2005

Ego Depletion, Working Memory, and the Executive Function of the Self

Brandon J. Schmeichel
EGO DEPLETION, WORKING MEMORY, AND THE EXECUTIVE FUNCTION OF THE SELF

By

BRANDON J. SCHMEICHEL

A Dissertation submitted to the Department of Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Degree Awarded: Summer Semester, 2005
The members of the Committee approve the Dissertation of Brandon J. Schmeichel defended on May 20th, 2005.

__________________________________
Roy F. Baumeister
Professor Directing Dissertation

__________________________________
Eddy Nahmias
Outside Committee Member

__________________________________
Dianne M. Tice
Committee Member

__________________________________
Jon K. Maner
Committee Member

__________________________________
Colleen M. Kelley
Committee Member

The Office of Graduate Studies has verified and approved the above named committee members.
ACKNOWLEDGEMENTS

Thank you to Roy Baumeister, Dianne Tice, and the members of my dissertation committee for their inspiration and expert guidance, and to Charlie Johnston, Will McIntosh, and my family for their enduring influence. I am grateful to Kristin Berglund, Olivia Gambale, Nicole Hover, Michael Pyle, Megan Schwartz, Erik Sellas, Sommer Shelley, Katie Roberson, and Kelly Weinstein for helping to conduct these studies, to the National Institute of Mental Health for fellowship support (MH 069139), and to Kate Catanese, Matt Gailliot, Anne Geyer, and Kathleen Vohs for their valuable contributions. Special thanks to Eden Silverman for her thoughtful advice and tender support.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Tables</td>
<td>v</td>
</tr>
<tr>
<td>Abstract</td>
<td>vi</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Attention Control and Working Memory</td>
<td>1</td>
</tr>
<tr>
<td>Self-Control Strength and Attention Control</td>
<td>2</td>
</tr>
<tr>
<td>Overview of Present Research</td>
<td>4</td>
</tr>
<tr>
<td>STUDY 1</td>
<td>5</td>
</tr>
<tr>
<td>STUDY 2</td>
<td>8</td>
</tr>
<tr>
<td>STUDY 3</td>
<td>11</td>
</tr>
<tr>
<td>STUDY 4</td>
<td>17</td>
</tr>
<tr>
<td>GENERAL DISCUSSION</td>
<td>23</td>
</tr>
<tr>
<td>Depleted Strength and Divided Attention</td>
<td>23</td>
</tr>
<tr>
<td>Implications and Future Directions</td>
<td>25</td>
</tr>
<tr>
<td>APPENDIX A: HUMAN SUBJECTS APPROVAL LETTER (STUDIES 1 – 3)</td>
<td>30</td>
</tr>
<tr>
<td>APPENDIX B: HUMAN SUBJECTS APPROVAL LETTER (STUDY 4)</td>
<td>32</td>
</tr>
<tr>
<td>APPENDIX C: INFORMED CONSENT FORM (STUDIES 1 – 3)</td>
<td>34</td>
</tr>
<tr>
<td>APPENDIX D: INFORMED CONSENT FORM (STUDY 4)</td>
<td>36</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>39</td>
</tr>
<tr>
<td>BIOGRAPHICAL SKETCH</td>
<td>44</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1: Operation Span Scores by Attention-Control or No Control Condition (Study 1) .......................................................... 26
Table 2: Sentence Span Scores by Attention-Control or No Control Condition (Study 2) .......................................................... 27
Table 3: Working Memory Scores by Task-Order and Viewing-Instruction Condition (Study 3) .......................................................... 28
Table 4: Cold Pressor Persistence by Reading Condition and Cognitive Load Condition (Study 4) .......................................................... 29
ABSTRACT

The ability to alter, regulate, or otherwise control one’s own behavior is a valuable but limited human capacity. Good self-control facilitates success in life, but self-control attempts often fail. The present work examined two causes of self-control failure, divided attention and depleted self-control strength, and sought to demonstrate that these are closely related but separate causes of self-control failure. In Studies 1 and 2, controlling (vs. not controlling) attention at the start of the study reduced the ability to divide attention during a subsequent test of working memory, indicating that the ability to control attention relies on a depletable internal resource or strength. In Study 3, performing (vs. not performing) a test of divided attention impaired subsequent emotion suppression ability, indicating that the act of dividing attention depletes the same strength that underlies dissimilar forms of self-control. In Study 4, regulating (vs. not regulating) emotional expression reduced subsequent pain tolerance, but concurrent divided attention did not reduce pain tolerance, indicating that divided attention and depleted strength have different effects on behavior. The findings converge to show that divided attention and self-control strength are related but distinct determinants of the capacity for self-control.
INTRODUCTION

Human behavior is shaped by forces that escape conscious awareness, but behavior may also be consciously intended. When people actively resist temptation, make choices, or plan for the future they exercise conscious self-control over their own behavior. Self-control refers to any attempt to alter, override, or otherwise manage one’s habitual, normal, or natural response (Baumeister & Heatherton, 1996). People who excel at self-control enjoy more satisfying interpersonal relationships, more success at school and work, higher self-esteem, and better health than people who are poor at self-control (e.g., Finkel & Campbell, 2001; Mischel, Shoda, & Peake, 1988; Tangney, Baumeister, & Boone, 2004). Simply said, self-control facilitates success in life.

Despite its undeniable benefits, self-control often fails. For instance, many types of addiction, crime, and mental and physical illness signal failures of self-control (Baumeister, Heatherton, & Tice, 1994; Davidson, Jackson, & Kalin, 2000; Gottfredson & Hirschi, 1990; Sayette, 2003; Tiffany, 1990; Tomarken & Keener, 1998). One cause of self-control failure is divided attention. Good self-control typically requires focused attention and awareness, hence distracted or divided attention undermines self-control. For example, dieters are more likely to inhibit food intake when they focus attention on dietary goals. Distracting dieters’ attention away from dietary goals disinhibits their food consumption (e.g., Ward & Mann, 2000). Another cause of self-control failure is previous acts of self-control. Exercising self-control appears to deplete a limited internal resource or strength, such that subsequent acts of self-control suffer as a result (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven & Baumeister, 2000). For example, dieters eat more when they have recently expended self-control strength in another domain (e.g., Kahan, Polivy, & Herman, 2003; Vohs & Heatherton, 2000).

The purpose of the present investigation was to test a set of hypotheses first relating divided attention and self-control strength to each other and then differentiating them as causes of self-control failure. The guiding premise of this work was that attention control and self-control strength are inextricably linked, but that self-control strength is the broader capacity. Self-control strength is believed to underlie attention control as well as other forms of self-control that are not predicated on focused attention. If this is true, then attention control should be impaired by prior self-control, and self-control should be impaired by prior attention control, because attentional and other forms of self-control rely on the same depletable strength. However, divided attention and depleted strength should have distinct effects on self-control that does not depend on focused attention. Prior self-control should impair even acts of self-control that are not affected by divided attention, thus differentiating depleted strength and divided attention as determinants of self-control failure.

Attention Control and Working Memory

The present work builds on theories relating attention control to working memory. Beginning with Baddeley and Hitch’s (1974) prominent model, working memory has been conceptualized as the ability to direct and control attention. By controlling the focus of attention, individuals actively determine which stimuli in the environment they contemplate and they control which thoughts are kept in conscious awareness and which ones are ignored or

\footnote{Some models of working memory also include ‘slave systems’ or other secondary components, but a central executive or attention control component is vital to most models (see Baddeley, 1996; Kane & Engle, 2003; Miyake & Shah, 1999). The present work focuses exclusively on the attention control aspect of working memory.}
forgotten (Baddeley, 1986; 1996; Engle, 2002; Feldman Barrett, Tugade, & Engle, 2004; Kane, Bleckley, Conway, & Engle, 2001; Logan, 2002). The capacity to control attention and manipulate the contents of conscious thought is a vital function of the human brain and mind that underlies a broad range of cognitive processes. For example, individual differences in attention control have been tied to differences in reading comprehension (Daneman & Carpenter, 1980), response inhibition (Kane & Engle, 2003), logical reasoning (Kane et al., 2004), and impulsive decision making (Hinson, Jameson, & Whitney, 2003). In each case, people with high working memory capacities (i.e., superior attention control abilities) outperform people with low capacities.

In addition to individual differences in capacity, the operation of working memory is also influenced by simultaneous cognitive activity. When attention must be divided between multiple concurrent tasks, performance on at least one of the tasks tends to suffer. For example, compared to studying list words, studying list words while performing other mental operations produces poorer memory for the words (Turner & Engle, 1989). Similarly, memory for the details of a melodramatic movie is impaired if the viewer attends to and suppresses emotional reactions while watching, compared to watching without suppression (Richards & Gross, 2000). Other forms of self-control are also impaired by divided attention. For example, one study found that an absorbing distraction undermined concurrent self-control of food consumption (Ward & Mann, 2000). These patterns indicate that the conscious workspace in working memory is finite, and dividing the workspace to accommodate concurrent tasks disrupts the operation of working memory.

Implicit in most conceptions of working memory is the view that, when the load on working memory is lifted and attention is no longer divided between tasks, attention control capacity rebounds immediately to pre-load levels. Hence, dividing attention between a melodramatic movie and one’s emotional responses to it would not impair the ability to control attention after the movie ends because working memory rebounds to full capacity when attention is undivided. In this view, the operation of working memory is restricted by the demands of the present moment, and activity from the recent past has little or no lasting consequence for ongoing working memory (i.e., attention control) capacity. The present research tested alternative predictions regarding cross-temporal fluctuations in the control of attention derived from the strength model of self-control. Specifically, I examined whether attention control impairs, and is impaired by, consecutive acts of self-control.

Self-Control Strength and Attention Control

The strength model of self-control proposes that acts of self-control consume a limited internal resource or strength. Like a muscle or an energy source, self-control strength is temporarily depleted by use and it rebounds to pre-exertion levels only after a rest or delay (Baumeister et al., 1998; Muraven & Baumeister, 2000). When self-control strength is low, known as a state of ego depletion, further attempts at self-control are prone to failure. Over 30 published studies have supported this basic premise of the strength model: Varied acts of self-control rely on the same depletable resource, such that performing one act of self-control temporarily impairs the ability to perform others (e.g., Muraven, Tice, & Baumeister, 1998; Richeson & Shelton, 2003; Vohs, Baumeister, & Ciarocco, 2005; Vohs & Schmeichel, 2003). As one example, compared to consuming delicious chocolates, resisting the temptation to consume chocolates reduced subsequent persistence at a difficult task (Baumeister et al., 1998).
Most germane to the present work is recent evidence that complex thought processes are impaired by ego depletion. Specifically, exercising self-control over attention or emotional responding impaired performance on subsequent tests of logical reasoning and reading comprehension, but initial tasks that did not require self-control did not affect later performance (Schmeichel, Vohs, & Baumeister, 2003). Thus, the self-control of attention or emotion appeared to deplete the same strength needed to direct high-level cognitive performance. Simpler, more automatic or routine cognitive tasks such as retrieving general knowledge from long-term memory were not affected by prior self-control, indicating that tasks that require little or no self-control are not adversely affected by depleted self-control strength.

The cognitive tasks that have proven vulnerable to impairment by ego depletion, such as cognitive estimation and logical reasoning, require some degree of control over attention, consistent with the possibility that working memory (i.e., attention control) capacity may be reduced by prior acts of self-control (Richeson & Shelton, 2003; Schmeichel et al., 2003). However, logical reasoning and other complex cognitive performances are not explainable in terms of attention control or working memory alone. For example, a recent analysis of the relationship between working memory and fluid intelligence concluded that the two abilities are not isomorphic (Kane et al., 2004). Thus, although past findings of cognitive impairment after self-control are consistent with the idea that working memory is impaired by ego depletion, it is possible that some other aspect of performance besides the ability to control attention was affected by depletion. The specific hypothesis that attention control is impaired by prior self-control has not been tested. Therefore, the present investigation began with a conservative and unambiguous test of the effect of initial self-control on the subsequent ability to divide or control attention (i.e., the operation of working memory).

The present work was also concerned with the differences between depleted strength and divided attention. The most obvious difference relates to the dimension of time. Divided attention undermines concurrent attempts at self-control, whereas the effects of depleted self-control strength unfold over time and are inferred from consecutive, not concurrent, impairments in self-control ability.

It is plausible that the effects of depleted self-control strength are due to divided attention, in which case there may be no difference between depleted strength and divided attention. That is, perhaps the effect of initial self-control on later self-control is simply another instance of self-control failure due to divided attention. For instance, the cognitive salience of a recent self-control attempt may occupy a prominent place in conscious awareness even after the self-control attempt has concluded (e.g., Wegner, 1994). If this is so, then current self-control may be impaired by prior self-control because attention is divided between the current self-control attempt and the previous one. If divided attention is the mechanism by which prior self-control impairs later self-control, then prior self-control and concurrent divided attention should have similar effects on self-control ability.

However, according to the strength model, consecutive decrements in self-control are due to depleted self-control strength, not divided attention (Baumeister et al., 1998). Thus, depleted strength and divided attention should have different effects on self-control, particularly forms of self-control that do not critically depend on focused attention. For example, the ability to tolerate pain requires self-control (e.g., Rosenbaum, 1980), but evidence suggests that divided attention does not impair pain tolerance (e.g., Grimm & Kanfer, 1976; McCaul & Haugtvedt, 1982). Self-control that is not impaired by divided attention may nevertheless be undermined by depleted self-control strength. If the effects of prior self-control are different from the effects of
concurrent divided attention, then it would appear that depleted strength and divided attention are distinct causes of self-control failure. Therefore, the present investigation also tested the hypothesis that prior self-control and concurrent divided attention may have different effects on self-control.

Overall, the view that self-control draws on a depletable internal strength suggests two hypotheses relating divided attention and self-control strength. First, insofar as dividing attention between multiple tasks is an effortful act of self-control that requires intention and conscious awareness (e.g., Gilbert, Krull, & Pelham, 1988; Logie, Cocchini, Delia Sala, & Baddeley, 2004; Wegner, 1994), then the ability to divide attention should be impaired by prior acts of self-control. Second, the act of dividing attention should itself deplete self-control strength and therefore impair subsequent self-control. Thus, the strength model predicts relationships between self-control and divided attention that stand in addition to the well-established finding of poorer concurrent self-control due to divided attention. Moreover, the strength model proposes a third hypothesis differentiating divided attention from depleted strength: Prior self-control and concurrent divided attention should have different effects on self-control attempts that do not depend on focused attention.

Overview of Present Research

Four studies tested whether attention control depends on self-control strength and whether the effects of depleted strength could be distinguished from divided attention. I first examined whether an initial act of attention control would undermine subsequent attempts to divide attention. Specifically, Studies 1 and 2 tested the prediction that exercising self-control over attention would impair the ability to divide attention on subsequent tests of working memory (the operation span task and the sentence span task, respectively), as compared to performing an initial exercise that did not require attention control. Study 3 tested whether the self-control of emotional expressions would impair the ability to divide attention on a subsequent test of working memory, despite the fact that the self-control of emotional expression appears to be only minimally related to working memory or attention control. Study 3 also reversed the order of these tasks, to test the prediction that dividing attention consumes self-control strength and therefore impairs subsequent acts of self-control.

Having thus shown that attention control relies on self-control strength, I then compared directly the effects of depleted strength and divided attention. If (as argued above) self-control strength is the more general cause of self-control failure, then some forms of self-control should be impaired by depleted strength but not by divided attention. Participants in Study 4 performed a test of pain tolerance (the cold pressor test) either after exercising or not exercising self-control over emotional expression and either with or without dividing attention during the cold pressor test. I predicted that the initial exercise in self-control would impair pain tolerance, but that concurrent divided attention would not impair pain tolerance, indicating that depleted strength and divided attention are distinct determinants of self-control failure.
STUDY 1

Study 1 tested the hypothesis that exercising self-control over attention would reduce subsequent working memory capacity. In the first phase of the study, participants watched a video clip of a woman talking as a series of words appear at the bottom of the screen. Participants in the attention control (ego depletion) condition were asked to focus their attention on the woman in the scene and to ignore the words at the bottom of the screen. Participants in the no control (no depletion) condition were asked simply to watch the clip and no mention was made of the irrelevant words. Thus, one group exercised self-control by keeping attention focused on only a part of the TV screen whereas the other group did not exercise self-control and attended to the TV screen in a free and unrestricted manner (see Schmeichel et al., 2003).

After the video clip and a mood measure, participants performed a test of divided attention – the operation span task (Turner & Engle, 1989). This task required participants to divide attention between performing mathematical calculations and trying to remember target words. Thus, the task tapped the operation of working memory, specifically managing attention and manipulating the contents of conscious thought.

The prediction was that carefully controlling (vs. not controlling) attention at the start of study would impair the ability to divide attention on the operation span task later on because the initial task depleted self-control strength. Impaired ability to divide attention would be evident in worse memory for the target words, incorrect evaluations of the math equations, or impairments in both aspects of the operation span task. Some evidence suggests that simple mathematical calculations like those included in the operation span task are achieved by automatic or routine cognitive processes that do not require a great deal of attention or self-control (e.g., Muraven et al., 1998). If this is true, then performance on the math portion of the test may proceed unaffected by depleted self-control strength. Nevertheless, I examined performance on both aspects of the test to measure fluctuations in the ability to divide attention.

Method

Participants. Eighty-five undergraduate students (66 women) enrolled in an introductory psychology class at Florida State University participated in exchange for course credit. Data from 6 participants (2 in the attention control condition and 4 in the no control condition) were excluded from all analyses due to failure to follow instructions or equipment failure, leaving a final sample of 79 students.

Materials and Procedure. In the first phase of the study, participants watched a 6-minute video clip depicting a woman being interviewed by an off-camera interviewer. The clip was played without audio, purportedly because the study concerned impressions of others’ nonverbal behavior. In addition to the woman being interviewed, a series of common one-syllable words (e.g., play) appeared at the bottom of the screen for 30 seconds each. The words were printed in black, framed by a white background, and confined to the bottom third of the screen. Thus, the words were clearly visible but did not dominate the main action on the screen (i.e., the interview). The words were unrelated to the interview, and none of the words appeared in the subsequent memory test.

Half the participants were randomly assigned simply to watch the woman being interviewed and were given no instructions regarding the irrelevant words at the bottom of the screen (no control condition). The other participants were instructed to watch the interview and also to “avoid looking at or reading any words that may appear on the screen”. Moreover, these participants were told to redirect their gaze to the woman being interviewed if they found
themselves looking at the words (attention control condition). After viewing the clip, all participants completed the Brief Mood Inspection Survey (BMIS; Mayer & Gaschke, 1988) as a measure of mood and arousal, and then the experimenter explained the working memory task.

The procedures for the operation span task in the second (final) phase of the study were identical for both groups. The operation span task presented two tasks to be performed concurrently. One task required participants to calculate mathematical equations and decide whether the provided answer was correct or incorrect. For example, participants saw “(9 X 3) – 1 = 2”, and had to indicate (by saying “Yes” or “No”) whether the given answer was correct. (In the example, the correct answer was “No”.) The second aspect of the operation span task was a memory task in which participants read target words and tried to recall them a short time later. One target word was presented after each mathematical equation. Thus, participants read an equation, indicated whether it was correct or incorrect, read a target word, and then advanced to the next equation/word pairing. Participants saw from 2 to 5 equation/word pairings before being prompted to recall the preceding set of target words. There were 15 sets of equation/word combinations in all (three 5-word sets, three 4-word sets, three 3-word sets, and six 2-word sets), presented in the same order for all participants. Participants did not know in advance how many target words they would be required to recall in any given set.

The operation span task was administered on a computer and participants controlled the presentation of stimuli with their responses. Participants were guided through two practice trials to ensure familiarity with the task. The experimenter recorded how long it took each participant to complete the task and tracked participants’ “Yes” or “No” evaluations of the math equations.

After the operation span task, participants rated the difficulty of watching the video clip as instructed. This measure served as a check of the self-control demands of the initial attention control task. Participants also rated the difficulty of the memory task, which allowed a test of whether the initial attention task influenced subsequent perceptions of the memory test. Both ratings were made on a scale from 1 = not at all difficult to 7 = very difficult. Then participants were probed for suspicion regarding the purpose of the study, debriefed, and thanked.

Results

Manipulation check. Ratings of the difficulty of the initial viewing task verified that the attention control instructions \( (M = 4.98, SD = 1.51) \) were more difficult to follow than the no control instructions \( (M = 2.95, SD = 1.39) \), \( F (1, 77) = 38.33, p < .001 \). This pattern lends support to the notion that the attention control task required more self-control than the no control task. Moreover, the two groups did not differ in how difficult they found the subsequent working memory task (attention control \( M = 5.12, SD = 1.17 \) vs. no control \( M = 4.76, SD = 1.40 \)), \( F (1, 77) = 1.56, p = .22 \). Thus, although the viewing instructions successfully manipulated the exercise of self-control, they did not alter the perceived difficulty of the subsequent memory test.

Working memory capacity. The primary goal of Study 1 was to determine whether exercising self-control over attention would impair subsequent working memory capacity. The operation span task afforded five measures of working memory capacity (one measure of math performance and four measures of recall: longest single word set, number of sets recalled in full, number of words in full sets, and total words recalled). Each of the recall measures offered modest to strong support for the ego depletion hypothesis. The results are displayed in Table 1. Compared to no-control participants, participants who controlled attention during the initial phase of the study scored worse in terms of the total number of word sets recalled correctly recalled, \( F (1, 77) = 5.93, p = .02 \), and the total number of words in the correctly recalled sets, \( F (1, 77) = 5.19, p = .03 \). Attention control participants also scored marginally worse on the span of
the single longest set recalled correctly, $F(1, 77) = 2.69, p = .10$, and total recall of individual words on the entire test, $F(1, 77) = 2.72, p = .10$. Altogether, the recall patterns indicate that working memory capacity was reduced by a previous act of self-regulation, with two measures revealing significant depletion effects and two measures showing marginally significant effects.

Regarding performance on the mathematical portion of the operation span task, participants in the attention-control and no-control groups gave a similar number of incorrect answers to the equations (attention control $M = 1.95, SD = 1.71$ vs. no control $M = 1.54, SD = 1.46$), $F(1, 77) = 1.30, p = .26$. Thus, the depletion of self-control strength impaired recall performance on the operation span task while math performance was unaffected. Perhaps a floor effect on math errors obscured any potential group-wide differences insofar as both groups had a low rate of incorrect math responses, or perhaps the mathematical calculations were accomplished with automatic and routine processes that do not depend on self-control strength (e.g., Muraven et al., 1998).

Further, because the duration of the task varied with the speed with which participants gave responses, it is possible that group-wide differences in the time to complete the task influenced the observed recall patterns. For example, participants in the attention control condition may have exhibited poorer memory performance because they rushed through the task. This was not the case. The attention control ($M = 394.43$ sec, $SD = 67.62$) and no control ($M = 391.27$ sec, $SD = 74.80$) groups took an equivalent amount of time to complete the task, $F < 1$. Insofar as time spent on task reflects effort expenditure, this finding suggests the two groups did not differ in terms of effort expended on the task. Thus, the effect of ego depletion on subsequent working memory performance was likely not due to changes in working speed or shifts in test-taking strategy as indicated by performance on the mathematical portion of the test.

**Self-reported mood.** The next set of analyses tested whether the attention control and no control tasks differentially affected participants’ moods. If carefully controlling attention while watching the videotape resulted in more negative affect or arousal than simply watching the tape, then working memory performance in the second phase of the study may have been affected by group-wide differences in mood. The mood measure (the BMIS) was administered immediately after the videotape and furnished separate scores for mood valence and arousal. Participants in the attention control condition reported feeling somewhat more negative and aroused than no control participants: for valence, $F(1, 77) = 2.58, p = .11$ (attention control $M = 8.00, SD = 11.38$; no control $M = 12.08, SD = 11.13$), and for arousal, $F(1, 77) = 2.76, p = .10$ (attention control $M = 24.43, SD = 7.88$; no control $M = 21.57, SD = 7.36$). However, controlling for the marginal differences in mood valence and arousal in the analyses of operation span performance did not change the observed pattern of results.

**Discussion**

Study 1 provided initial evidence that prior self-control impairs the capacity to divide attention. Participants who exercised self-control over attention in the first phase of the study performed worse on a subsequent test of working memory than participants who did not carefully control attention in the first phase. More specifically, attention control participants performed worse on the memory portion on the operation span task while math performance was unaffected. Further, mood states, processing speed (as measured by time to complete the test) and treatment of the distracting, mathematical portion of the memory test did not appear to account for the observed differences in recall. Study 1 supports the strength model of self-control: The ability to divide attention between concurrent tasks was impaired by a previous exercise of attention control.
STUDY 2

Study 2 sought to build on Study 1 by examining performance on a different dependent measure of attention control. (Replication using a different depleting self-control task was saved for Study 3.) Working memory capacity can be assessed with a variety of tasks. All working memory span tasks tap the key functions of working memory, specifically the control of attention and the manipulation of thoughts in conscious awareness. However, the specific content of the tasks may vary. For example, some tests of working memory include mathematical calculations as the distracting portion of the test (as the operation span task did in Study 1), whereas others use verbal or spatial distractors. In order to establish the robustness of the effect of depleted self-control strength on the ability to divide attention, I replicated Study 1 using a sentence-span task to assess working memory capacity.

As in Study 1, some participants exercised self-control by carefully controlling the focus of their attention while watching a video clip whereas others did not exercise self-control over attention. After the video clip and a mood measure, participants performed a test of divided attention—a sentence span task. The sentence span task required participants to answer questions about simple statements while also trying to remember the final words from each statement (see Ashcraft & Kirk, 2001; Salthouse & Babcock, 1990). Thus, participants had to divide attention between concurrent tasks but did not have to perform mathematical computations.

Following Study 1, the prediction was that participants who carefully controlled (vs. did not control) attention during the initial video task would show poorer performance on the subsequent sentence span task because the initial attention control task depleted self-control strength. Impaired ability to divide attention during the sentence span task could manifest in poorer performance on the memory portion of the test, more incorrect responses to the content-based multiple choice questions, or both. Therefore, I analyzed performance on both aspects of the sentence span task to assess fluctuations in the ability to divide attention.

Method

Participants. Seventy undergraduate students (46 women) from introductory psychology classes at Florida State University participated in exchange for partial course credit. Data from 8 participants (3 in the attention control condition and 5 in the no control condition) were excluded from all reported analyses, leaving a final sample of 62 students. Of the 8 excluded participants, four reported trying to memorize the irrelevant words on the screen during the viewing task and four indicated taking the same memory test in a different study earlier in the same academic semester.

Materials and Procedure. As in Study 1, participants in the attention control condition carefully controlled attentional focus while watching a video clip and participants in the no control condition watched the same clip without purposefully controlling attention. The video clip and the viewing instructions were the same as in Study 1 (see also Schmeichel et al., 2003). Participants completed a mood scale (BMIS; Mayer & Gaschke, 1988) after the video clip, and then the experimenter explained the working memory task.

The procedures for the sentence span task in the second (final) phase of the study were identical for both groups. On a given trial of the task, the participant heard a sentence and then read and answered a simple multiple-choice question about the sentence they just heard. For example, the experimenter would read aloud a sentence such as “The passengers on the train were happy.” Then, participants consulted a question sheet which contained one multiple-choice
question for every sentence read by the experimenter. In this case, the relevant question was “Where were the passengers?”, and the response options were “On the plane”, “On the boat”, and “On the train”. (The correct answer was “On the train”.) After participants selected a response, the experimenter read the next sentence, participants responded to a short question about it, and so on. Participants performed sets of 2, 3, 4, or 5 of these sentence/question combinations before being prompted to recall the final word from each sentence in the set. Participants completed two practice sets and then 15 experimental sets totaling 50 sentences in all. The sentence/question sets were presented in the same order for each participant and the experimenter surreptitiously timed and recorded the duration of the memory task for each participant.

After the sentence span task, participants rated the difficulty of watching the video clip as they had been instructed and also the difficulty of the sentence span task (both ratings made on a scale from 1 = not at all to 7 = very). Then participants were probed for suspicion and debriefed regarding the true purpose of the study.

Results

Manipulation check. Participants rated the difficulty of watching the videotaped interview as instructed. The attention control instructions were more difficult to follow ($M = 4.45, SD = 1.80$) than the no control instructions ($M = 2.58, SD = 1.88$), $F (1, 60) = 16.02, p < .001$, suggesting that the attention control task required more self-control than the no-control task. The two groups did not differ in how difficult they found the subsequent sentence span task, $F (1, 60) = 1.56, p = .22$ (attention control $M = 5.23, SD = 1.38$ vs. no control $M = 4.74, SD = 1.65$). Thus, the viewing instructions successfully manipulated the exercise of self-control but did not reliably influence the self-reported difficulty of the subsequent memory task.

Working memory capacity. The main purpose of Study 2 was to test whether exercising self-control over attention would impair subsequent working memory capacity as measured by the sentence span task. The sentence span task afforded five different measures of working memory (sentence comprehension, as measured by responses to the multiple-choice questions, and four measures of recall: longest single word set, number of sets recalled in full, number of words in full sets, and total words recalled). Each of the recall measure offered modest to strong support for the ego depletion hypothesis. The results are displayed in Table 2. Compared to no control participants, participants who exercised self-control over attention during the initial video clip scored worse in terms of the span of the single longest set recalled correctly, $F (1, 60) = 4.15, p < .05$, and total recall of individual words on the entire test, $F (1, 60) = 4.43, p < .05$. Attention control participants also scored marginally worse on the total number of word sets recalled correctly, $F (1, 60) = 3.59, p = .06$, and the total number of words in the correctly recalled sets, $F (1, 60) = 3.61, p = .06$. Altogether, these patterns indicate that recall performance on the working memory test was reduced after an attention control task, with two measures revealing significant effects and two others revealing nearly-significant effects.

Regarding performance on the distracting multiple-choice portion of the sentence span task, participants in the attention control and no control groups gave similarly small numbers of incorrect answers, $F < 1$ (attention control $M = 0.32, SD = 0.60$ vs. no control $M = 0.35 SD = 0.55$). Thus, the depletion of self-control strength impaired recall performance on the sentence span task while performance on the distracting multiple-choice questions was unaffected. Further, the two groups took an equivalent amount of time to complete the test, $F < 1$ (attention control $M = 403.35$ sec, $SD = 56.56$ vs. no control $M = 398.61$ sec, $SD = 62.40$). Thus, the effect of depleted self-control strength on subsequent sentence span performance likely was not due to
changes in working speed or shifts in testing strategy as indicated by responses to the distracting multiple-choice items.

**Self-reported mood.** I again considered whether the attention control and no control viewing instructions may have differentially affected participants’ moods. The two groups reported similar mood states on both subscales of the mood measure: for valence, $F(1, 60) = 1.30, p = .26$ (attention control $M = 9.13, SD = 10.87$; no control $M = 12.32, SD = 11.19$), and for arousal, $F(1, 60) = 0.22, p = .63$ (attention control $M = 22.22, SD = 8.17$; no control $M = 23.13, SD = 6.80$). Therefore, the two sets of viewing instructions did not result in different mood states, suggesting that the effect of initial attention control on later working memory was not attributable to mood. The null mood findings in Study 2 also support the conclusion that the marginal effects of attention control on mood and arousal in Study 1 were not responsible for the observed effects on later working memory capacity.

**Discussion**

Study 2 replicated the main finding of Study 1: The ability to divide attention was impaired after a depleting act of attention control. More specifically, participants in the attention control (vs. no control) condition performed worse on the memory portion of the sentence span task. Performance on the distracting multiple-choice questions was unaffected. The ego depletion effect was statistically significant (in a few cases, marginally so) across multiple measures of memory performance afforded by the operation span task (Study 1) and the sentence span task (Study 2). Apparently, the impairments that follow self-control are not specific to one type of working memory measure and instead reflect a more general impairment of the ability to divide or control attention. Moreover, poorer working memory after the attention control task could not be attributed to group-wide differences in mood or arousal, working speed, or reduced attention to the distracting aspect of the memory test. In sum, these studies indicate that the ability to control attention is impaired by prior attention control.
**STUDY 3**

In Studies 1 and 2, an initial attention control task impaired working memory capacity subsequently. Although the findings supported the ego depletion hypothesis derived from the strength model of self-control, it may be possible to explain those results solely in terms of working memory, without reference to self-control strength. Working memory is considered the locus of the capacity to control attention (e.g., Kane et al., 2004). Perhaps working memory capacity was impaired in both studies because attention control in the form of directing attention to only part of a television screen was required during the initial task. That is, perhaps attention control at one point in time disrupted the successful control of attention at a later point in time, but other, more disparate forms of self-control would have had little or no effect on subsequent attention control. Although the observed patterns challenge the traditional view that attention control is limited only by concurrent and not previous activity, the findings are consistent with the ego depletion hypothesis. However, it is possible that the self-control strength played little or no role in the observed patterns and that attention control or working memory models, with the simple addition of a hangover or depletion hypothesis, can best account for the findings.

In Study 3, I sought to provide a more liberal and dramatic test of the role of self-control strength in attention control by replicating the previous studies with a different manipulation of initial self-control. According to the strength model, virtually any type of self-control should reduce self-control strength (i.e., cause ego depletion) and therefore reduce subsequent working memory capacity. For instance, a task that requires the self-control of facial expressions should cause ego depletion (DePaulo, Blank, Swaim, & Hairfield, 1992; Schmeichel, Demaree, Robinson, & Pu, in press) and therefore impair the ability to divide attention, even though control of facial expression appears to have very little to do with working memory. The goal of an expressive regulation task is to control the configuration of one’s facial muscles, not to manipulate ongoing thought processes or attend to specific events in the environment. Therefore, in Study 3 participants either did or did not attempt to control their facial expressions while watching emotional film clips. If self-control strength underlies the capacity to divide or control attention, then depleting strength by first controlling facial expressions (both positive emotional expressions and negative ones) should impair working memory subsequently. This pattern would be difficult to explain in terms of working memory alone, insofar as working memory plays a lesser role in controlling facial expressions than in controlling attentional focus (as in Studies 1 and 2).

Study 3 tested an additional hypothesis derived from the strength model. Attention control should deplete self-control strength (see Studies 1 and 2). Therefore, dividing attention to perform a working memory test should impair subsequent, apparently unrelated forms of self-control such as exercising control over facial expressions. This pattern would suggest that not only does exercising control over attention reduce subsequent working memory capacity, it also disrupt other forms of self-control, consistent with the view that controlling attention depletes the self’s general-purpose self-control strength.

In Study 3, the operation span task was used as the working memory test. Good performance on this task required the ability to divide attention, so it should deplete self-control strength in addition to being sensitive to fluctuations in strength. To reiterate, the predictions were that an initial act of expressive suppression would impair subsequent working memory performance, and that initial performance of the working memory test would impair the subsequent suppression of emotional expressions.
Method

Participants. One hundred undergraduate students (59 women) enrolled in introductory psychology classes at Florida State University participated in exchange for course credit. Data from 11 participants (6 in the natural-viewing condition and 5 in the suppress-expression condition) were excluded from all reported analyses, leaving a final sample of 89 students. Seven participants were excluded because they indicated performing the same memory test in a different experiment earlier in the same semester, and the other four were excluded because the digitized video clips did not play through to the end.

Materials and Procedure. Participants were randomly assigned to one of four treatment conditions: films first/natural expression, films first/suppress expression, memory first/natural expression, or memory first/suppress expression.

The study began with a brief description of the two major tasks to be performed, which were characterized as “related to emotions” and “related to memory”, respectively. A more thorough introduction to each task was provided immediately prior to their respective performance. Prior to film-clip viewing, all participants were told they would be watching two short clips that tend to elicit emotional reactions in college students. (Participants in the film-clip first condition were assured that the memory portion of the experiment would not involve memory for the content of the film clips.) Participants were also informed that as they watched the clips they would be videotaped “for record keeping purposes”.

Participants then received one of two sets of viewing instructions. Participants in the no suppression condition were told to “watch the clips as if you were at home watching TV – if you feel anything as you watch please express it in whatever way is natural and normal for you”. In contrast, participants in the suppress expression condition were told to “be sure you do not show any emotions on your face – watch the clips but if you feel anything as you watch please suppress your emotional expressions”. After participants indicated they understood their viewing instructions, the film clips began. One clip showed jokes and comedy routines from a popular late-night talk show and the other depicted gruesome scenes from an animal slaughterhouse. Both clips lasted two minutes, for a total of four minutes of film-clip viewing. Immediately before and after watching the clips, all participants completed a state measure of mood (the PANAS; Watson, Clark, & Tellegen, 1988) to allow assessment of the emotional consequences of viewing the film clips as instructed.

Prior to taking the working memory test, participants were given a thorough overview of the test’s procedure. As in Study 1, the operation span task required participants to divide attention between calculating mathematical equations and trying to remember target words. The experimenter surreptitiously recorded how long it took each participant to complete the test and tracked participants’ “Yes” or “No” evaluations of the math equations.

At the end of the experiment, participants rated the difficulty of watching the film clips as instructed and the difficulty of the memory task (both ratings on scales from 1 = not at all to 7 = very). Then participants were debriefed and thanked for their participation.

Results

Manipulation check. Ratings of the difficulty of the video-watching task indicated that the suppress expression instructions were more difficult to follow (\(M = 4.35, SD = 1.83\)) than the no suppression instructions (\(M = 2.39, SD = 1.77\)), \(F(1, 85) = 25.42, p < .001\). This pattern was not affected by whether participants watched the films first or took the memory test first, \(F < 1\). Moreover, the difficulty of the memory test was not affected by whether it was performed before or after the film clips, nor by whether participants had previously attempted to suppress
expressions or not, \( F_s < 1 \). Thus, although the viewing instructions successfully manipulated the exercise of self-control, the difficulty of the memory test was not affected by when it was performed or by the nature of the activity that preceded it.

**Working memory performance.** As in Studies 1 and 2, the hypothesis was that an initial act of self-control (expressive suppression) would reduce subsequent working memory (attention control) capacity. The means are displayed in Table 3. Working memory performance was examined with 2 (Task Order: Films First vs. Memory Test First) X 2 (Viewing Instructions: Suppression vs. No Suppression) ANOVAs. Four measures of recall performance on the working memory test were considered (longest single set, number of sets recalled in full, number of words in full sets, and total words recalled). (As in the previous studies, the number of errors on the distracting portion of the test was uniformly low across conditions, \( F < 1 \).) As predicted, the task order and viewing instruction variables interacted to influence the single longest word set recalled correctly, \( F (1, 85) = 3.92, p = .05 \), the number of sets correctly recalled in full, \( F (1, 85) = 4.47, p = .04 \), and the total number of words recalled on the entire memory test, \( F (1, 85) = 4.09, p = .05 \). The task order X viewing instruction interaction was marginally significant for the number of words recalled in only the full sets, \( F (1, 85) = 3.43, p = .07 \).

In order to decompose the interaction effects, I examined working memory performance in the films-first (memory-last) condition by comparing participants who had previously suppressed emotional expressions to the film clips versus those who had watched the clips naturally (non-suppressors). Note that these analyses mirror those performed in Studies 1 and 2 by testing the effects of initial self-control on later working memory. Participants who had suppressed expressions performed worse on the subsequent memory test than participants who did not initially suppress expressions. Specifically, suppressors scored worse than non-suppressors in terms of the longest single set of words recalled correctly, \( F (1, 41) = 6.30, p = .02 \) and the total number of individual words recalled on the entire task, \( F (1, 41) = 4.30, p = .04 \). Suppressors were marginally worse in terms of the number of word sets recalled correctly in full, \( F (1, 41) = 3.42, p = .07 \), and the number of words in correctly recalled word sets, \( F (1, 41) = 2.89, p = .10 \). Thus, self-regulatory exertion reduced subsequent working memory capacity.

The design of the present study also allowed a test of whether working memory was affected by the presence versus absence of a prior emotional experience. Participants who took the memory test after watching the clips naturally (non-suppressors) performed about the same as participants who took the memory test before watching the film clips, all \( F_s < 1.10, p_s > .30 \). However, participants who took the memory test after suppressing reactions to the clips performed significantly worse than participants who took the memory test before the film clips. A focused contrast analysis comparing participants who initially suppressed to those who had not yet seen the film clips revealed that suppressors scored worse in terms of the mean longest set recalled, \( t (86) = 2.64, p = .01 \), the total number of sets correctly recalled, \( t (86) = 2.73, p = .01 \), the total number of words comprising the correctly recalled sets, \( t (86) = 2.50, p = .01 \), and marginally worse on total recall of individual words on the entire test, \( t (86) = 1.86, p = .07 \).

In sum, suppressing expressions impaired subsequent working memory performance. This pattern was observed when suppressors were compared to participants who had watched the film clips without attempting to suppress and to participants who took the memory test at the beginning of the study, prior to watching the film clips. Further, no differences in working memory capacity emerged between participants who had simply watched the film clips and those who had yet to view the clips. This pattern indicates that an emotional experience prior to the memory test did not influence memory performance. Indeed, only concerted efforts to suppress
emotional expressions impaired subsequent working memory, consistent with the ego depletion hypothesis.

**Self-control of emotional expression.** The second major aim of Study 3 was to test the hypothesis that taking a working memory test (i.e., dividing attention) would impair subsequent attempts to suppress emotional expression. Two naïve coders rated the videotapes of participants’ faces in terms of expressed arousal and expressed emotion (on scales from 0 = none to 90 = a lot). The ratings of the coders were highly correlated ($r_s > .68, ps < .01$) so I averaged them together and used the average scores to examine whether participants who were instructed to suppress their emotional reactions actually did so, and whether the ability to suppress expressions varied according to the placement of the working memory test.

First, parallel 2 (Task Order) X 2 (Viewing Instruction) ANOVAs indicated that the viewing instructions led to reliable differences in facial expressiveness, such that suppressors expressed less arousal, $F(1, 85) = 75.60, p < .01$, and less emotion, $F(1, 85) = 63.11, p < .01$, than non-suppressors. The task-order main effects were non-significant, both $Fs < 1$. The interaction between task order and viewing condition was marginally significant for both expressed arousal, $F(1, 85) = 3.26, p = .07$ and expressed emotion, $F(1, 85) = 2.94, p = .09$.

The decisive planned comparison in these interactions pits suppression performance in phase two of the study, after the memory test, to suppression in phase one, prior to the memory test. If dividing attention to perform the working memory test depleted self-control strength, then suppression should be less successful after taking the memory test than before taking it. This hypothesis was supported. Both expressed arousal, $F(1, 44) = 5.75, p = .02$ and expressed emotion, $F(1, 44) = 4.49, p = .04$, were lower among participants who suppressed reactions prior to taking the memory test versus those who suppressed after taking the test (for expressed arousal, phase one suppress $M = 6.21, SD = 3.62$ vs. phase two suppress $M = 15.24, SD = 3.32$; for expressed emotion, phase one suppress $M = 9.38, SD = 4.24$ vs. phase two suppress $M = 19.46, SD = 3.89$). This pattern supports the view that performing a test of working memory disrupts later acts of emotion regulation. It is worth noting that even after taking the depleting memory test, suppressors showed less emotion than their non-suppressing counterparts. This suggests that expressions could indeed be suppressed after completing the working memory test, but the suppression attempt was less successful after the test than it was before the test.

**Self-control of emotional experience.** Although participants had been instructed to suppress (or not) their outward emotional expressions, I also considered whether expressive suppression affected emotional experience (e.g., Gross & Levenson, 1993, 1997) and whether any such effect was influenced by the placement of the working memory test. Changes in emotional experience were derived by subtracting the pre-film clip PANAS ratings from the post-clip ratings. The interaction effect crossing the task-order and viewing condition variables was significant in the case of change in negative affect, $F(1, 85) = 4.60, p < .05$ but non-significant for change in positive affect, $F(1, 85) = 0.04, p = .84$.

To decompose the significant interaction effect, I examined film-first participants and memory-first (film-last) participants separately. Among film-first participants, those who watched naturally ($M = 5.00, SD = 6.20$) experienced a greater increase in negative affect than those who suppressed reactions ($M = 1.13, SD = 5.33$), $F(1, 41) = 4.85, p = .03$. Thus, suppressing reactions prevented an increase in negative emotion when participants had not previously expended self-control strength.

However, after expending self-control strength to perform the working memory test, suppressors and non-suppressors reported similar internal reactions to the film clips. Neither
change in PA, $F(1, 44) = 1.60, p = .21$, nor change in NA, $F(1, 44) = 0.55, p = .46$, differed between suppressors and non-suppressors. For negative affect, suppressors ($M = 1.71, SD = 6.14$) and non-suppressors ($M = 0.55, SD = 4.21$) showed similarly small changes from pre- to post-film. These findings are consistent with the view that performing the working memory task reduced the ability to suppress distress in response to the emotional film clips.

It is important to note that non-suppressors who watched the clips before taking the memory test reported a larger change in negative affect than non-suppressors who watched the clips after taking the test, $F(1, 39) = 7.42, p < .05$. Thus, although suppression (vs. non-suppression) prior to the memory test reduced negative affect and suppression (vs. non-suppression) after the test did not, this pattern is due in part to the low level of negative affect among participants who watched the clips after taking the memory test.

**Discussion**

Study 3 conceptually replicated Studies 1 and 2 in finding that the self-control of facial expressions reduces subsequent working memory performance. Thus controlling facial expressions reduced working memory capacity much like controlling visual attention did in Studies 1 and 2, consistent with the view that these varied acts of self-control all rely on the same underlying resource or strength. Moreover, Study 3 revealed that dividing attention to perform a test of working memory impaired the subsequent suppression of emotional expressions. This pattern also supports the view that working memory and the control of facial expressions draw upon a common and depletable strength.

In total, Studies 1 - 3 show that the ability to divide or control attention relies on self-control strength. The findings contrast with a traditional view of working memory which implies that working memory capacity immediately rebounds to pre-exertion levels as soon as the load on working memory is lifted. Instead it appears that exercising control over attention depletes self-control strength and impairs self-control (including but not limited to attention control) for a short while thereafter.

As discussed in the Introduction, past research has shown that depleted self-control strength may undermine subsequent cognitive processes, particularly complex ones such as logical reasoning (Schmeichel et al., 2003). The present findings suggest depleted self-control strength impairs high level cognition because it undermines the ability to control attention. Logical reasoning, reading comprehension, and fluid intelligence have all been linked to working memory (Baddeley, 1996; Kane et al., 2004), and some theorists have proposed that working memory or attention control forms the basis of all those abilities (e.g., Smith & Jonides, 1999). Hence, by depleting the resources that contribute to attention control capacity, acts of self-control disrupt these more complex cognitive performances as well.

However, it is possible that reduced working memory capacity is not the only means by which the prior self-control disturbs high-level cognitive performance. A comparison of the effects in the current research and those reported in Schmeichel et al. (2003) suggests substantial differences in the effect of depleted strength on working memory and high-level cognition, respectively, although both sets of studies used similar manipulations of ego depletion. In the present studies, the effect of initial self-control on subsequent working memory was consistently moderate in size (see Cohen, 1988). In terms of the number of word sets recalled on the working memory tests, participants who initially exercised self-control scored approximately one-half of a standard deviation worse than participants who did not initially exercise self-control. In contrast, the size of the depletion effects on logical reasoning, cognitive estimation, and complex reading comprehension reported in Schmeichel et al. (2003) ranged from three-fourths to one-and-one-
half standard deviations, indicating large to very large effects. Thus, the effect of depleted strength on cognitive performance was larger when performance relied on more than working memory or attention control alone. Apparently, the magnitude of the depletion effect is directly related to the complexity of the cognitive task: Performance on basic measures of working memory is impaired by depletion, but performance on more complex cognitive tasks, which appear to demand even more of the test-taker than the working memory span tasks do, is impaired even more severely.

The discrepancy in the size of the depletion effect on working memory tests versus more complicated cognitive tests is consistent with the view that ego depletion impairs more than working memory capacity alone. Further, the present research shows that exercising control over working memory disrupts the ability subsequently to control facial expressions (Study 3). It is not clear how the self-control of facial expressions might be explained in terms of working memory. To my knowledge, no prior evidence exists to suggest either that the ability to control facial expressions relates to working memory capacity or that concurrent cognitive activity (which would also undermine working memory) undermines expressive suppression. However, the self-control strength model has a suitable explanation for the connection between working memory and control over facial expressions: They are linked by their reliance on a common pool of self-control strength, which is used in all acts that require active self-control. (For a related view of attention control as one instance of a broader set of self-control abilities, see Ruff & Rothbart, 1996.)

Nonetheless, it is conceivable that working memory does play some role in the control of facial expressions. For example, participants in the suppression conditions in Study 3 had to attend to the film clip, monitor their facial expressions, and suppress those expressions all at the same time, so it is reasonable to assume that attention occasionally had to be divided or controlled to accomplish expressive suppression (Richards & Gross, 1999, 2000). In order to clarify the relationship between self-control strength and attention control capacity, Study 4 compared the effects of depleted strength and divided attention on a test of self-controlled pain tolerance, the cold-pressor task.
STUDY 4

Studies 1 – 3 showed that the capacity to control attention relies on depletable self-control strength. Thus, attention control is similar to other forms of self-control, including task persistence and emotion regulation, which also draw upon the self’s limited self-control resource or strength (Baumeister et al., 1998; Vohs & Schmeichel, 2003).

Given the evidence in the previous studies that divided attention and depleted strength are closely related, Study 4 examined whether the effects of depleted strength may be dissociated from the effects of divided attention. Specifically, Study 4 tested the hypothesis that performance on a test of pain tolerance may be impaired by a previous act of self-control but not by concurrent divided attention. Evidence that some acts of self-control are impaired by previous self-control but are not impaired by divided attention would support the view that self-control strength and divided attention or working memory capacity are distinct determinants of self-control failure.

Study 4 also addressed a potential alternate explanation for the effects of depleted strength. According to the strength model, one act of self-control impairs the next because the first act undermines self-control ability. Literally, the energy or strength required to exercise self-control is weakened by the previous exercise of self-control. An alternative explanation is that prior self-control impairs self-control via divided attention, not reduced strength. For example, some evidence suggests that cognitive activation associated with self-control remains high even after the self-control attempt has concluded (e.g., Salkovskis & Campbell, 1994; Wegner, 1994). Thus, it is plausible that subsequent self-control suffers because attention is divided between the current attempt and the previous one. In this view the mechanism of impairment in consecutive acts of self-control is divided attention. If this is true, then prior self-control and concurrent divided attention should have the same effect on self-controlled behavior.

In contrast, the strength model predicts that divided attention and depleted strength should have different effects on self-control, particularly acts of self-control that do not rely on focused attention. Insofar as self-control strength is used in acts of self-control that do not depend on focused attention, then depleted strength may impair some self-control that is not also impaired by divided attention. In Study 4, I used a measure of pain tolerance, the cold pressor task, to assess self-control ability because prior research suggests attention control is not crucial to pain tolerance. Indeed, factors that distract or divide attention occasionally improve performance at the cold pressor test (e.g., Grimm & Kanfer, 1976; McCaul & Hauktvedt, 1982). Finding that divided attention and prior self-control have different effects on this measure of self-control would differentiate divided attention from depleted strength and would argue against the view that divided attention is the mechanism by which prior self-control impairs later self-control.

Participants in Study 4 performed a reading task in one of two ways. One group was required to exercise self-control strength by regulating the emotional tenor of their reading, and the other group read normally and naturally and so did not exercise self-control to accomplish the reading task. Only the active self-control group was expected to experience depleted self-control strength. Next, all participants performed the cold pressor task by immersing their non-dominant hand in near-freezing ice water for as long as they could. The cold pressor task requires self-control in the form of surmounting the desire to remove one’s hand from the painful cold water, so persistence at this task should vary depending upon recent expenditure of self-control strength.
In order to determine whether cold-pressor persistence would also be affected by a concurrent division of attention, some participants performed the cold pressor task while counting backwards by threes (cognitive load condition) whereas other participants performed the cold pressor task with no concurrent task (no load condition). If dividing attention between the pain tolerance task and the counting task does not reduce cold-pressor persistence, but a previous act of self-control of emotional expression does reduce persistence, it would appear as though depleted strength and divided attention were distinct effects.

Further, Study 4 included a third task to test the hypothesis that multiple acts of self-control (i.e., self-control of emotion and pain tolerance) would reduce cognitive performance more profoundly than a single act of self-control (i.e., self-control of emotion or pain tolerance). At the end of the study, all participants performed a cognitive estimation task that has been shown to fluctuate in accordance with the state of self-control strength (Schmeichel et al., 2003). Thus, performance on the cognitive estimation task may indicate the effects of single versus multiple acts of prior self-control.

**Method**

**Participants.** One hundred two undergraduate students (62 women) enrolled in an introductory psychology course at Florida State University participated in exchange for partial course credit. Data from 4 participants were excluded from all analyses, leaving a final sample of 98. Two of the excluded participants refused to perform the cold pressor test and two failed to follow directions.

**Materials and Procedure.** The study began with a brief description of the major tasks to be performed, which were characterized as related to emotions (reading task) and related to stamina (cold pressor task), respectively. In order to manipulate the exercise of self-control, participants were randomly assigned to read a dull and dense passage of text about the workings of the inner ear in one of two ways (see Vohs & Schmeichel, 2003). In the *natural reading condition*, they were told to “read the text out loud in whatever way is normal and natural for you. Please read this as if it were an assignment for class.” In contrast, participants in the *exaggerate reading condition* were told to “read the text out loud in a way that expresses interest and enthusiasm in what you’re reading. Please read this as if it were the most exciting thing you have ever read.” After participants indicated they understood the reading instructions, they read the passage of text aloud while being recorded by a video camera. Immediately after reading the text, all participants completed a state measure of mood (BMIS; Mayer & Gaschke, 1988), which served as an assessment of the emotional consequences of exaggerating versus not exaggerating enthusiasm while reading the dull text. (Naïve raters later watched the videotapes of participants’ reading and coded them in terms of expressed excitement and arousal to allow a determination of whether participants followed their respective reading instructions.)

After the reading task, all participants performed the cold pressor test. Specifically, participants were asked to immerse their non-dominant hand in cold water (approximately 33° F, circulated by an air pump) and to keep it there until they deemed the task too uncomfortable to continue. We imposed a 3 minute ceiling on cold-pressor persistence, but participants were not informed of the 3-minute ceiling prior to starting the task. The experimenter recorded the duration for which participants immersed their non-dominant hand in the near-freezing water.

Participants were randomly assigned to perform the cold pressor task in one of two ways. Participants in the *cognitive load condition* were asked to count backwards in increments of 3, beginning at 881, as they kept their hand immersed in the water. Participants assigned to the *no
load condition performed the cold pressor task without having to perform a concurrent cognitive task. Thus, one group had to divide attention during the cold pressor test and one group did not.

After the cold pressor test, all participants put their non-dominant hand in warm water for 30 seconds to alleviate any lingering discomfort. Then participants performed the Cognitive Estimation Test (CET; Fein, Gleeson, Bullard, Mapou, & Kaplan, 1998; Shallice & Evans, 1978). This test required participants to extrapolate from known information to make estimates about unknown quantities (e.g., “How many seeds are there in a watermelon?”). Good performance on the CET requires cognitive self-control, and prior research has shown that estimation accuracy suffers when self-control strength has been depleted (Schmeichel et al., 2003).

At the end of the study, participants rated the difficulty of reading the dull text as instructed, the difficulty of the cold pressor test, the amount of attention they paid to the sensations in their hand during the cold pressor test, and the degree of physical discomfort experienced during cold pressor test (on scales from 1 = not at all to 7 = very).

Thus, Study 4 included four groups (natural reading/no load during cold pressor; natural reading/cognitive load during cold pressor; exaggerated reading/no load during cold pressor; exaggerated reading/cognitive load during cold pressor) to test the hypothesis that performance on a test of self-control (physical endurance) may be reduced by a previous exercise of self-control but not by concurrent divided attention. Further, we included participants’ sex in the analyses of cold pressor persistence because of possible gender differences in pain tolerance.

Results

Manipulation checks. Reading a boring passage of text aloud with exaggerated enthusiasm was rated more difficult ($M = 5.68, SD = 1.45$) than simply reading the dull text aloud ($M = 4.88, SD = 1.59$), $F(1, 96) = 6.86, p < .05$. This pattern suggests that exaggerated reading required more self-control than natural reading. Further, naïve raters watched the videotapes of participants reading and rated the participants’ faces in terms of expressed emotion and arousal. The two sets of ratings were highly correlated ($r_s > .50, ps < .01$) so they were averaged together. Exaggerators expressed more arousal and emotion than natural readers, $F_s > 10, ps < .01$, indicating that participants adhered to their respective reading instructions.

Mood effects. After reading the dull passage of text, participants reported their mood state and arousal level. Participants who exaggerated emotion while reading reported marginally more arousal immediately after the reading task ($M = 23.40, SD = 8.75$) than did participants who read aloud without exaggerating ($M = 19.83, SD = 9.66$), $F(1, 96) = 3.67, p = .06$. There were no group-wide differences in emotional valence following the reading task, $F < 1$. Thus, exaggerated (vs. normal) reading was associated with heightened internal arousal in addition to increased outward expression of emotion and arousal.

Cold pressor persistence. The primary purpose of this study was to test whether an emotion exaggeration (vs. natural reading) task would reduce persistence at the subsequent cold pressor task, and whether divided attention would have a similar derogatory effect on persistence. Because self-reported arousal was correlated with cold pressor persistence, $r (98) = .24, p < .05$, I controlled for arousal in the following analysis. A 2 (Depletion Condition: Exaggerated Reading vs. Natural Reading) X 2 (Cognitive Load vs. No Load) ANCOVA on cold pressor persistence revealed only a significant main effect of reading condition, $F(1, 93) = 7.74, p < .01$. The means are displayed in the first column of Table 4. Participants who read the boring text with enthusiasm and excitement persisted less at the subsequent endurance test than participants who read the boring text normally and naturally. Participants in the cognitive load
condition tended to persist longer at the cold pressor test than no-load participants, although this
difference was not statistically significant, $F(1, 93) = 1.78, p = .19$. The interaction between
cognitive load and ego depletion was not statistically significant, $F < 1$.

Including gender in these analyses revealed no main effects or interactions involving
gender, and the main effect of depletion condition remained significant. Follow-up analyses
using Tukey’s post-hoc tests revealed that the cognitive load manipulation increased cold pressor
persistence among women, $t(59) = 2.20, p = .03$, but not among men, $t < 1$.

Cognitive estimation performance. A 2 (Depletion Condition) X 2 (Cognitive Load
Condition) ANOVA on performance on the Cognitive Estimation Test revealed no significant
effects. Past research has shown that estimation performance suffers after expending self-control
strength (Schmeichel et al., 2003). Given that all participants in the present study had expended
self-control strength on at least one task prior to this test (i.e., on the cold pressor task), this null
effect is perhaps not surprising.

Subsidiary analyses. At the end of the study participants rated the difficulty of
performing the cold pressor task, the degree of physical discomfort experienced during the cold
pressor, and how much attention they paid to hand sensations during the cold pressor task.
Regarding self-reported difficulty of the cold pressor task, analyses revealed a marginal main
effect of reading condition, $F(1, 94) = 3.56, p = .06$, and a main effect of cognitive load
condition, $F(1, 94) = 9.31, p < .01$. The interaction between the two variables was not
statistically significant, $F < 1$. Descriptively, participants who read the boring text with
enthusiasm and excitement rated the subsequent cold pressor task somewhat more difficult to
perform ($M = 5.39, SD = 1.50$) than did participants who read the boring text normally and
naturally ($M = 4.77, SD = 1.56$). This pattern is consistent with the persistence patterns reported
above: Depleted participants found the cold pressor task more difficult and they persisted less at
it than non-depleted participants.

Further, performing the cold pressor with a concurrent cognitive load was more difficult
($M = 5.50, SD = 1.41$) than performing the cold pressor with no concurrent load ($M = 4.60, SD =
1.57$), consistent with the intent of the cognitive load manipulation. However, as described
above, cognitive load only increased persistence among the female participants. These patterns
suggest that persistence at the pain tolerance test was not solely or mainly a function of the
subjective difficulty of the test.

Moreover, compared to participants who read the dull text in normal (unregulated)
manner, participants who read with exaggerated enthusiasm attended more closely to the
sensations in their hand and experienced more physical discomfort during the ensuing cold
pressor test, both $F$s > 5.50, ps < .05. The relevant means are displayed in the last two columns
of Table 4. Perhaps surprisingly, the presence (vs. absence) of a concurrent cognitive load had no
significant effect on attention to hand sensations or discomfort during the cold pressor task, $F$s <
2, ps > .15. These patterns also buttress the cold-pressor persistence patterns. It is likely that
increased attention toward hand sensations and increased physical discomfort among participants
who had previously exaggerated emotion helps to explain their reduced persistence at the cold
pressor task.

Mediational analyses. Studies 1 - 3 indicated that an initial act of self-control reduced
subsequent attention control capacity. Perhaps the group-wide differences in pain tolerance in
Study 4 might also be due to the effect of prior self-control on the control of attention. To
provide a formal test of the hypothesis that reduced attention control helps explain the effect of
initial self-control on later cold pressor persistence, I performed two separate mediational
analyses. One was conducted to determine whether attention to hand sensations mediated the effect the initial self-control exercise on cold pressor persistence. The other was conducted to determine whether the experience of discomfort during the cold pressor mediated the effect of ego depletion on cold pressor persistence.

First, I built a regression model that contained all the components of interest to see if attention to hand sensations during the cold pressor mediated the link between depletion condition and subsequent cold pressor persistence. In this model, cold pressor persistence was regressed on self-reported attention paid to hand sensations and depletion condition (dummy coded as 0 = natural reading and 1 = exaggerated reading). The results provided some support for notion that attention mediated the effect of initial self-control on later persistence. The depletion effect remained significant, \( t(95) = -1.96, p = .05 \) (\( \beta = -.18 \)), and the effect of attention paid to hand sensations was also significant, \( t(95) = -3.86, p < .01 \) (\( \beta = -.35 \)). A Sobel test of mediation (Sobel, 1982) was significant, Sobel test = -1.99, \( p < .05 \). Thus, attention to hand sensations appeared to partially mediate the effect of prior self-control on subsequent cold pressor persistence.

Next, I built a regression model to examine whether physical discomfort during the cold pressor mediated the link between depletion condition and subsequent cold pressor persistence. In this model, self-reported physical discomfort during the cold pressor test and self-control depletion condition were used to predict cold pressor persistence. In this model, the depletion effect remained significant, \( t(95) = -2.11, p = .04 \) (\( \beta = -.21 \)). The effect of experienced discomfort was also significant, \( t(95) = -2.23, p = .03 \) (\( \beta = -.22 \)). A Sobel test of mediation (Sobel, 1982) was marginally significant, Sobel test = -1.67, \( p < .10 \). Thus, physical discomfort appeared to partially mediate the relationship between depletion condition and cold pressor persistence.

**Discussion**

In Study 4, reading a dull passage of text in an enthusiastic and excited manner reduced subsequent pain tolerance compared to reading the text in a normal, natural voice. This finding supports the strength model of self-control insofar as an initial act of self-control (i.e., exaggerated reading) impaired a subsequent act of self-control (i.e., cold pressor persistence). Moreover, pain tolerance was not reliably influenced by the performance of a concurrent cognitive task (except among female participants, for whom the concurrent cognitive load increased persistence). Finding that cold pressor persistence is undermined by prior self-control but not by concurrent divided attention dissociates reduced self-control strength (i.e., ego depletion) from reduced attentional capacity.

In addition to the differential effects of prior self-control and concurrent divided attention on cold pressor persistence, analyses showed that attentional factors only partially mediated the effect of prior self-control on later persistence. Specifically, participants who exercised self-control over emotional expression during the reading task paid more attention to physical sensations and experienced more discomfort during the subsequent pain tolerance test than participants who did not initially exercise self-control. These patterns indicate that the initial self-control task reduced participants’ ability to ignore or distract attention away from pain caused by the near-freezing water. Participants who did not exercise self-control during the reading task were better able to control attention during the cold pressor test, and so they were relatively more able to ignore painful sensations. As a result, non-depleted participants kept their hand in the ice water longer than depleted participants did. However, the effect of ego depletion on pain
tolerance remained significant even after accounting for the effect of depletion on attention. These findings suggest that the depletion effect was not attributable to attentional factors alone.

According to the strength model, the self’s resources underlie all manner of self-control, including but not limited to the control of attention or working memory. In this view, working memory capacity relates primarily to cognitive performance and less so to other, non-cognitive forms of self-control. Thus, cold pressor persistence, which requires self-control to surmount the desire to remove one’s hand from the near-freezing water, was undermined by a previous act of self-control as predicted by the strength model. However, differences in attention control only partially explained cold pressor persistence, and concurrent divided attention did not reduce cold pressor persistence and in fact increased it among female participants. These patterns help to refine the distinction between self-control strength and attention control by identifying a self-control task (i.e., pain tolerance) in which the state of self-control strength but not reduced or divided attention affects self-controlled performance.
GENERAL DISCUSSION

People who succeed at self-control enjoy more success in life than people who fail at self-control (Tangney et al., 2004). The present investigation examined two causes of self-control failure, divided attention and depleted self-control strength, and revealed that they are closely related but distinct determinants of failure at self-control.

According to the present results, divided attention and self-control strength are related because the ability to divide attention requires self-control strength. The present research provides two sources of support for this view. First, acts that deplete self-control strength undermine the ability to divide attention. Specifically, controlling attention (Studies 1 – 3) or emotional expression (Studies 3 and 4) impaired the ability to divide attention subsequently. Second, dividing attention consumes self-control strength and therefore undermines subsequent attempts at self-control. Specifically, dividing attention to perform a test of working memory impaired the subsequent self-control of emotional expression (Study 3).

These findings support the strength model of self-control (Baumeister et al., 1998). Varied acts of self-control, from sustaining the focus of visual attention to dividing the workspace in working memory to controlling facial expressions, draw upon a common, depletable strength. Performing any one of these acts depletes this strength, and in the interim – after the initial act but before self-control strength has recovered – self-control ability is impaired.

The current findings do not support a traditional account of attention and working memory. According to the traditional account, the ability to divide attention is affected by concurrent, but not prior, activity. The conscious workspace in working memory is constrained because only a limited amount of information can be captured in awareness at any moment in time (e.g., Baddeley, 1986). When two or more tasks are performed concurrently, performance on at least one of the tasks may suffer because the workspace cannot accommodate both tasks. The implicit view in the traditional account of working memory is that the ability to control attention rebounds to peak operating capacity as soon as attention is no longer divided or the dual-task episode has ended.

The present findings challenge the traditional view because they show that controlling attention or otherwise exercising self-control reduces working memory (i.e., attention control) capacity even after the initial act has concluded. Thus, instead of being constrained solely by concurrent activity, the ability to control attention fluctuates over time because it relies on a resource or strength that is depleted by the self’s controlling or self-regulatory activity.

Depleted Strength and Divided Attention

In addition to relating the ability to divide attention to self-control strength, the present work also sought to differentiate divided attention from depleted strength. As described in the preceding paragraphs, the most obvious difference between them concerns the dimension of time: Divided attention impairs concurrent acts of self-control, whereas depleted strength impairs subsequent acts of self-control. Is it possible to explain the effects of depleted strength with divided attention? For example, perhaps prior self-control impairs ensuing self-control because attention is distracted or divided during the second (ensuing) act. Support for this idea was provided by past research on thought suppression. After exercising self-control to suppress a forbidden thought, the forbidden thought rebounds to occupy a prominent place in the conscious workspace of the suppressor (Wegner, 1989, 1994). Therefore, it is plausible that a previous act
of self-control (e.g., regulating emotional expression) could compete for access to conscious awareness with a subsequent act of self-control (e.g., pain tolerance), creating a division of attention that undermines performance of the subsequent act.

In contrast, I hypothesized that depleted self-control strength and divided attention are distinct causes of self-control failure, such that depleted strength and divided attention have different effects on self-control. The final study of the present investigation (Study 4) compared directly the effects of prior self-control and concurrent divided attention to test these competing predictions: If the effects of depleted self-control strength are due to divided attention, then prior self-control and concurrent divided attention should have similar effects on self-control. However, if depleted strength and divided attention are distinct causes of self-control failure, then they may have different effects on self-control.

The results of Study 4 indicated that depleted strength and divided attention had different effects. Specifically, divided attention did not reduce persistence on a pain tolerance (cold pressor) test, and in fact it increased persistence among female participants. However, self-control of emotional expression prior to the pain test substantially reduced later persistence. The impairment of pain tolerance by prior expenditure of self-control strength was only partially explained by attentional factors. Depleted participants paid more attention to the painful sensations caused by the cold pressor test than non-depleted participants did. This effect is consistent with a reduced capacity to control attention after exercising self-control, as demonstrated in Studies 1-3. However, even after statistically controlling for the group-wide differences in attention to pain, the effect of prior self-control on pain tolerance remained significant. Thus, the effect of depleted strength was dissimilar to the effect of divided attention, and attentional factors alone did not explain the depletion effect. Apparently, depleted strength and divided attention have separable effects on self-control.

The dependent measure of self-control ability in Study 4, pain tolerance on the cold pressor test, was chosen because it seemed particularly likely to produce a difference between the effects of prior self-control and concurrent divided attention. However, other forms of self-control such as restrained eating or restrained drinking do rely at least in part on focused attention (e.g., Ward & Mann, 2000), and so these probably would not reveal differences in the effects of depleted strength and divided attention.

Cold pressor persistence requires self-control in the form of overriding the urge to alleviate pain (e.g., Rosenbaum, 1980), and past studies have found that dividing attention during the cold pressor either has no significant effect on persistence (e.g., Cioffi & Halloway, 1993; McCaul & Malott, 1984) or actually increases persistence (e.g., Grimm & Kanfer, 1976; McCaul & Haugtvedt, 1982). The present study found increased persistence in the divided attention condition among female but not male participants. The inconsistent effects of divided attention on cold pressor persistence in past research and the significant finding only among female participants in the present study underscore the notion that attention control is not the driving factor in cold pressor persistence.

Attention and the control of attention are vital components of many forms of active self-control (Baumeister et al., 1994; Carver & Scheier, 1981; Mischel & Ebbeson, 1970; Wegner, 1994). Indeed, manipulations that distract or divide attention are commonly used in research on self-control, and the typical finding is that distracting attention away from self-control hastens self-control failure (e.g., Gilbert, Pelham, & Krull, 1988; Wegner, Erber, & Zanakos, 1993). However, the present work suggests that at least some forms of self-control are not impaired by divided attention but are impaired by depleted strength.
Implications and Future Directions

The picture that emerges is that some self-control is impaired when attention is distracted or divided, but some self-control is not impaired by divided attention and occasionally may be improved by it. However, depleted strength impairs both kinds of self-control. Divided attention undermines self-control because it draws attention away from the self-control attempt. When good self-control relies on focused attention, divided attention triggers self-control failure. Unlike divided attention, prior acts of self-control do not appear to distract attention away from later self-control. Instead of distracting attention, prior acts of self-control deplete self-control strength and therefore undermine the ability to control attention or other processes.

One issue left unresolved by the present studies concerns the specific nature of the deficits in attention control and other forms of self-control that are created by depleted strength. Regarding attention control, perhaps the effect of prior self-control is to make the shifting of attention less efficient or reliable. A lack of efficiency in shifting attention between two tasks would impair performance on one or both tasks. Or, perhaps prior self-control restricts the scope of attention, reducing the amount of information which can be accommodated in conscious awareness. A restricted scope of attention would limit the ability to process concurrent streams of information. The present results support both possibilities and do not distinguish between them.

Past research has shown that performing concurrent tasks reduces the scope of attention, creating a state of attentional myopia in which only highly salient stimuli in the environment gain access to conscious awareness (e.g., Mann & Ward, 2004). It is possible that prior self-control also creates a state of attentional myopia, but without the addition of an explicit concurrent activity or distraction. For example, in Study 4 a prior act of self-regulation led to greater subjective discomfort on the cold pressor task, and this finding may reflect a tendency for highly salient information (e.g., pain due to the cold pressor) to dominate attention after engaging in self-control.

Future work should examine whether the scope of attention, the ability to control attention, or both are influenced by prior self-regulation. Some work has found that attentional myopia may actually improve self-control if the salient cues in the environment – those that gain privileged access to conscious awareness – promote good self-control (e.g., Mann & Ward, 2004). If prior self-control reduces the scope of attention, then prior self-control might facilitate subsequent self-control when the appropriate cues are highly salient. Testing whether depleted self-control strength produces attentional myopia, and whether this may improve or impair self-control depending on the salient environmental cues, will help to specify the nature of the effect of depleted strength on the control of attention, and might reveal a counter-intuitive instance in which depleted strength leads to good self-control.

In sum, the current work elucidates the nature of the self’s capacity for self-control. Both self-control strength and the ability to focus or control attention are vital components of the human capacity for self-control, with self-control strength underlying cross-temporal fluctuations in attention control as well as other forms of self-control.
Table 1

*Operation Span Scores by Attention-Control or No Control Condition (Study 1)*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sets Recalled</th>
<th>Mean Longest Set</th>
<th>Words in Correct Sets</th>
<th>Total Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>No control</td>
<td>7.65&lt;sub&gt;a&lt;/sub&gt; (2.52)</td>
<td>3.41* (0.93)</td>
<td>18.92&lt;sub&gt;a&lt;/sub&gt; (8.69)</td>
<td>34.68* (5.50)</td>
</tr>
<tr>
<td>Attention control</td>
<td>6.33&lt;sub&gt;b&lt;/sub&gt; (2.28)</td>
<td>3.10* (0.76)</td>
<td>15.00&lt;sub&gt;b&lt;/sub&gt; (6.56)</td>
<td>32.88* (4.15)</td>
</tr>
</tbody>
</table>

*Note.* Means in the same column with different subscripts differ at $p < .05$. Means in the same column with an asterisk differ at $p = .10$. Numbers in parentheses are standard deviations.
Table 2

*Sentence Span Scores by Attention-Control or No Control Condition (Study 2)*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sets Recalled</th>
<th>Mean Longest Set</th>
<th>Words in Correct Sets</th>
<th>Total Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>No control</td>
<td>8.48* (2.84)</td>
<td>4.00a (0.77)</td>
<td>23.03* (10.39)</td>
<td>38.32a (6.54)</td>
</tr>
<tr>
<td>Attention control</td>
<td>7.13* (2.79)</td>
<td>3.55b (0.96)</td>
<td>18.26* (9.37)</td>
<td>34.81b (6.61)</td>
</tr>
</tbody>
</table>

*Note.* Means in the same column with different subscripts differ at *p* < .05. Means in the same column with an asterisk differ by *p* = .06. Numbers in parentheses are standard deviations.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Sets Recalled</th>
<th>Mean Longest Set</th>
<th>Words in Correct Sets</th>
<th>Total Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Films-First</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural/WM</td>
<td>7.37&lt;sup&gt;ac&lt;/sup&gt; (2.03)</td>
<td>3.26&lt;sup&gt;a&lt;/sup&gt; (0.65)</td>
<td>17.16&lt;sup&gt;a&lt;/sup&gt; (6.37)</td>
<td>34.84&lt;sup&gt;a&lt;/sup&gt; (3.59)</td>
</tr>
<tr>
<td>Suppress/WM</td>
<td>6.17&lt;sup&gt;a&lt;/sup&gt; (2.18)</td>
<td>2.75&lt;sup&gt;b&lt;/sup&gt; (0.68)</td>
<td>13.88&lt;sup&gt;b&lt;/sup&gt; (6.22)</td>
<td>32.25&lt;sup&gt;b&lt;/sup&gt; (4.41)</td>
</tr>
<tr>
<td><strong>Memory-First</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WM/Natural</td>
<td>7.27&lt;sup&gt;ac&lt;/sup&gt; (2.35)</td>
<td>3.18&lt;sup&gt;a&lt;/sup&gt; (0.85)</td>
<td>17.05&lt;sup&gt;a&lt;/sup&gt; (7.36)</td>
<td>33.68&lt;sup&gt;ab&lt;/sup&gt; (5.20)</td>
</tr>
<tr>
<td>WM/Suppress</td>
<td>8.04&lt;sup&gt;c&lt;/sup&gt; (2.16)</td>
<td>3.29&lt;sup&gt;a&lt;/sup&gt; (0.75)</td>
<td>19.04&lt;sup&gt;a&lt;/sup&gt; (6.74)</td>
<td>35.00&lt;sup&gt;a&lt;/sup&gt; (4.68)</td>
</tr>
</tbody>
</table>

*Note.* Means in the same column with different subscripts differ at *p* < .05. Numbers in parentheses are standard deviations.
Table 4

*Cold Pressor Persistence by Reading Condition and Cognitive Load Condition (Study 4)*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cold Pressor Persistence (in sec)</th>
<th>Physical Discomfort</th>
<th>Attention to Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural Reading</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Load</td>
<td>57.30 (49.55)</td>
<td>5.12 (0.97)</td>
<td>5.32 (1.82)</td>
</tr>
<tr>
<td>Cognitive Load</td>
<td>67.70 (47.20)</td>
<td>5.30 (1.58)</td>
<td>4.87 (1.58)</td>
</tr>
<tr>
<td><strong>Exaggerate Reading</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Load</td>
<td>38.15 (34.73)</td>
<td>5.65 (1.30)</td>
<td>6.04 (1.22)</td>
</tr>
<tr>
<td>Cognitive Load</td>
<td>49.09 (47.00)</td>
<td>6.00 (1.00)</td>
<td>5.67 (1.57)</td>
</tr>
</tbody>
</table>

*Note.* Numbers in parentheses are standard deviations.
APPENDIX A

HUMAN SUBJECTS APPROVAL LETTER (STUDIES 1 – 3)
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8633 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 2/17/2004

To: Brandon J. Schmeichel
Mc 1270

Dept.: Psychology

From: John Tomkowiak, Chair

Re: Use of Human Subjects in Research
Emotions and Memories

The forms that you submitted to this office in regard to the use of human subjects in the proposal
referenced above have been reviewed by the Human Subjects Committee at its meeting on
2/11/2004. Your project was approved by the Committee.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh
the risk to the human participants and the aspects of the proposal related to potential risk and
benefit. This approval does not replace any departmental or other approvals which may be required.

If the project has not been completed by 2/10/2005 you must request renewed approval for
continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the
project to the Committee for approval. Also, the principal investigator must promptly report, in
writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is
reminded that he/she is responsible for being informed concerning research projects involving
human subjects in the department, and should review protocols of such investigations as often as
needed to insure that the project is being conducted in compliance with our institution and with DHHS
regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The
Assurance Number is IRB00000446.

cc: Roy Baumeister
HSC No. 2004.048
APPENDIX B

HUMAN SUBJECTS APPROVAL LETTER (STUDY 4)
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8633 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 1/10/2005

To:
Brandon Schmeichel
Mc 1270

Dept.: PSYCHOLOGY DEPARTMENT

From: John Tomkowiak, Chair

Re: Use of Human Subjects in Research
Emotions and Physical Endurance

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Human Subjects Committee at its meeting on 12/8/2004. Your project was approved by the Committee.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals which may be required.

If the project has not been completed by 12/7/2005 you must request renewed approval for continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must promptly report, in writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446.

cc: Roy Baumeister
HSC No. 2004.854
APPENDIX C

INFORMED CONSENT FORM (STUDIES 1 – 3)
Emotions and Memories

I HAVE BEEN INFORMED THAT:

Brandon Schmeichel, a graduate student in the psychology department under the advisement of Dr. Roy F. Baumeister, has requested my participation in a research study at FSU. The purpose of the research is to explore the relationships between emotions and memories. The researchers intend to survey 80 FSU students from General Psychology courses in order to understand whether memory and emotional experiences are related. My participation will involve performing a memory task and watching a short film clip. The film clip may contain emotional scenes, and some participants may find those scenes somewhat disturbing. I will also complete questionnaires about myself and the experiment. Also, I understand that I will be videotaped by the researcher. These tapes will be kept by the researcher in a locked filing cabinet, and will only be used to verify that I watch the film clip as I was instructed. I understand that only the researcher will have access to these tapes and that they will be destroyed by January 1st, 2011. The experiment will last approximately 30-40 minutes.

My participation is voluntary. Choosing not to participate will not affect my current or future relations with the University. There is no penalty, loss of benefits, or affect on my grade for not participating or for discontinuing my participation. My consent may be withdrawn at any time without prejudice, penalty, or loss of benefits to which I am otherwise entitled.

There are no foreseeable risks or discomforts of participating in this study beyond those that occur in everyday life. Also, although there may be no direct benefits to me, participating in this research provides the opportunity to contribute to psychological science and to acquire first-hand experience with theory testing and experiment design in psychology.

The results of this research study may be published but my name or identity will not be revealed. Information obtained during the course of the study will remain confidential, to the extent allowed by law. The records of this study will be kept private. All of my responses will be kept confidential and identified only by a participant code number. My name will never be linked to my responses and will not appear on any of the results. The master list containing participants’ names will be destroyed after code numbers have been assigned. Research records will be kept in a file behind locked doors. Access to the records will be limited to the researchers; however, please note that sponsors, funding agencies, regulatory agencies, and the Institutional Review Board may review the research records.

I will not be paid for my participation, but I will receive one credit point to apply toward the research requirement in my Introductory Psychology course.

Any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by Brandon J Schmeichel, 102 Psychology Building, Ph. 645-1497, Schmeichel@psv.fsu.edu or his advisor, Roy F. Baumeister, Ph. D., 102a Psychology Building, Baumeister@psv.fsu.edu. If I have questions about my rights as a subject/participant in this research, or if I feel I have been placed at risk, I can contact the Chair of the Human Subjects Committee, Institutional Review Board, through the Office of the Vice President for Research, at (850) 644-8633.

I have read the above informed consent form. I understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefits to which I may otherwise be entitled. In signing this consent form, I am not waiving any legal claims, rights or remedies. A copy of this consent form will be given (offered) to me.

Subject's Signature ______________________________ (Date)
INFORMED CONSENT FORM
"Emotions and Physical Endurance" 2004

You are being asked to participate in a research study of emotion and physical endurance. You were selected as a possible participant because of your enrollment in Introductory Psychology. We ask that you read this form and ask any questions that you may have before agreeing to be in the study. Researchers at Florida State University are conducting this study.

Background Information and Purpose:
The purpose of this study is to study how emotional processes might influence physical endurance.

Procedures:
If you agree to be in this study, we would ask you to do the following things during a single 1 hour session: read a short passage of text, answer some questions about yourself and the experiment, and perform a physical endurance task that requires you to place your hand in cold water. The total time commitment should be no longer than 50 minutes.

Compensation:
You will receive one extra credit point toward your Introductory Psychology course, and you will learn about the experimental process.

Confidentiality:
The records of this study will be kept private to the extent allowed by law. All of your answers to the questions will be kept confidential and identified by a participant code number. Your name will never be linked to the data collected, and will not appear on any of the results. No individual responses will be reported. Only group findings will be reported. In any sort of report we might publish, we will not include any information that will make it possible to identify a participant. Research records will be kept in a file behind locked doors. Access to the records will be limited to the researchers; however, please note that sponsors, funding agencies, regulatory agencies, and the Institutional Review Board may review the research records.

Risks and Benefits to Being in the Study:
There are no foreseen risks of participating in this study beyond those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests. You may experience some discomfort with some parts of the study, but these should be no greater than daily experiences. However, students may benefit from participating in this research through hands-on application of psychological principles. In addition, participants learn about theory testing and experimental design through their participation in psychology experiments. Group results will be sent to you upon request.

Voluntary Nature of the Study:
Your participation is voluntary. If you choose not to participate, it will not affect your current or future relations with the University. There is no penalty or loss of benefits for not participating or for discontinuing your participation. You will not lose course credit for discontinuing this experiment before completion, nor will your grade in General Psychology be affected. This consent may be withdrawn at any time without prejudice, penalty, or loss of benefits to which you are otherwise entitled. You are able to stop your participation at any time you wish.
Contacts and Questions:
You may ask any questions concerning this study at this time or during the study.

The researchers conducting this study are Brandon Schmeichel and Dr. Roy Baumeister, who is a Professor of Psychology at Florida State University. You may ask any questions you have now. If you have any questions later, you may contact Dr. Baumeister at 850-644-4200 about this research or your rights. You may also contact the Human Subjects Committee at 850-644-8833 if you have questions about this research.

In addition, the Florida State University Student Counseling Center offers FREE and CONFIDENTIAL individual counseling with a counselor to discuss a personal concern relating to academic difficulties, stress, relationship problems, anxiety, depression or other personal matters. SCC is located on the 2nd floor of the Student Life Building, (850) 644-2003.

You will be given a copy of this form to keep for your records upon your request.

Statement of Consent:
I have read the above information. I have received answers to the questions I have asked to my satisfaction.

I am at least 18 years of age.

I freely and voluntarily and without element of force or coercion, consent to be a participant in this research project entitled "Emotions and Physical Endurance".

Print Name of Participant: ________________________________

Signature of Participant: ________________________________ Date: ________________
REFERENCES


BIOGRAPHICAL SKETCH

Brandon J. Schmeichel was born and raised in O’Neill, Nebraska. He earned a Bachelor of Arts degree in Psychology from the University of Nebraska-Lincoln and a Master of Science degree in Experimental Psychology from Georgia Southern University. His research has been published in *Journal of Personality and Social Psychology*, *Personality and Social Psychology Bulletin*, and *Journal of Experimental Social Psychology*. 