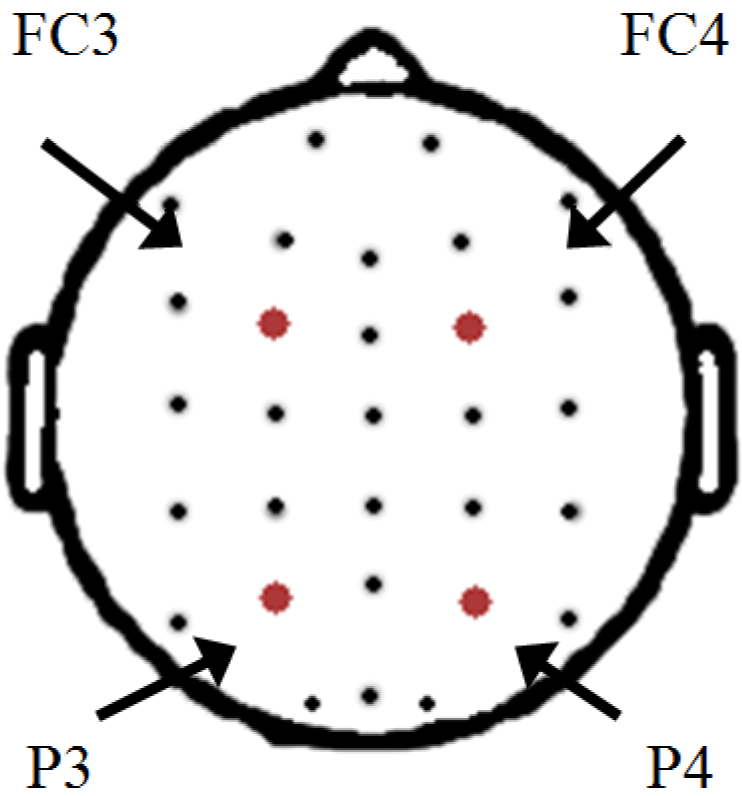

FIGURE 12: Image showing the position of frontal electrodes (FC3 & FC4) and parietal electrodes (P3 & P4).

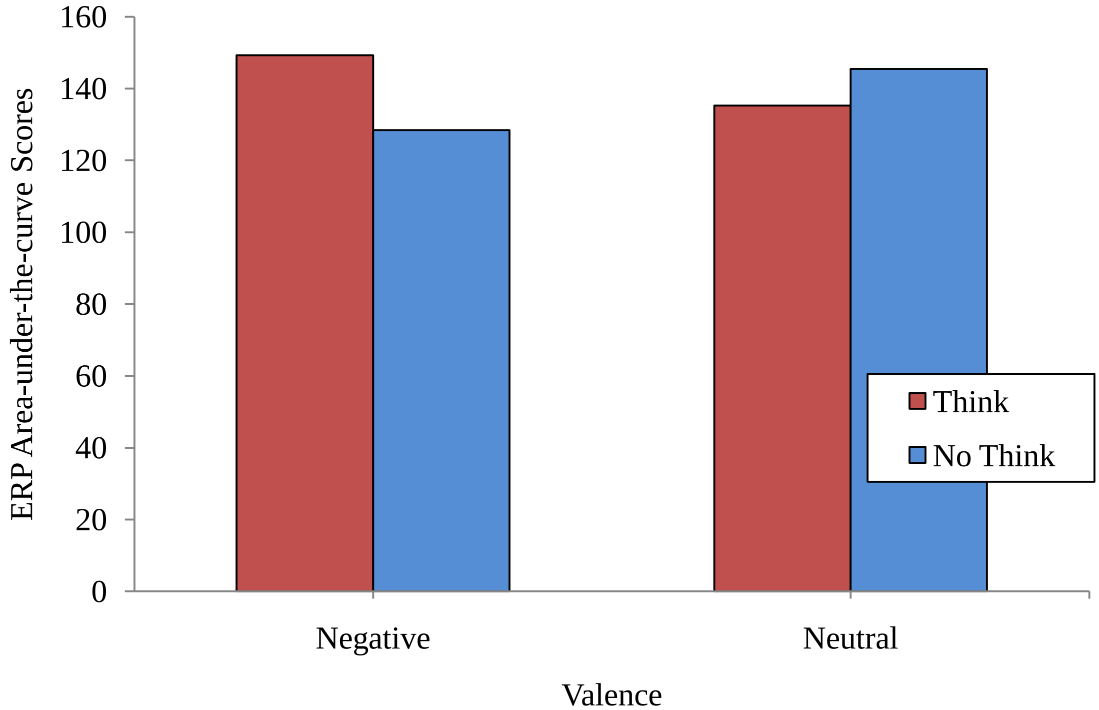

FIGURE 13: Posterior P1 component Strategy x Valence interaction (*p* = .019). The same pattern is seen in a significant 3-way Strategy x Valence x Laterality interaction (*p* = .006) at both the P3 and P4 electrodes, where the effect appears stronger at the P3 electrode (left side).

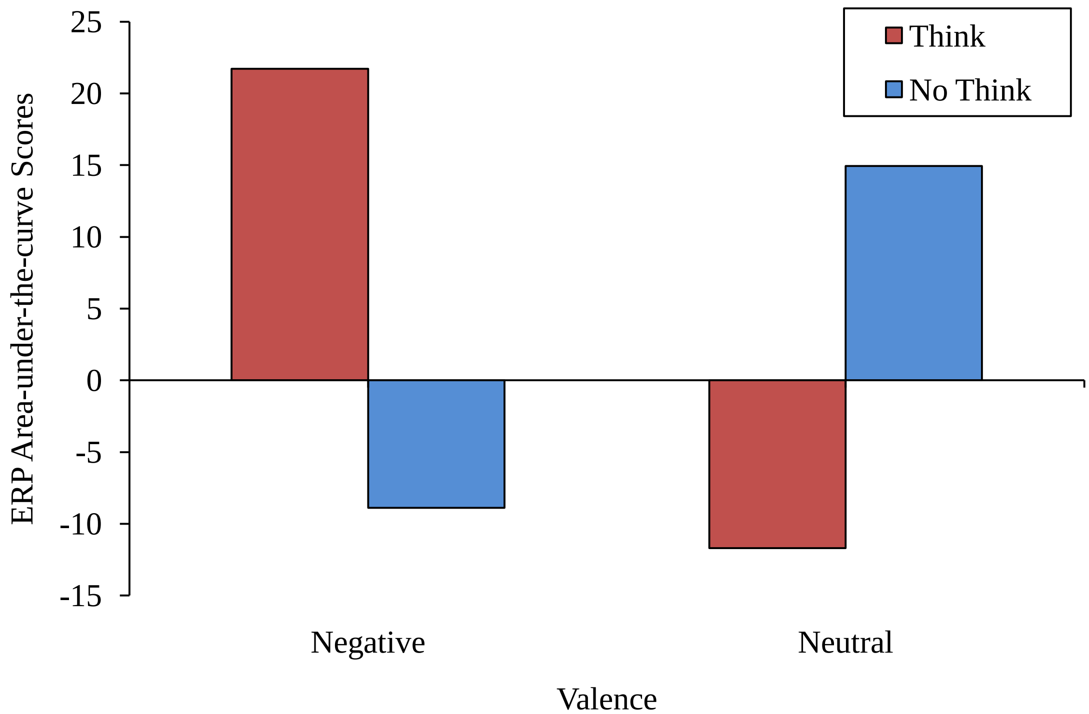

FIGURE 14: Anterior N2 Strategy x Valence interaction (*p* = .040), showing that the valence of the images produced a reversed pattern of ERP activity on different levels of strategy.

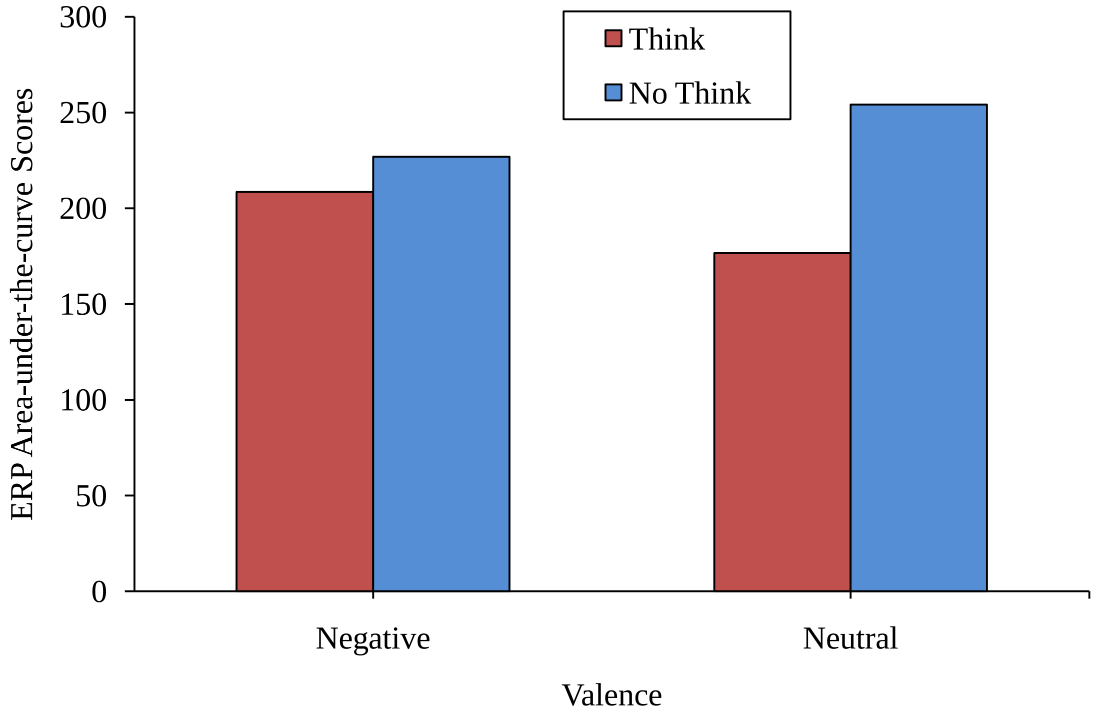

FIGURE 15: Posterior N2 Strategy x Valence interaction (*p* = .043), showing that the valence of the remembered stimuli produced a greater difference in ERP activity with neutral stimuli than negative.

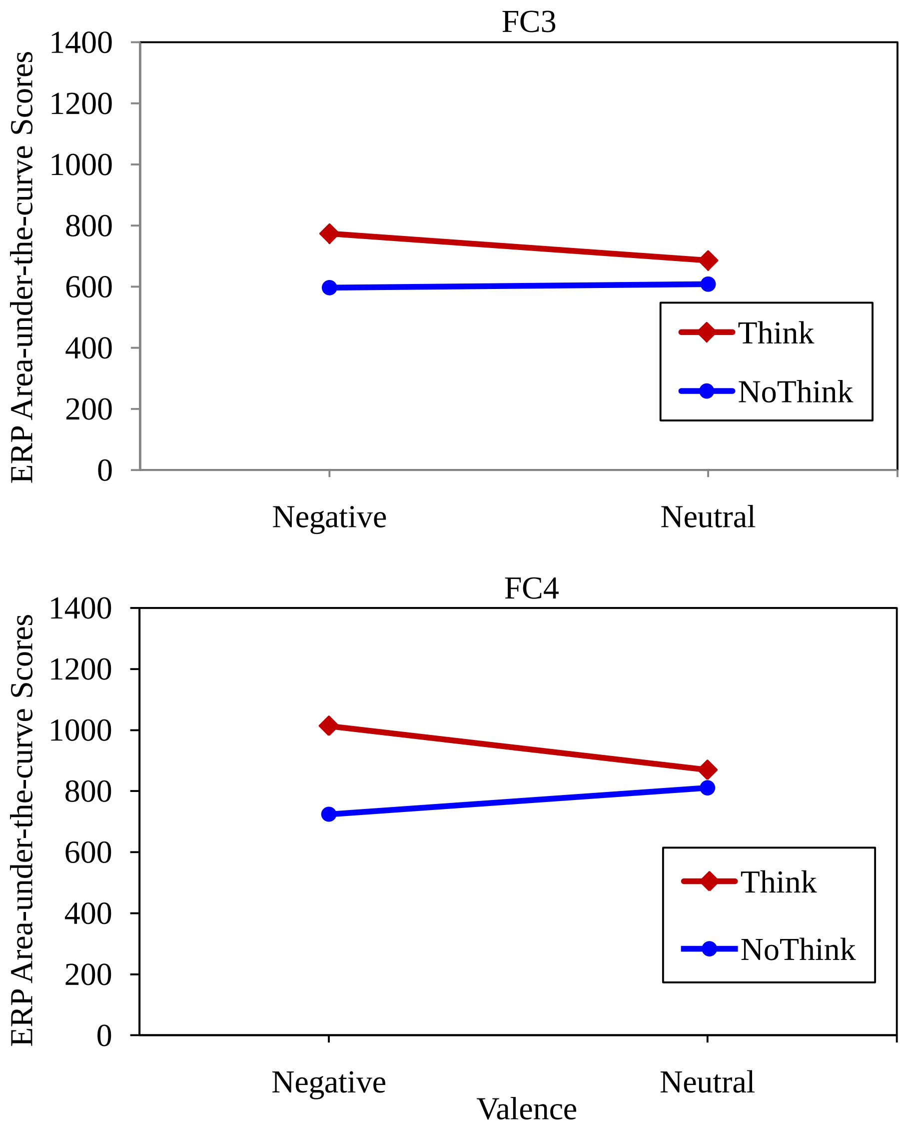

FIGURE 16: Late anterior 3-way interaction between Strategy x Valence x Laterality (*p* = .032) depicting the pattern of means in which the effect of valence on strategy is greater in the negative condition than the neutral condition and greater again at anterior electrodes.

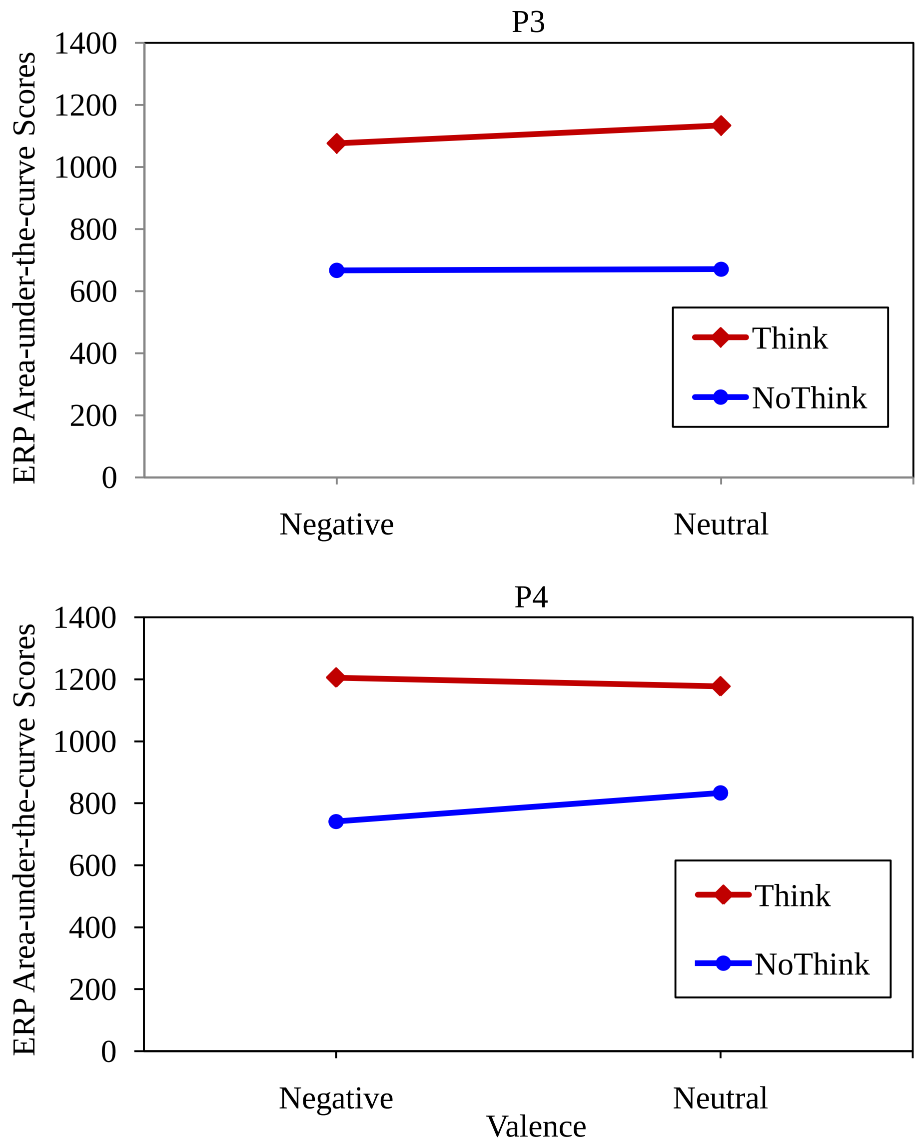

FIGURE 17: Late posterior 3-way interaction between Strategy x Valence x Laterality ($p = .023$) depicting the pattern of means in which the effect of valence on strategy is greater in the think condition at FC3 and the no-think condition at FC4.

APPENDIX A: RESEARCH ASSISTANT SCRIPT & INSTRUCTIONS

Cognitive Influences on Memory for Faces and Pictures: An EEG/ERP Study

PART 1 — Script & Run Information

1. Welcome the participants and give them a copy of the consent form to read.

2. After they've had a chance to read it completely, read the following script (or say it in your own words).

   "As you read, this is a two-part study. You are now participating in Part 1. This part of the study is a short session designed to orient you to the task and allow you to fill out several questionnaires before the main study. At the end of Part 1, I will schedule an individual time with each of you for Part 2. Part 1 is currently taking just under an hour, but Part 2 is generally taking a little longer, closer to three hours. The credits work out the same, but the time is shifted a little bit.

   "Part 2 will be an EEG study. That is, it involves an electrode cap. As a result, be sure to read the preparation instructions in Sona for the day of the study. Be sure to get a good night's rest the night before (~ 7-8 hours) and eat something before coming to the study. Try to avoid a big meal, though, as that might make you sleepy. Also, please wash your hair the day of the study, but do not use conditioner or makeup, especially bronzer or cover-up.

   "Finally, there are three important areas related to research in general that I want to be sure you understand. First, research is always voluntary. As a result, if you decide to stop participating for any reason, just tell us 'I want to stop the study,' and we'll immediately stop collecting data and start getting you out of there. If you leave during Part 1, you'll only get credit for the first part, but if you leave during Part 2, you'll get the full credit. Of course, this data is important to us, so if you can participate until the end, we would appreciate it. Second, the information you give us will be kept confidential. We only store your name on one document (the

consent form) which will be destroyed when we no longer need to keep it. The rest of the data will all be recorded using a number that will be assigned to you, and you can expect that anything you tell us will not be shared with people outside the lab. Third, there is no harm in participating in research. You should leave in the same condition you arrived! During this task, there may be some scalp discomfort when we are working on the electrodes. Just let us know, and we'll leave that spot alone. You shouldn't feel pain as part of this study. Also, some of the images are somewhat disturbing, but they are not worse than images you would see on the evening news.

"Do you have any questions?"

"Given that information, would you still like to participate?

3. If they agree to participate, have them sign the consent form and *sign after them*. Offer them a blank consent form if they would like to take one with them

4. Administer a Part 1 packet to each participant. When each has one, read the following statement.

   "Before you is a packet of measures that will ask you about a number of different things related to how you act and feel in your day-to-day life. Be sure to read the instructions carefully for each measure as they are sometimes quite different. If you get stuck on an answer, just choose the one that describes you the best, even if it isn't very good. However, it is very important that you answer all the questions, so please don't leave any blank. Do you have any questions? *(Pause.)* **Then, please get started. When you have finished, please let me know, and we'll schedule you for Part 2."**

5. When a participant has completed the packet, quickly *review each page* to ensure that they answered each questions. [VERY IMPORTANT] Pay special attention to Item I on the BDI-SF on suicide. *If the participant has selected anything except choice 0 "I don't have any thoughts of killing myself," excuse*

yourself discretely and try to reach Dr. Faust or Josh Eyer immediately. If you cannot, tell the participant that you noticed their answer to that question, indicate that you are concerned about them, give them a brochure for the Counseling Center, and offer to walk over with him or her to talk to someone there. Otherwise, *initial the page* at the bottom to indicate that you reviewed it.

6. Offer the participant a choice of open slots, and schedule him or her into the slot he or she prefers. If no slots work, take the students' contact information and tell him or her that a researcher will be contacting him or her soon to schedule a time for Part 2. Pass that information on to Dr. Faust and Josh Eyer.

7. Thank them for their participation

APPENDIX A (continued)

Cognitive Influences on Memory for Faces and Pictures

--- An EEG/ERP Study

PART 2 — Script & Run Information

1. Welcome the participant back and make sure they remember what you'll be doing.

2. Administer the two-measure packet (RRS and MAAS). Remind the participant to read the instructions and answer all the questions.

3. Ask the participant how much sleep he or she had the night before and how long before the study time the participant last ate. Record these values. If the participant has not eaten in several hours, offer him or her a short break if he or she would like to run get some food from the vending machines on the other side of the Colvard Breezeway.

4. After the paper measures, seat the participant at the computer in the testing room. Allow the participant to become comfortable, then adjust the screen so that it is between 53-60 cm from the participant's face.

5. Administer <u>the first task</u>, the ANT.
   On the first page of the Instructions for the ANT, *point out to the participant that the center arrow is in the third position of the five.*
   Later, when the task describes the star that appears above and below the center cross, *say*:
   "Be sure to focus on the middle cross, no matter where the star appears. You can notice it without moving your eyes. I want you to be sure to keep your eyes on the cross despite the distraction of the star appearing above, below, or under it."

6. Next, administer the second task, the SSPAN (spatial/symmetry working memory task).
   Say, **"This task is a little demanding, so be sure to give it your best effort. Let me know if you have any questions."** Then, stay with the participant during the instructions in case he or she has any questions.
   When the task is completed, write the results on the back of the RRS/MAAS packet.

7. After the SSPAN task, ask the participant if he or she needs a restroom. If not, begin cap application [Alcohol & exfoliant soap]. Once the eye electrodes and nose reference are attached, seat the participant at the computer again, and say the following statement.
   "We have a memory task for you to do now. While you are memorizing these images, we will be working on the electrodes. We will be putting goo into each electrode, like this. *(Demonstrate.)* **Later, we will also be working on the connection between the electrodes and your scalp. When we do that, we may need to rub some of the electrode sites. Please do your best to ignore us and focus on memorizing the pairs. However, if you develop any tenderness at any of the sites, please let us know by saying 'Ow' or 'That hurts there.' We will stop it and move on. Any questions about that?"**
   If there are none, then have the participant begin task 3a, the Training Phase.

8. While the participant is involved in training, fill all electrode cups and then check DC values and impedances. Ensure a good connection at F3, F4, P3, and P4. Be careful not to obstruct their vision during this process. Once the cap is prepared, quietly leave the room and allow the participant to complete the training phase. You may turn off NeuroScan recording until the start of the next task.
   NOTE: If the lab account has money in it, it is allowable to go get the participant a Coke or other beverage at this point. You may ask while putting the cap on or during a pause for instructions during the training phase what, if anything, the participant desires.

9. When the training phase is complete, begin the Task 3b, the Testing Phase. First, start the NeuroScan recording. Then, after allowing the participant to read the Instructions for the Testing Phase, ask him or her, **"So, what will you be doing on this part of the study?"**

   This is a quick test for comprehension of the directions. If his or her response is not correct, clarify what he or she will be doing on the task. If his or her response is satisfactory, continue by showing the participant his or her brain activity and reading/saying the following statement.

   "These are your brain waves! You'll see that if you stay still, they get very calm, and if you blink now, it gets much more active. One way to think of this is that if your brain is a party, your muscles are all the music and people talking. Your brain waves are like your friend trying to whisper next to you. So for this task, we need you to try to keep your movements, blinking, tongue movements, tooth grinding, etc., to a minimum. If you need to blink, you can wait one or two seconds after you first see an image and blink then. Try not to blink during the gap between pictures or when you first see an image. I'll let you know how you're doing with blinks during the first break."

   Then, continue with the following description of the study.

   "This part of the task is the main part of this study. The only way you're interacting with the computer is through your brain. We'll be recording your brain activity during this task and trying to tell a difference between how your brain acts during the green border trials and the red border trials. That means, I need you to focus really hard on the correct image when you have a green border, and focus really hard on NOT remembering the paired image when you have the red border. Do you think you can do that for us?"

   If the participant is ready, allow him or her to start the task. Go to the recording room and watch for blinks. They should not occur within a half-second before the stimulus code or a full second after. If they do, let the participant know during the next break. If the blinks are fine, tell him or her that at the break.

10. There will be four breaks during the task. Each block takes about 10 minutes. You can watch the event count on the status window in NeuroScan. There are 128 events in each block and five blocks. During each break, go into the testing room and engage the participant in conversation.

11. After the Testing Phase is completed, you should stop the Neuroscan recording. Take a prepared stimulus response sheet (pages of face photographs) on a clipboard into the room. You may remove the participant's chinstrap at this point. Start task 3c, the Final Recall Task, and allow the participant to read it before saying the following.
    "If the last task was the most important because we were reading your brain waves, this task is very important because it shows us exactly what you've learned and what you haven't, so I need you to remember the best you can. Then, we will know which of these you pairs you managed to memorize. We don't expect you to remember all of them. The task starts quickly, so don't start it until you're ready. Any questions? *(Pause.)* **You may begin when you're ready."**
    Do your best to keep up with the subject as he or she responds. If the participant appears to become frustrated or discouraged because of forgotten pairs, you may say,
    "That's okay. We don't expect you to remember all of them. Just do your best."
    If you have trouble keeping up because the participant is saying a lot of words, you may say,
    "Please keep your responses to just a few words."
    In both cases, it is best to wait until a missed pair to say these. Several common abbreviations may be helpful DK or DR mean "Don't Know" or "Don't Remember" and NR means "No Response."

12. When the Final Recall Phase is complete, give the participant the Debriefing

Form and a pen, but do not move the participant yet. When the Debriefing form is finished, provide the participant with a towel, shampoo, and privacy, if desired.

13. Thank him or her for participating and give him or her a brief description of the study!

APPENDIX B: SELF-REPORT MEASURES

Contents of Testing Packets for the Pretesting and Main Testing Sessions

Pretesting (In order administered)

- Consent
- Biographical Information Form
- Edinburgh Handedness Inventory–Revised
- Beck Depression Inventory–Short Form
- Five Facet Mindfulness Questionnaire
- White Bear Suppression Inventory
- Perceived Stress Scale

Primary Testing Session

- Supplementary Information Form
- Ruminative Responses Scale
- Mindful Attention Awareness Scale
- Debriefing Form

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Informed Consent for: ***ERP investigation of cognitive influences on memory for faces and pictures***

Purpose. Thank you for participating in this research study of the cognitive influences on our ability to remember and forget. Your participation will form part of a set of results that should shed some light on how important cognitive factors affect memory.

Investigators. This study is being conducted by: Dr. Mark Faust, Assistant Professor, Psychology Department, UNC Charlotte &
Joshua Eyer, M.S., Doctoral Student, Psychology Department, UNC Charlotte

Eligibility. You may participate in this study if you are (a) a UNC Charlotte student, (b) 18 years of age or older, (c) a native speaker of English, and (d) right-handed with (e) normal or corrected-to-normal vision. You may be ineligible for this study if you have (e) an existing condition that might affect your ability to view, remember, and recall visual images or visually induced seizures. Vision should be good enough to view images displayed on a computer screen. You may and should wear eyeglasses or contact lenses if you need them. Any data collected from those not eligible for the study will be confidentially destroyed.

Overall Description of Participation. This is a two-stage study completed over two sessions. During Stage One, you will be asked to complete a number of measures related to your current emotional state and past difficulties with memory, attention, and stress. During Stage Two, you will be trained in a simple memory task using images presented on a computer screen. Once you have mastered this part of the task, you will move on to the experiment, again involving images displayed on a computer screen, during which EEG recordings will be made of your brain waves. To do this, you will be asked to wear a cap (like a swim cap) containing electrodes that will record the electrical activity in your brain. A mild abrasive cleanser will be used on your skin to eliminate facial oils where the electrodes will be placed. A gel (similar in consistency to hair styling gel) will be inserted between your scalp and the electrodes, which do not actually touch your scalp directly. This will allow the electrical signals from your brain to be transmitted to the electrodes in the cap. Several spots on your face will be cleaned with alcohol wipes, a layer of gel will be applied and electrodes taped in place on top of the gel, allowing recording of eye and facial movements. Following participation, you will need to wash the gel from your hair as it will dry in a manner similar to a very strong hair styling gel. The gel is water soluble and easily washed out, even after it dries. After completion, you will be tested on your memory for these images. During the task, you will be given regular breaks, and after completion, you will be debriefed on the purpose of the study and given the chance to ask questions.

Length of Participation. The total study time will be approximately 4 hours (240 min) over two periods. For Stage One, you will be oriented to the study and complete several measures for approximately 90 min. For the second stage, you will complete several computer-based tasks for approximately 150 minutes, divided into 30 min of testing, 45 min of training, 50 min of experiment, 15 min of testing, and 10 min to discuss your participation. Credit will be awarded at the end of Stage Two. No partial credit will be granted to eligible participants. If you decide to participate, you will be 1 of 60–80 participants in this study.

Risks of Participation. The only foreseeable risks associated with this study are minimal. They are that you may experience some frustration or cognitive fatigue related to performing the cognitive task or some minor discomfort when completing the measures related to thinking about how you are feeling, while viewing some of the images, or during the application of the electrode cap. However, you should feel no pain or experience no harm during this process and should inform the researcher if you feel any discomfort. The gel and tape used to hold some electrodes in place are hypoallergenic and pose no known risk of allergic reaction.

Benefits of Participation. This research will help us all to understand better how different factors affect memory. If this research is of interest to you, you may enjoy your participation and will have the option of viewing a recording of your brain. Finally, if you signed up for this study on the Department of Psychology Research Signup system, you will be awarded **4 credits** for your participation.

Volunteer Statement. You are a volunteer. The decision to participate in this study is completely up to you. If you decide to be in the study, you may stop at any time with no penalty. You will not be treated any differently if you decide not to participate in the study or if you stop once you have started. You will still receive credit for your participation.

Confidentiality Statement. At the start of the study, your name will be linked with a number. All data collected by these investigators will be archived using this number. The data will not contain any information able to link to you or your participation in this study. Computer records and other recordings will never include your name, social security number, or any other information that would allow anyone to know that the data came from you. The only document linking your name with the number will be kept in a secured location separate from the data until the study is completed, whereupon it will be destroyed.

Statement of Fair Treatment and Respect. UNC Charlotte wants to make sure that you are treated in a fair and respectful manner. Contact the UNCC Research Compliance Office (704-687-3309) if you have any questions about how you are treated as a study participant. If you have any questions about the project, please contact Dr. Mark Faust (704-687-3564, mefaust@uncc.edu).

Approval Date. This form was approved for use on **02/08/10** for the period of one year.

Participant Consent. I have read the information in this consent form. I have had the chance to ask questions about this study, and those questions have been answered to my satisfaction. I am at least 18 years of age, and I agree to participate in this research project. I understand that, if desired, I will receive a copy of this form after it has been signed by me and the principal investigator.

Printed Name	Signature of Participant	Date
	Signature of Investigator	Date

Biographical Information Form (Part 1)

Number: ________________ Age (in years/months): ________/________

Gender: ______________ Ethnicity (ask): ________________ Year in School: ___________

EXCLUSION CRITERIA:

HANDEDNESS (SELF-REPORT): RIGHT / LEFT / AMBIDEXTROUS LQ: ___________

NATIVE SPEAKER OF ENGLISH? Y / N

OTHER LANGUAGES:

1) ___________________ LEVEL: Basic / Conversant / Proficient / Fluent / Bilingual / Native

2) ___________________ LEVEL: Basic / Conversant / Proficient / Fluent / Bilingual / Native

3) ___________________ LEVEL: Basic / Conversant / Proficient / Fluent / Bilingual / Native

Do you have a condition that would substantially reduce your performance reading, remembering, and recalling words or images presented on a computer screen? Y / N

Have you ever experienced a seizure caused by something you have seen? Y / N

Edinburgh Handedness Inventory (Revised)

Please mark the box that best describes which hand you use for the activity in question

	Always Left	*Usually Left*	*No Preference*	*Usually Right*	*Always Right*
Writing					
Throwing					
Scissors					
Toothbrush					
Knife (without fork)					
Spoon					
Match (when striking)					
Computer mouse					

* **"A major revision of the Edinburgh Handedness Inventory" by Dr Stephen M. Williams**

rev. 1/21/10 (J. Eyer)

BDI-SF

PARTICIPANT NUMBER: ________

This questionnaire contains groups of statements. Please read each group of statements carefully, then pick out the one statement in each group which <u>best</u> describes the way you have been feeling over the past week, including today. Circle the number next to the statement you picked. If several statements in the group seem to apply equally well, circle each one. Be sure to read all the statements in each group before marking your choice.

A

0 I do not feel sad.
1 I feel sad.
2 I am sad all the time and I can't snap out of it.
3 I am so sad or unhappy that I can't stand it.

B

0 I am not particularly discouraged about the future.
1 I feel discouraged about the future.
2 I feel I have nothing to look forward to.
3 I feel that the future is hopeless and that things cannot improve.

C

0 I do not feel like a failure.
1 I feel I have failed more than the average person.
2 As I look back on my life, all I can see is a lot of failure.
3 I feel I am a complete failure as a person.

D

0 I get as much satisfaction out of things as I used to.
1 I don't enjoy things the way I used to.
2 I don't get real satisfaction out of anything anymore.
3 I am dissatisfied or bored with everything.

E

0 I don't feel particularly guilty.
1 I feel guilty a good part of the time.
2 I feel quite guilty most of the time.
3 I feel guilty all of the time.

F

0 I don't feel I am being punished.
1 I feel I may be punished.
2 I expect to be punished.
3 I feel I am being punished.

G

0 I don't feel disappointed in myself.
1 I am disappointed in myself.
2 I am disgusted with myself.
3 I hate myself.

H

0 I don't feel I am worse than anybody else.
1 I am critical of myself for my weakness or mistakes.
2 I blame myself all the time for my faults.
3 I blame myself for everything bad that happens.

I

0 I don't have any thoughts of killing myself.
1 I have thoughts of killing myself, but I would not carry them out.
2 I would like to kill myself.
3 I would kill myself if I had the chance.

J

0 I don't cry anymore than usual.
1 I cry more now than I used to.
2 I cry all the time now.
3 I used to be able to cry, but now I can't cry even though I want to.

K

0 I am no more irritated now than I ever am.
1 I get annoyed or irritated more easily than I used to.
2 I feel irritated all the time now.
3 I don't get irritated at all by the things that used to irritate me.

L

0 I have not lost interest in other people.
1 I am less interested in other people than I used to be.
2 I have lost most of my interest in other people.
3 I have lost all of my interest in other people.

M

0 I make decisions about as well as I ever could.
1 I put off making decisions at all anymore.
2 I have greater difficulty in making decisions than before.
3 I can't make decisions at all anymore.

Investigator Initials: _______

FFMQ

PARTICIPANT NUMBER: ________

Please rate each of the following statements using the scale provided. Write the number in the blank that best describes your own opinion of what is generally true for you.

1	2	3	4	5
Never or Very Rarely True	Rarely True	Sometimes True	Often True	Very Often or Always True

_____ 1. When I'm walking, I deliberately notice the sensations of my body moving.

_____ 2. I'm good at finding words to describe my feelings.

_____ 3. I criticize myself for having irrational or inappropriate emotions.

_____ 4. I perceive my feelings and emotions without having to react to them.

_____ 5. When I do things, my mind wanders off and I'm easily distracted.

_____ 6. When I take a shower or bath, I stay alert to the sensations of water on my body.

_____ 7. I can easily put my beliefs, opinions, and expectations into words.

_____ 8. I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.

_____ 9. I watch my feelings without getting lost in them.

_____ 10. I tell myself I shouldn't be feeling the way I'm feeling.

_____ 11. I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.

_____ 12. It's hard for me to find the words to describe what I'm thinking.

_____ 13. I am easily distracted.

_____ 14. I believe some of my thoughts are abnormal or bad and I shouldn't think that way.

_____ 15. I pay attention to sensations, such as the wind in my hair or sun on my face.

_____ 16. I have trouble thinking of the right words to express how I feel about things

_____ 17. I make judgments about whether my thoughts are good or bad.

_____ 18. I find it difficult to stay focused on what's happening in the present.

_____ 19. When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it.

_____ 20. I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.

(Please continue on the next page.)

FFMQ continued.

PARTICIPANT NUMBER: ________

1	2	3	4	5
Never or Very Rarely True	Rarely True	Sometimes True	Often True	Very Often or Always True

_____ 21. In difficult situations, I can pause without immediately reacting.

_____ 22. When I have a sensation in my body, it's difficult for me to describe it because I can't find the right words.

_____ 23. It seems I am "running on automatic" without much awareness of what I'm doing.

_____ 24. When I have distressing thoughts or images, I feel calm soon after.

_____ 25. I tell myself that I shouldn't be thinking the way I'm thinking.

_____ 26. I notice the smells and aromas of things.

_____ 27. Even when I'm feeling terribly upset, I can find a way to put it into words.

_____ 28. I rush through activities without being really attentive to them.

_____ 29. When I have distressing thoughts or images I am able just to notice them without reacting.

_____ 30. I think some of my emotions are bad or inappropriate and I shouldn't feel them.

_____ 31. I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.

_____ 32. My natural tendency is to put my experiences into words.

_____ 33. When I have distressing thoughts or images, I just notice them and let them go.

_____ 34. I do jobs or tasks automatically without being aware of what I'm doing.

_____ 35. When I have distressing thoughts or images, I judge myself as good or bad, depending what the thought/image is about.

_____ 36. I pay attention to how my emotions affect my thoughts and behavior.

_____ 37. I can usually describe how I feel at the moment in considerable detail.

_____ 38. I find myself doing things without paying attention.

_____ 39. I disapprove of myself when I have irrational ideas.

WBSI

PARTICIPANT NUMBER: ________

This survey is about thoughts. There are no right or wrong answers, so please respond honestly to each of the items below. Be sure to answer every item by circling the appropriate letter beside each.

1. There are things I prefer not to think about.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
2. Sometimes I wonder why I have the thoughts I do.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
3. I have thoughts that I cannot stop.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
4. There are images that come to mind that I cannot erase.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
5. My thoughts frequently return to one idea.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
6. I wish I could stop thinking of certain things.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
7. Sometimes my mind races so fast I wish I could stop it.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
8. I always try to put problems out of mind.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
9. There are thoughts that keep jumping into my head.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
10. There are things that I try not to think about.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
11. Sometimes I really wish I could stop thinking.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
12. I often do things to distract myself from my thoughts.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
13. I have thoughts that I try to avoid.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
14. There are many thoughts that I have that I don't tell anyone.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree
15. Sometimes I stay busy just to keep thoughts from intruding on my mind.	Strongly Disagree	Disagree	Neutral or Don't Know	Agree	Strongly Agree

PSS

PARTICIPANT NUMBER: ________

Instructions: The questions in this scale ask you about your feelings and thoughts during the last month. In each case, please circle how often you felt or thought a certain way.

1. In the last month, how often have you been upset because of something that happened unexpectedly?	Never	Almost Never	Sometimes	Fairly Often	Very Often
2. In the last month, how often have you felt that you were unable to control the important things in your life?	Never	Almost Never	Sometimes	Fairly Often	Very Often
3. In the last month, how often have you felt nervous and "stressed"?	Never	Almost Never	Sometimes	Fairly Often	Very Often
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	Never	Almost Never	Sometimes	Fairly Often	Very Often
5. In the last month, how often have you felt that things were going your way?	Never	Almost Never	Sometimes	Fairly Often	Very Often
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	Never	Almost Never	Sometimes	Fairly Often	Very Often
7. In the last month, how often have you been able to control irritations in your life?	Never	Almost Never	Sometimes	Fairly Often	Very Often
8. In the last month, how often have you felt that you were on top of things?	Never	Almost Never	Sometimes	Fairly Often	Very Often
9. In the last month, how often have you been angered because of things that were outside of your control?	Never	Almost Never	Sometimes	Fairly Often	Very Often
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	Never	Almost Never	Sometimes	Fairly Often	Very Often

Biographical Information Form (Part 2)

Number: ____________________

VISION:	Do you need glasses to see a computer screen (Farsighted)?	Y / N
	If yes, is the participant wearing . . .	GLASSES / CONTACTS / NONE

OTHER VARIABLES AFFECTING PERFORMANCE:

Are you currently taking any medications that might affect your performance on this task? Y / N

How much sleep did you get last night? _______________ (hrs)

How long ago did you last eat? _______________ (min)

Other Comments:

rev. 1/21/10 (J. Eyer)

RRS

PARTICIPANT NUMBER: ________

People think and do many different things when they feel depressed. Please read each of the items below and indicate whether you never, sometimes, often, or always think or do each one when you feel down, sad, or depressed. Please indicate what you *generally* do, not what you think you should do.

HOW OFTEN DO YOU:

1. Think about how alone you feel.	Never	Sometimes	Often	Always
2. Think "I won't be able to do my job if I don't snap out of this."	Never	Sometimes	Often	Always
3. Think about your feelings of fatigue and achiness.	Never	Sometimes	Often	Always
4. Think about how hard it is to concentrate.	Never	Sometimes	Often	Always
5. Think "What am I doing to deserve this?"	Never	Sometimes	Often	Always
6. Think about how passive and unmotivated you feel.	Never	Sometimes	Often	Always
7. Analyze recent events to try to understand why you are depressed.	Never	Sometimes	Often	Always
8. Think about how you don't seem to feel anything anymore.	Never	Sometimes	Often	Always
9. Think "Why can't I get going?"	Never	Sometimes	Often	Always
10. Think "Why do I always react this way?"	Never	Sometimes	Often	Always
11. Go away by yourself and think about why you feel this way.	Never	Sometimes	Often	Always
12. Write down what you are thinking about and analyze it.	Never	Sometimes	Often	Always
13. Think about a recent situation, wishing it had gone better.	Never	Sometimes	Often	Always
14. Think "I won't be able to concentrate if I keep feeling this way."	Never	Sometimes	Often	Always
15. Think "Why do I have problems other people don't have?"	Never	Sometimes	Often	Always
16. Think "Why can't I handle things better?"	Never	Sometimes	Often	Always
17. Think about how sad you feel.	Never	Sometimes	Often	Always
18. Think about all your shortcomings, failings, faults, mistakes.	Never	Sometimes	Often	Always
19. Think about how you don't feel up to doing anything.	Never	Sometimes	Often	Always
20. Analyze your personality to try to understand why you are depressed.	Never	Sometimes	Often	Always
21. Go someplace alone to think about your feelings.	Never	Sometimes	Often	Always
22. Think about how angry you are with yourself.	Never	Sometimes	Often	Always

MAAS

PARTICIPANT NUMBER: ________

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what *really reflects* your experience rather than what you think your experience should be. Please treat each item separately from every other item.

1	2	3	4	5	6
Almost Always	Very Frequently	Somewhat Frequently	Somewhat Infrequently	Very Infrequently	Almost Never

1. I could be experiencing some emotion and not be conscious of it until some time later.	1	2	3	4	5	6
2. I break or spill things because of carelessness, not paying attention, or thinking of something else.	1	2	3	4	5	6
3. I find it difficult to stay focused on what's happening in the present.	1	2	3	4	5	6
4. I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.	1	2	3	4	5	6
5. I tend not to notice feelings of physical tension or discomfort until they really grab my attention.	1	2	3	4	5	6
6. I forget a person's name almost as soon as I've been told it for the first time.	1	2	3	4	5	6
7. It seems I am "running on automatic," without much awareness of what I'm doing.	1	2	3	4	5	6
8. I rush through activities without being really attentive to them.	1	2	3	4	5	6
9. I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.	1	2	3	4	5	6
10. I do jobs or tasks automatically, without being aware of what I'm doing.	1	2	3	4	5	6
11. I find myself listening to someone with one ear, doing something else at the same time.	1	2	3	4	5	6
12. I drive places on 'automatic pilot' and then wonder why I went there.	1	2	3	4	5	6
13. I find myself preoccupied with the future or the past.	1	2	3	4	5	6
14. I find myself doing things without paying attention.	1	2	3	4	5	6
15. I snack without being aware that I'm eating.	1	2	3	4	5	6

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Debriefing: ***ERP Evidence for Individual Differences in Memory Processes***

Subject ID: ____________________________ **Date:** ___________________________

Please complete the questions on the following two pages related to your participation in the study.

Question 1. Describe any strategies or techniques you used to help yourself remember the pairs better?

Question 2. When instructed to suppress certain images, did you use specific strategies to avoid consciously remembering them? Describe these strategies.

Question 3. Did you find it easier to avoid thinking about certain images over others (i.e., negative or neutral)? If so, which one did you find easier? Why do you think that is?

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Question 4. Did you find anything distracting or disrupting while you were doing the task? Describe these distractions.

Question 5. Is there any reason your performance may have suffered today? Please explain these reasons.

Question 6. On a scale of 1 to 5, rate your ability to perform the red border ("no-think") part of the experiment?

1	2	3	4	5
Really Well	Well	Not Sure or Neither Well nor Not Well	Poorly	Really Poorly

Question 7. Have you previously learned how to meditate or another meditation/mindfulness technique? If yes, please describe the training you received and how often you meditate or do mindfulness relaxation?

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Debriefing: ***ERP Evidence for Individual Differences in Memory Processes***

The purpose of the study you participated in today is to examine the ability of people to regulate how memories are retrieved. People are often confronted with reminders of things they would prefer not to think about. When this happens, they often attempt to put the unwanted memories out of awareness. Recent research shows that people have the capacity to actively suppress retrieving such memories. For example, if a certain person reminds you of a negative event in your life, when you see that person's face, it may cause you to remember that negative event. However, you may also be able to prevent yourself from making that connection, keeping the negative memory from coming to mind.

Today, we asked you to learn face-picture associations, and then, for some of these pairs, we asked you not to think about the associated picture when you saw the face matched with it. By doing this we were measuring your ability to suppress or halt the retrieval of an unwanted memory. We measured how well you did this suppression task both by measuring your brain response when you were asked to suppress the associated picture and by a final memory test.

The questionnaires you were administered before the experiment began were additional measures of styles of thinking that may help or hinder performance on the task. The images presented were also divided into neutral and negative stimuli, as research has shown that some people are better able to suppress the negative images than others. If the results found are significant, this research could have important implications for clinical psychologists as it will improve their ability to distinguish and treat symptoms of difficulties controlling thoughts and may help us understand why some people are better than others.

Thank you for your participation in our research project!

(Please remove this sheet to take with you.)