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Intellectual Performance and Ego Depletion: Role of the Self in Logical Reasoning and Other Information Processing

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Some complex thinking requires active guidance by the self, but simpler mental activities do not. Depletion of the self's regulatory resources should therefore impair the former and not the latter. Resource depletion was manipulated by having some participants initially regulate attention (Studies 1 and 3) or emotion (Study 2). As compared with no-regulation participants who did not perform such exercises, depleted participants performed worse at logic and reasoning (Study 1), cognitive extrapolation (Study 2), and a test of thoughtful reading comprehension (Study 3). The same manipulations failed to cause decrements on a test of general knowledge (Study 2) or on memorization and recall of nonsense syllables (Study 3). Successful performance at complex thinking may therefore rely on limited regulatory resources.

A major purpose of the self is to exert control over responses, ranging from overt behavior to inner processes. As the agent or executive function, the self is responsible for acts of volition, including making choices, overriding incipient responses, being active instead of passive, and replacing one response with another. Recent findings have suggested that active self-control can be costly in the sense that it depletes some inner resource, akin to energy or strength. When this resource is depleted, the self's performance of its functions is often impaired.

The purpose of the present investigation was to study the role of the self in intelligent thought. More precisely, we undertook to demonstrate that resource depletion leads to impaired performance on tasks requiring high-level cognitive control. In contrast, information processing that does not depend on executive control might continue unaffected by resource depletion.

Human intelligence presumably functions at multiple levels. Recent theories of human information processing have suggested that processing occurs at two levels, and that logical reasoning is generally reserved for the more limited, inefficient, and costly level (e.g., Bargh, 1989, 1994; Kahneman & Frederick, 2002; Lieberman, Gaunt, Gilbert, & Trope, 2002). Perceiving, categorizing, interpreting, storing, and retrieving information may proceed relatively automatically, without requiring the self to take an active role in directing the process. In contrast, using logic to draw conclusions and implications from ideas, extrapolating from known facts to make estimates about unknowns, and generating novel ideas may require active self-control. This level of processing is costly in the sense that it consumes more resources.

Depletion of self-regulatory resources should impair performance on tasks that require controlled processing, such as active problem solving. However, depletion should not affect simpler, more basic forms of information processing, insofar as these can proceed by well-learned or standard procedures without active self-control. Therefore, we expected that the effects of resource depletion would materialize mainly on complex forms of information processing, whereas basic information processing would remain undisturbed.

Limited Resources and Ego Depletion

According to the limited resource view, the self has one limited stock of some resource that resembles energy or strength, which it expends whenever it actively changes, overrides, or otherwise regulates responses (Baumeister & Heatherton, 1996; Muraven & Baumeister, 2000). Crucially, the same resource is used for many different tasks, including regulating thoughts, controlling emotions, inhibiting impulses, sustaining physical stamina, and persisting in the face of frustration or failure. If that is correct, then this resource is a general-purpose asset that functions broadly in widely assorted acts of self-control and executive functioning, as opposed to being specifically earmarked for a particular response.

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Evidence for the limited resource model takes the form of decrements in self-regulatory performance as a function of prior exertion. In these studies, participants have been instructed to engage in an act of self-regulation, such as resisting temptation or controlling their emotions. Performance on a subsequent self-regulatory task, such as emotion control or task persistence, is then assessed. Typically, performance on the second self-regulatory task is impaired as a result of the initial self-regulatory behavior (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven, Tice, & Baumeister, 1998; Vohs & Heatherton, 2000). These effects suggest that both acts require some common resource that was depleted by the initial act.

Some data suggest that the limited resource is used for more than self-regulation: Other acts of executive functioning may deplete the same resource. These other acts include making deliberate behavioral choices, responding actively instead of passively, and making decisions about consumer goods (Baumeister et al., 1998; Baumeister, Twenge, & Nuss, 2002; Vohs & Faber, in press). Thus, choice making and initiative also require the self's executive function and have been shown to rely on the same resource as other self-regulatory behavior.

The Self as Problem Solver

Intelligent thought is one of the most important and adaptive activities of the human psyche. The present investigation was concerned with the role of self-regulatory resources in intelligent thought.

The self's potential relevance to cognitive functioning was suggested by Sternberg (1985), who characterized executive functioning as the planning, monitoring, and revision of information processing. In a recent review, Crinella and Yu (2000) further advanced this point by arguing that virtually all problem solving requires executive control. Baddeley's (1986, 1996; Baddeley & Hitch, 1974) working memory (WM) model is also a major contribution to theories of active cognitive control. The WM system has three parts. The most essential part is the central executive, which controls cognitive resources and monitors information processing. The central executive is served by two slave systems, the visuospatial sketchpad and the phonological loop; the former deals with visuospatial information and mental images, and the latter stores and rehearses verbal information. Crucially, the slave systems require little guidance and can operate automatically, whereas the central executive requires controlled processes and is resource dependent. Hence, some forms of thought, specifically higher order cognitive processes, require executive functioning and active self-regulation.

As one example, solutions to complex logic problems rarely present themselves immediately. Instead, the thinker must take an active role in choosing to invest effort in solving the problem, deciding how to construe the problem, and determining how to proceed. Initial or incipient responses may have to be overridden so that the problem can be approached in a less obvious—but ultimately more promising—manner. Thus, choice making can play a crucial role in intelligent performance. Further, the higher order cognitive processes used to solve complex logic problems may require active deliberation, sustained attention, and persistence, all of which may be construed as self-regulatory and central executive acts (Baddeley, 1986, 1996; Barkley, 1997; Broadbent, 1977; Norman & Shallice, 1986).

Insofar as solving problems and reasoning require active self-control, these may deplete limited self-regulatory resources. In keeping with other findings on ego depletion, performance on these tasks should be impaired if the self has already expended some of its resources on other acts of volition or self-regulation. Therefore, our first hypothesis was that intelligent performance on reasoning and similar central executive tasks would be impaired among people who have recently engaged in self-regulation.

Yet not all information processing should be affected by ego depletion. A great deal of information processing occurs in a relatively automatic and effortless manner without requiring much active intervention or control by the self (Baddeley, 1986, 1996; Bargh, 1994; Bargh & Ferguson, 2000; Gollwitzer & Moskowitz, 1996; Norman & Shallice, 1986). For example, the verbal and spatial slave systems in WM function effectively with no self-direction (Baddeley, 1986). Therefore, these types of processes should not be affected by whether the self's resources are fully available or depleted.

The full hypothesis for the present investigation was therefore that depletion of self-regulatory resources would impair only some kinds of cognitive activity. Mental performances that require the self to exert control, such as reasoning, problem solving, and other central executive operations, will become poorer if the self's resources have been depleted. In contrast, simple and straightforward forms of information processing, such as rote memory, should fare about the same regardless of previous expenditure of resources.

The distinction between active reasoning and more basic information processing approximates the distinction between fluid and crystallized intelligence. Fluid intelligence has been defined as the capacity to reason, manipulate abstractions, and discern logical relationships (Cattell, 1987; Garlick, 2002), and may thus particularly rely on volitional resources. Fluid intelligence has also been linked to WM (Engle, Tuholski, Laughlin, & Conway, 1999). Conversely, crystallized intelligence, which involves the retrieval of knowledge acquired through experience and education (such as vocabulary and general knowledge), may be relatively immune to the depletion of regulatory resources because they require little active control. Put in those terms, we predicted that ego depletion would affect fluid but not crystallized intelligence.

Present Research

The present investigation consisted of three studies. Collectively they were designed to test our multipart hypothesis: Ego depletion due to prior self-control should impair performance on intellectual tasks that involve higher order cognitive processes, including logic and reasoning—but the same resource depletion would not necessarily impair other, more basic forms of information processing. In each study, we manipulated ego depletion at the start of each trial by having participants either perform a task that required self-regulation or perform an alternative task that was hypothesized to be less likely to deplete regulatory resources. The two groups were then compared on subsequent intellectual performance.

Operationally, we manipulated ego depletion using two tasks that required two different forms of self-regulation: attention regulation and emotion control. Experiments 1 and 3 used an attention control task to deplete regulatory resources, whereas Experiment 2 used an emotion regulation task. Specifically, the manipulations of ego depletion required participants to ignore extraneous stimuli (Experiments 1 and 3) or to stifle emotional distress in response to an upsetting video clip (Experiment 2).

Tests designed to evaluate intellectual ability often assess both simple and more advanced types of cognitive processing. Some test items tap general knowledge and require only simple information retrieval from memory (e.g., “Who wrote *Gone With the Wind*?”). Other test items demand a more active and effortful processing approach, requiring the test taker to choose and implement an analytic strategy, select among a variety of information, and decide what is useful and what is to be ignored. According to the regulatory resource model, only those processing demands that require active, deliberate, and regulated effort on the part of the thinker should be susceptible to impairment due to prior resource depletion.

In Experiment 1, subsequent cognitive functioning was assessed using items from the Analytical subtest of the Graduate Record Exam (GRE; see Yang & Johnson-Laird, 2001). In Experiment 2, we assessed performance on the Cognitive Estimation Test (CET; Fein, Gleeson, Bullard, Mapou, & Kaplan, 1998; Shallice & Evans, 1978) and the General Mental Abilities Test (GMAT; Janda, 1996). The latter measure was included to demonstrate the specificity of resource depletion effects, insofar as it measures crystallized intelligence (general knowledge), which should be relatively immune to the impact of ego depletion. Experiment 3 examined cognitive performance with questions from the Verbal subtest of the GRE. This task involved reading and comprehending a passage and then demonstrating an interpretive understanding of the information; complex reading comprehension has been said to require the central executive in WM (Baddeley, 1996). Experiment 3 also included a nonsense syllable memorization task. The contrast between the two measures in Experiment 3 was intended to provide converging evidence that ego depletion would impair intellectual functions that require active cognitive control (such as reasoning and complex reading comprehension) but not impair activities that are not as dependent on controlled responding (such as rote memory for nonsense syllables). Thus, in these experiments we used an assortment of intellectual performance measures, each of which was selected on the basis of being either a measure of controlled reasoning or of more basic information processing.

Experiment 1

Experiment 1 provided a first test of the hypothesis that ego depletion could impair subsequent cognitive performance. (The second part of the hypothesis, regarding the forms of information processing that might remain unaffected by depletion of resources, was left to the second and third experiments.)

The manipulation of self-regulatory resources was borrowed from Gilbert, Krull, and Pelham (1988). All participants watched a video of a woman being interviewed. At the bottom of the screen flashed a series of words that were irrelevant to the interview. In the ego depletion condition, participants were instructed to direct their attention away from the words and to focus exclusively on the woman. This task involved self-regulation insofar as people were required to manage their attention and redirect it back to the interview whenever they began to notice the irrelevant words. In the control condition, participants were given no such instructions.

Intellectual functioning was measured by performance on a section of the GRE, a standard test given to most aspirants to graduate study in the United States. The GRE has long been considered a measure of general cognitive ability (Kuncel, Hezlett, & Ones, 2001), and successful performance on it requires active cognitive control and self-regulated thinking (Yang & Johnson-Laird, 2001). We used items from the Analytical subtest of the GRE to require participants to construct applicable mental models, make inferences, and derive logical conclusions on the basis of a set of postulates.

The GRE reasoning test was administered after the video of the interview was completely finished (and after a mood measure). Therefore, any findings would indicate the residual aftereffects of self-regulation, and not the effects of performing concurrent regulatory tasks. We expected that the attention control manipulation would deplete regulatory resources and therefore impair subsequent performance on this test of higher order cognitive processing.

Method

Participants. Twenty-six undergraduates (16 men, 10 women) participated in exchange for partial course credit. The data from 2 participants were not used because of procedural breakdowns: With 1 participant, the time limit for the intelligence problems was not adhered to; the videotape failed for the other participant. The data from 24 participants were used in the following analyses.

Procedure. Participants came to the laboratory individually, where they were first asked to watch a short videotape. Similar to procedures used by Gilbert et al. (1988), participants were asked to watch a 6-min videotape (without audio) that featured a woman being interviewed by an off-camera interviewer. Participants were told that they would later be making person-perception judgments of the interviewee because the experiment concerned nonverbal assessments of personality. In addition to the woman being interviewed, the tape showed a series of common one-syllable words (e.g., *play*) at the bottom of the screen for 30 s each. The words were printed in black, framed by a white background, and were confined to the bottom quarter of the screen. Thus, the words were readily apparent but did not dominate the main action on the screen. These words had no relationship to the woman being interviewed. Half of the participants were given no instructions regarding the irrelevant words, nor were they made aware of the words prior to viewing the video, whereas the other participants were instructed “not to read or look at any words that may appear on the screen.” Moreover, participants in the attention control condition were told to redirect their gaze to the woman being interviewed if they found themselves looking at the words. After viewing the video, participants completed a mood scale (the state version of the Positive and Negative Affectivity Schedule [PANAS]; Watson, Clark, & Tellegen, 1988). Thus, Experiment 1 included two cells, attention control versus no-control, as an initial investigation of our hypotheses.

Participants then attempted 13 problems from the Analytical section of the GRE. Participants worked until they had completed all of the GRE problems or until the experimenter stopped them because they had reached the predetermined time limit of 10 min. Last, participants were given a postexperimental questionnaire, debriefed, and thanked.

Results

Manipulation checks. A *t* test was conducted to confirm that the difficulty of the video-watching task varied by condition. This expectation was confirmed: When asked to rate the difficulty of performing the instructions they were given prior to the video (where 1 = *not at all difficult* and 10 = *very difficult*), participants in the attention-control condition rated the video-watching task as much more difficult than those in the no-control condition, $t(22) = 3.60$, $p < .01$, $d = 1.53$ (M attention control = 6.55, $SD = 2.33$ vs. M no-control = 3.08, $SD = 2.36$). Thus, the manipulation was successful in varying the degree of regulatory exertion.

Intellectual performance. The main prediction for Experiment 1 was that after actively controlling attention, participants would perform worse on the GRE Analytical items. We tested this hypothesis on three different performance measures: the number of items answered correctly, the number of items attempted (i.e., number of items for which participants recorded an answer), and the proportion of items answered correctly. Number correct represents the primary global measure of performance, number attempted is a measure of working speed and effort, and proportion of correct answers assesses overall accuracy. For each measure, we computed a t test to compare performance in the attention control versus no-control conditions.

Consistent with the ego depletion model, all three measures of controlled cognitive performance indicated an impairment among participants who had engaged in the self-regulation (attention control) task, as compared with the no-control group. Attention control participants achieved fewer correct answers than participants in the no-control condition, $t(22) = 3.87$, $p < .01$, $d = 1.61$. They likewise attempted fewer problems overall, $t(22) = 3.41$, $p < .01$, $d = 1.42$. Last, the attention control participants had a lower proportion of correct answers, $t(22) = 2.39$, $p < .03$, $d = 0.97$. In short, the prior exercise of self-regulation apparently had a detrimental effect on total achievement, effort/speed, and accuracy (see Table 1).

Tests of possible mood effects. One possible interpretation of the results is that the impact of the first self-regulation task was mediated by mood, in that trying to control attention may have been sufficiently averse that it put people in a bad mood. This interpretation is important to investigate because some bad moods have been shown to facilitate careful cognitive elaboration (e.g., Bless, Mackie, & Schwarz, 1992). Applying this line of reasoning to the current experiment, this alternate explanation would suggest that being in a negative mood would have increased cognitive elaboration and therefore facilitated performance on GRE problems, which is the opposite of what we found. Still, other mood-mediation hypotheses could probably be proposed. We therefore assessed whether differences in self-reported mood state emerged

Table 1
GRE-Analytical Performance by Condition (Experiment 1)

	No. correct		No. attempts		Prop correct	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attention control	3.46_a	1.64	5.27_a	1.95	0.65_a	0.17
No-control	7.23_b	2.86	8.85_b	2.97	0.81_b	0.16

Note. Means in the same column with different subscripts are significantly different at $p < .05$. GRE = Graduate Record Exam; Prop correct = proportion of correct answers for questions attempted.

as a result of the attention control manipulation and whether mood states influenced subsequent cognitive performance. Our mood measure was the PANAS (Watson et al., 1988), which yields separate scores of positive affect (PA) and negative affect (NA). We performed t tests and found no significant differences on the PA ($t < 1$, $d = 0.06$) or NA ($t < 1$, $d = 0.32$) subscales as a function of experimental condition. Descriptively, these null results indicate that attention control participants reported PA and NA states equivalent to no-control participants (attention control: M positive = 32.54, $SD = 7.41$ and M negative = 26.46, $SD = 5.99$; no-control: M positive = 32.09, $SD = 7.66$ and M negative = 28.73, $SD = 8.68$).

It is worth noting that high scores on the PA subscale of the PANAS have been thought to reflect high energy and engagement, whereas low scores on the PA subscale can reflect lethargy and a relative lack of energy (Watson et al., 1988). If the attention control manipulation resulted in simple bodily lethargy or fatigue, then depleted participants should report lower PA scores than the no-depletion participants. This pattern was not obtained. Next, we analyzed the three PANAS items that most directly relate to arousal or energy, but the two groups did not differ on any of these items. Specifically, attention control and no-control participants responded similarly to the items labeled “alert” ($M = 3.00$, $SD = 1.23$ vs. $M = 3.27$, $SD = 2.05$), “active” ($M = 3.23$, $SD = 1.48$ vs. $M = 3.45$, $SD = 1.57$), and “attentive” ($M = 2.92$, $SD = 1.32$ vs. $M = 2.72$, $SD = 1.35$), respectively. None of the differences even approached significance (all ts < 1, ds < 0.20). These null results suggest that the adverse impact of the attention control manipulation was not due to greater physical lethargy or fatigue than the no-control condition.

We then tried another analysis strategy as a way of exploring the possibility that mood states accounted for the link between the experimental manipulations and cognitive performance. To see if GRE performance was more affected by mood in one condition than another, we compared the link between mood and GRE performance among participants in the attention control condition versus those in the no-control condition. Consistent with the between-groups comparisons on self-reported affect, no differences emerged between conditions in the strength of the NA–GRE association and the PA–GRE association (all zs < 1.0, all ps $> .35$). In the attention control condition, GRE performance (measured as percent correct) did not significantly correlate with NA, $r(11) = -.12$, *ns*, or PA, $r(11) = .61$, *ns*; also, in the no-control condition, GRE performance did not significantly correlate with NA, $r(13) = -.42$, *ns*, or with PA, $r(13) = .37$, *ns*. Although there were no significant correlations between affect subscales and GRE performance, we acknowledge that small cell sizes may have prevented us from obtaining significant correlations. Even if one ignores the lack of significance and notes only the strength of the correlations, it does not appear that the relationship between mood and performance differed by condition, and therefore the differences between conditions in performance cannot be accounted for by mood. In total, it does not appear that mood substantially influenced the cognitive performance results.

Discussion

The results of Experiment 1 supported the hypothesis that engaging in self-regulation impairs subsequent ability to engage in intelligent thought. An initial exercise of attention regulation impaired subsequent cognitive performance on a reasoning task, as measured by items from the GRE Analytical test.

We measured performance in three ways and found decrements on all three measures. Participants who had performed the attention control exercise were subsequently less successful in terms of the total number of correct answers they furnished. They also attempted fewer problems, suggesting reduced speed of working and, by implication, less effort marshaled for the task. Finally, depleted participants got a lower proportion of correct answers among the problems they did attempt, indicating that their reasoning processes were less effective even at the slower speed. The latter two findings clearly help explain the first, in that reduced speed and reduced accuracy will almost invariably produce a poorer tally of correct responses.

It is somewhat surprising that both speed and accuracy decreased in the ego depletion condition, insofar as the traditional assumption is that performers trade off speed and accuracy such as by reducing speed to increase accuracy. If depleted participants had shifted to become slower but more accurate, for example, one might interpret such findings as indicating a change in test-taking strategy. However, simultaneous decrements in both speed and accuracy indicate a fairly global impairment of performance, consistent with the resource depletion explanation.

Furthermore, the observed decrements in cognitive performance were not attributable to mood states. The attention control manipulation did not lead to mood differences between the two groups, and the relationships between mood and performance were similar in the attention control and no-control conditions.

These findings are consistent with the hypothesis that regulatory resources play an important role in intelligent thought. Apparently, the exercise of trying to ignore irrelevant stimuli while watching the videotape depleted some resource that was later needed to manage effective performance on the logic and reasoning problems. This study was based on the assumption that logic and reasoning require active self-control. Solving analytical GRE problems required the construction of mental models, the inhibition of irrelevant information, and other controlled cognition to think through the implications of the information provided (see Yang & Johnson-Laird, 2001). Hence, impairment of regulatory resources left the self less able to control thinking so as to succeed at logical reasoning. If that view is correct, then ego depletion would not impair other kinds of information processing as long as these did not require the self to take an active role. Experiment 2 was designed to test that distinction.

Experiment 2

Experiment 2 attempted to show that the effect of ego depletion would be specific to only some kinds of cognitive performance. We reasoned that ego depletion would impair performances that involved active reasoning and executive control by the self—but would not affect simple and straightforward information processing, insofar as these can proceed without active guidance by the self.

Therefore, Experiment 2 gave two separate cognitive measures to each participant. The GMAT (Janda, Fulk, Janda, & Wallace, 1995; reprinted in Janda, 1996) was our measure of relatively simple information processing. The GMAT includes multiple-choice questions of vocabulary, general knowledge, and mathematical ability. Thus, doing well on this test involves retrieving information from memory and applying simple rules. In this respect, the GMAT is consistent with many other intelligence tests that rely in part on direct measures of vocabulary and other general knowledge. Because those cognitive processes would not require active guidance by the self's executive function, we predicted that performance on that task would not be affected by depletion of executive resources.

The second measure of intelligent functioning was the CET (Fein et al., 1998; Hodges, 1994; Shallice & Evans, 1978). The CET has been construed as a frontal lobe task (Kopera-Frye, Dehaene, & Streissguth, 1996; Shallice & Evans, 1978) and requires more elaborate information processing than the GMAT. To do well on this test, a person must extrapolate from existing knowledge and make plausible, appropriate adjustments, and so both reasoning and elaboration are required. Information retrieval from memory (as is decisive on the GMAT) is necessary but not sufficient for good performance on the CET. The need for executive control of these processes led to the prediction that ego depletion would impair performance on the CET.

A second goal of Experiment 2 was to provide a conceptual replication of Experiment 1. Appropriate responses on the CET require controlled processing, and so we predicted that ego depletion would impair performance on it. This finding could provide a parallel to the impaired performance on the GRE Analytical problems in Experiment 1. The novel prediction in Study 2 was that ego depletion would not have a comparable effect on the GMAT because it involves relatively simple and straightforward information processing, and the self does not have to actively manage each response such as by selecting strategies or generating novel information.

To provide converging evidence with the findings of Experiment 1, we used a different manipulation of ego depletion. Experiment 1 used an attention control task; Experiment 2 relied on an affect regulation task. For this manipulation, all participants in Experiment 2 were shown an emotionally upsetting video. To deplete regulatory resources, half the participants were instructed to stifle their emotional responses to the video. Past work has suggested that suppressing emotional responses requires self-regulation and depletes self-regulatory resources (Muraven et al., 1998).

Method

Participants. Thirty-seven undergraduates volunteered to participate in exchange for course credit. There were 15 men and 22 women.

Materials and procedure. The experimenter explained to participants that they would be watching a short video clip and then answering questions about their reactions to it. Participants were also informed that their faces would be videotaped while viewing the video clip for "record keeping purposes." Videotaping the participants allowed for a check of the emotion regulation manipulation (described below) and helped to ensure that participants were following directions. Next, participants were told that, following the video clip, they would be engaging in two cognitive tasks that the experimenter was evaluating for possible use in a future experiment. (In actuality, these were the dependent variables of the study.)

Prior to arrival at the laboratory, participants were randomly assigned to the emotion regulation or no-regulation condition. In both conditions, participants watched a 10-min excerpt from the film *Mondo Cane* (Jacopetti, 1964). This film clip presented emotional scenes of environmental pollution and depicted the harmful effects of pollution on wildlife and ecology. The experimenter read one of two sets of viewing directions regarding the clip (see Gross, 1998). In the emotion suppression condition, participants were instructed to suppress, both internally and externally, their emotional reactions to the film clip. In the natural (no-regulation) condition, participants were instructed to react naturally to the film clip.

After providing the viewing instructions, the experimenter started the video camera and the video clip, and exited the room. When the film clip ended, he returned to the room and announced: "That concludes the video clip portion of the experiment. Now I want you to fill out a questionnaire about how you're feeling and then will have you do two cognitive tasks that I am pretesting for potential use in another experiment."

After participants had completed the state version of the PANAS (Watson et al., 1988), the experimenter announced that participants would have 9 min to complete as many items as they could on a cognitive test. The GMAT (Janda et al., 1995; reprinted in Janda, 1996) was developed as a written, multiple-choice intelligence test suitable for administration to groups. The test includes measures of general knowledge, vocabulary, mathematical ability, and spatial ability (although the time limit did not allow participants to attempt any of the spatial ability section of the test). Testing was stopped after the predetermined time limit of 9 min. Participants were then given the CET (Fein et al., 1998; see also Hodges, 1994; Shallice & Evans, 1978) and were instructed to finish it at their own pace. The CET consists of 20 questions that have unclear answers that can be approximated by reasoning and consideration of related knowledge (e.g., "How many seeds are there in a watermelon?"; "How long does it take to iron a shirt?"). The CET is an open-ended test, which means that participants are required to actively generate novel responses for each test item. The CET served as our measure of fluid cognitive functioning, whereas the GMAT was included as a test of more basic information processing (e.g., vocabulary words and general knowledge questions such as "Which city is known as the Windy City?"). Thus, emotion control versus no-control was a between-subjects factor and task type (i.e., CET vs. GMAT) was a within-subjects factor.

A postexperimental questionnaire was administered to serve as a check of the emotion regulation manipulation. This questionnaire asked participants if they had been given any specific instructions regarding watching the clip, how difficult it was to follow any such instructions (1 = *not at all difficult*, 7 = *extremely difficult*), and to speculate on the nature of the experiment. Finally, participants were fully debriefed regarding the purpose of the experiment and were also informed that the cognitive test (GMAT) was not a good measurement of cognitive ability, because they were given only 9 min to work on a test that takes most people 20–30 min to complete.

Results

Manipulation checks. The postexperimental questionnaire asked several questions designed to verify that participants did or did not manage their reactions to the film clip as instructed. All participants correctly restated the instructions they had been given regarding how to watch the film. As in Experiment 1, we also sought to verify that the self-regulation task was experienced as somewhat difficult or effortful. As expected, emotion suppression participants ($M = 3.37$, $SD = 1.89$) reported somewhat more difficulty in performing their task than did participants in the no-regulation condition ($M = 2.33$, $SD = 1.33$), $t(35) = 1.92$, $p = .06$, $d = 0.64$.

An additional and more objective check on the emotion regulation manipulation was conducted (see also Vohs & Heatherton, 2000). Two raters blind to experimental hypotheses coded three 1-min segments of each participant viewing the film clip. These raters coded visible levels of emotionality in participants' faces on a scale from 1 (*not at all expressive*) to 7 (*extremely expressive*). Raters were unable to code data from 6 participants because of equipment malfunction or because the participant's face was not clearly observable. Ratings for each remaining participant were summed across the 1-min intervals, creating a possible range of expressivity scores from 3 to 21. Raters' assessments of emotionality were averaged, and a *t* test on these facial expressivity scores revealed that emotion suppression participants showed less facial emotionality ($M = 4.18$, $SD = 0.95$) than did control condition participants ($M = 6.57$, $SD = 2.31$), $t(29) = 3.90$, $p < .01$, $d = 1.35$, indicating that emotion suppression participants were indeed complying with the experimental manipulation.

Intellectual performance: CET. The main dependent measures were scores on the intellectual tests. The CET was conceptually similar to the GRE test used in Experiment 1, in that it required some degree of active participation by the self for reasoning and extrapolation and is assumed to engage the central executive of the WM system. Thus, we predicted that the emotion regulation would impair performance on the CET.

Scores on the CET were calculated such that very inappropriate estimates were assigned 2 points, mildly inappropriate estimates were assigned 1 point, and estimates that fell within an acceptable range were assigned 0 points (Hodges, 1994). The scoring criteria were based on performance by an adult sample reported by Fein et al. (1998) and were as follows: Responses that fell between the 25th and 75th percentile of the response range received a score of 0 (acceptable); responses that fell in the response range of 90% of the adult sample but not within the 25th and 75th percentiles received a score of 1 (mildly inappropriate); all other responses were assigned 2 points (very inappropriate). Thus, higher scores on this test reflect poorer performance. Scores in this sample ranged from 3 to 16. Providing a conceptual replication of the results of Experiment 1, there was a significant difference on CET scores as a function of prior self-regulation. Emotion suppression participants ($M = 8.84$, $SD = 3.35$) scored worse than no-regulation participants ($M = 6.56$, $SD = 2.73$), $t(35) = 2.27$, $p = .03$, $d = 0.75$. (Because the test was not timed, all participants were able to complete it, and so there were no differences on number attempted. Consequently, proportion of correct answers is the same as number of correct answers.)

The CET can also be scored so that responses are categorized either as correct (i.e., estimates fell within the acceptable 25th to 75th percentile range) or incorrect (i.e., estimates that are considered mildly or wildly incorrect; that is, responses previously assigned 1 or 2 points). Comparing the number of accurate estimates in the two groups showed that participants in the emotion suppression condition had fewer correct responses than participants in the no-regulation condition, $t(35) = 2.10$, $p < .05$, $d = 0.69$ (see Table 2). Fewer correct estimates in the emotion control condition are consistent with the hypothesized effects of ego depletion on complex cognitive processing.

Still another way that the CET has been scored is to analyze the prevalence of participants who gave very unintelligent (i.e., very inappropriate, 2 points) responses. Past research indicates that participants who are unable to use an appropriate strategy or who fail to adjust their initial estimates adequately are more likely to give very inappropriate responses (Shallice & Evans, 1978). Accordingly, if the emotion control manipulation led to a state of ego depletion, we would expect a greater prevalence of very inappropriate responses by the emotion regulation participants. A chi-square analysis in which participants were categorized as having given one or more very inappropriate answers versus none of these answers revealed a trend in that direction. There were more participants who provided very inappropriate (2 points) answers in the emotion regulation condition than in the no-regulation condition, $\chi^2(1, N = 37) = 3.28$, $p = .07$. Descriptively, this analysis revealed that 14 out of 19 emotion regulation participants made at least one such unintelligent response, whereas in the no-regulation condition, only 8 of 18 participants did.

Intellectual performance: GMAT. For the second part of our main hypothesis, we tested the prediction that performance on the GMAT would not be affected by the emotion regulation manipulation. A t test supported this expectation in showing that participants in the two conditions correctly answered a similar number of GMAT questions correctly ($t < 1$, $d = 0.17$; see Table 2). Thus, exerting self-regulatory effort by suppressing emotions did not adversely affect performance on a cognitive test involving straightforward information processing and simple retrieval from memory.

Because the GMAT was timed and because none of the participants finished the entire test, we were able to analyze speed (number of attempts) and accuracy (proportion correct) separately. Once again, no differences were found between the two conditions. Participants in the emotion regulation condition attempted about the same number of problems as participants in the no-regulation condition ($t < 1$, $d = 0.11$). Likewise, the proportion of correct answers, which was computed by dividing the number correct by the number attempted, revealed nearly identical scores in the no-regulation and emotion regulation conditions ($t < 1$, $d = 0.11$). Relevant means and standard deviations are presented in Table 2.

Intellectual performance: Direct comparisons of cognitive tests. To address the full hypothesis that resource depletion influences higher order cognition but not more basic information processing, we compared performance on the two cognitive tasks using a mixed-factors analysis of variance (ANOVA). Emotion regulation condition was the between-subjects factor and type of test (i.e., GMAT or CET) was the within-subjects factor. Performance was compared by standardizing the number of correct responses on the GMAT and the CET. A marginal interaction indicated that the emotion regulation manipulation impaired CET performance but not GMAT performance, $F(1, 35) = 2.86$, $p = .10$. The marginally significant interaction suggests that participants' cognitive abilities depended on the joint combination of ego depletion condition and type of test. The breakdowns of performance within each test by ego depletion condition were detailed in the univariate analyses above. In the mixed-ANOVA model, the two main effects of test type and emotion regulation condition were nonsignificant (Fs < 2.00, ps $> .20$).

Table 2
Cognitive Performance by Condition (Experiment 2)

	CET		GMAT					
	No. correct		No. correct		No. attempts		Prop correct	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Emotion control	10.16_a	3.13	21.58	6.13	30.63	8.44	0.70	0.19
No-control	12.11_b	2.47	22.94	9.25	31.61	8.68	0.72	0.17

Note. Means in the same column with different subscripts are significantly different at $p < .05$. CET = Cognitive Estimation Test; GMAT = General Mental Abilities Test; Prop correct = proportion of correct answers for questions attempted.

Tests of possible mood effects. We again assessed whether mood differences between groups may have influenced cognitive performance. We focused on the CET because it was the test that showed group-wide differences in cognitive performance that may have reflected contaminating effects of mood. Two t tests on scores on the PA ($t < 1$, $d = 0.31$) and NA ($t < 1$, $d = 0.23$) subscales of the PANAS (Watson et al., 1988) revealed no significant differences between the two groups (emotion suppression condition, positive $M = 23.53$, $SD = 7.35$, and negative $M = 17.74$, $SD = 7.06$; no-suppression condition, positive $M = 21.61$, $SD = 4.85$, and negative $M = 16.39$, $SD = 4.19$, respectively).

As in Experiment 1, we also compared the depletion and no-depletion groups on the three PANAS items that directly relate to energy or fatigue: "alert" (depletion $M = 2.84$, $SD = 1.34$ vs. no-depletion $M = 2.78$, $SD = 0.94$), "attentive" (depletion $M = 3.21$, $SD = 1.13$ vs. no-depletion $M = 2.94$, $SD = 1.00$), and "active" (depletion $M = 2.47$, $SD = 1.35$ vs. no-depletion $M = 2.17$, $SD = 0.86$). No differences emerged between groups on any of these items (all ts < 1, all ds $< .28$). Thus, participants who suppressed their emotions self-reported an affective experience that was quite similar to that of participants who did not regulate their emotions. One should recall also that participants who suppressed their emotional reactions showed less emotional expressivity on their faces than participants who viewed the clips naturally. The behavioral coding and self-report results largely support prior work on emotion suppression and show that although suppression does not reliably alter self-reported emotional experience, it does minimize the behavioral expression of emotion (Gross, 1998).

We further explored potential mood effects by computing correlations between NA and CET scores and between PA and CET scores within each condition. As expected, correlations between PA and CET performance in the two conditions did not differ reliably ($z = -0.19$, *ns*), nor did correlations between NA and CET performance ($z = 0.21$, *ns*). None of the individual correlations was significant: in the depletion condition, PA and CET performance, $r(19) = -.02$, *ns*; NA and CET performance, $r(19) = -.06$, *ns;* in the no-depletion condition, PA and CET performance, $r(18) = -.10$, *ns*; NA and CET performance, $r(18) = -.06$, *ns*. Similar (null) relationships were obtained when CET performance was operationalized as the number of correct responses. These analyses support our contention that differences in high-level cognitive performance were a function of depletion condition and not mood.

Discussion

Experiment 2 demonstrated that ego depletion impaired subsequent higher order cognitive processing, whereas more basic information processing abilities remained intact. Although all participants viewed the same upsetting video, those who controlled their emotional reactions generated poorer cognitive estimates (as evidenced by scores on the CET) than participants who had not depleted their limited regulatory resource by controlling their emotions. However, emotion control and no-control participants showed equivalent performance on a test requiring simple information retrieval and rule application (i.e., the GMAT). These results attest to the specificity of the effects of ego depletion: Only those processes that demand the self's executive function appear to be impaired by ego depletion.

The hypothesis that ego depletion impairs higher order but not more basic information processing was supported in Experiment 2. Results from the univariate analyses conformed to our predictions regarding the effect of ego depletion on tasks varying in cognitive processing demands; however, the mixed-model analysis indicated that the differential impact of our manipulation was only marginally significant. It is possible, however, that the two tests used as dependent measures in Experiment 2 did not provide the best assessment of our full hypothesis. Specifically, it is reasonable to assume that the GMAT, our measure of basic information processing, may have required some degree of higher order information processing (such as elaboration and mental persistence) in addition to basic information recall from memory. Rather than ascertain the processing requirements of the GMAT, we conducted Experiment 3 for clarification in the form of two cognitive tasks that, on an a priori basis, most certainly required different levels of mental processing.

To be sure, some alternative interpretations for our findings could be proposed in view of methodological factors. One difference between the two tests in Experiment 2 was that the GMAT was timed whereas the CET was untimed. Expert opinion among intelligence testers is divided as to whether timed or untimed tests are most appropriate for assessing intelligence, and so we felt it important to use both kinds of tests. The fact that we found differences on the untimed test (the CET) but not on the timed one (the GMAT) might raise the possibility that ego depletion affects performance on untimed but not timed tests. This alternative interpretation is however contradicted by the fact that we did find significant differences on a timed test in Experiment 1 (as well as in Experiment 3; see below). Similarly, the CET was an open-ended test whereas the GMAT was a multiple-choice test, and so it may be that ego depletion only impairs performance on open-ended tests. However, again, ego depletion impaired performance on a multiple-choice test in Experiment 1 (and, as will be seen, also in Experiment 3) as well as on an open-ended test (the CET). It appears that the complex and controlled processing that the GRE and CET tests require is impaired by ego depletion, and that this effect obtains despite variation in the structural features (e.g., time limit, response format) of the cognitive performance measures.

Another possible confound is the order of measures. In Experiment 2, all participants completed the GMAT before the CET, and the different results on the two tests raises the possibility of order effects. In retrospect, it would have been better to counterbalance the order of tests. Nevertheless, the most likely order effect would involve impairments on the first test immediately after the depletion manipulation, with the effect of ego depletion possibly becoming attenuated over time and therefore being weaker on the second measure. The present results showed the opposite pattern, which renders an order effect interpretation somewhat less plausible. We note, however, that it is possible that resource depletion that resulted from the emotion regulation task was exacerbated by performing the GMAT before the more complex CET. This possibility suggests that poorer CET performance may have been due to performing both the GMAT and the emotion regulation task. In any case, the procedures of Experiment 3 counterbalanced the order of the tasks to allow for direct assessment of possible order effects.

As in Experiment 1, mood and emotion failed to mediate the results. Indeed, the manipulation failed to produce significant differences on our mood measure (the PANAS, Watson et al., 1988). The possibility of mood mediation was especially salient in this experiment, insofar as the manipulation involved exposure to a distressing video and participants were instructed to stifle their emotions or to watch and respond naturally. The lack of mood effects suggests that mood was not responsible for the differences in cognitive performance. This pattern is consistent with previous studies on ego depletion and the limited resource model of self-regulation (Baumeister et al., 1998; Muraven et al., 1998; Vohs & Heatherton, 2000).

Experiment 3

The purpose of Experiment 3 was to provide a conceptual replication of the findings of Experiments 1 and 2 while also implementing several methodological improvements. As noted, the findings of Experiment 2 were somewhat compromised by the possibility of order effects, by some degree of overlap in the processing demands of the two tasks, and by a possible confound between timed versus untimed tasks. Experiment 3 therefore used two tasks that demanded quite different cognitive operations, counterbalanced the order of the two tasks, and enforced a strict time limit on both.

To increase generalizability and to assess ego depletion effects using two more disparate mental tasks, Experiment 3 introduced two measures of cognitive performance that were not included in the previous studies. These were a reading comprehension task taken from the GRE and a nonsense syllable memory task. Complex reading comprehension requires the central executive component of WM (Baddeley, 1996), and so performance on this task is particularly likely to be impaired by ego depletion.

The passages and the reading comprehension questions were taken from published versions of actual GRE tests (Lurie, 2001). We selected the relatively difficult questions that required some degree of reasoning, as opposed to questions that simply required the person to report back verbatim what he or she just read (see Baumeister et al., 2002). Thus, to answer these questions effectively, the person had to engage in active cognitive control. Correct responses required participants to comprehend and store the information first, retrieve it from memory (although the text on which questions were based was available for reference; thus participants had to remember that they had read the relevant information and where to find it on the page), select among the stored knowledge for the precise information relevant to the question, and then (crucially) elaborate on that information to generate or identify the correct response. Insofar as these operations require active self-management and central executive operations, we predicted that successful performance would draw on the self's regulatory resources, and therefore ego depletion would cause poorer performance.

In contrast, the nonsense syllable task was selected precisely because it is a standard exercise used by cognitive researchers to study rote memory and basic information processing and, as such, does not require active cognitive control to the same degree as the reading comprehension task (e.g., Hellige & Marks, 2001). Participants read a list of nonsense syllables and then, after a filler (distracter) task, were instructed to write down as many of the nonsense syllables as they could remember. Performing this task requires only minimal involvement by the self, because the person simply reproduces the exact stimuli read minutes earlier. To be sure, the initiation of rehearsal of the nonsense syllable items may be construed as a function of the central executive component of WM (Baddeley, 1986), but the filler task was designed to minimize opportunities for rehearsal, and in any case it is safe to assume that the reading comprehension task demanded more extensive cognitive control than the nonsense syllable task.

The prediction was the same as for Experiment 2, albeit with the new tasks substituted. Ego depletion should impair performance on the higher order cognitive task that requires active self-control, and so we predicted effects on the GRE reading comprehension task. In contrast, depletion should not affect the lower level, straightforward information processing, and so no differences on the nonsense syllable task were predicted.

Method

Participants. Thirty-six undergraduates volunteered to participate in exchange for course credit. There were 19 men and 17 women.

Procedure. The manipulation of regulatory resource depletion was the same as in Experiment 1 (see Gilbert et al., 1988): Participants watched the same video depicting a woman being interviewed while irrelevant words flashed on the screen. Half of the participants were instructed to avoid looking at the irrelevant words (attention control condition), whereas the other half were given no specific viewing instructions and were therefore free to direct their attention as they pleased. After watching the video, participants were asked to complete the state version of the PANAS (Watson et al., 1988) as a mood measure.

Subsequently, participants were given two tasks—memorizing a list of nonsense syllables and a reading comprehension test from the Verbal section of the GRE. The order of administration of these tasks was randomly determined to test for possible order effects.

In the nonsense syllables task, participants were given 1 min to read and memorize a list of 15 meaningless, three-letter combinations (e.g., *vaw*, *rox*), which was followed by a 90-s interval in which participants were given a list of math problems to complete as a filler task. As the last step in this task, participants were given a free-recall task for 1 min to assess their memory for the meaningless words.

The reading comprehension task asked participants to answer nine questions that tested the ability to comprehend and think intelligently about two different reading passages. The passages and the reading comprehension questions were taken from published versions of actual GRE tests (Lurie, 2001). Questions required participants to go beyond the information given to draw reasonable conclusions about the passages. Some questions, for example, asked participants to infer the author's primary purpose in writing the passage, and others asked participants to deduce why the author included certain types of information in the passage. Answers to these questions were not explicit or obvious from the text, and so participants had to engage in intelligent thought to determine the correct response. We imposed a 9-min time limit on the reading comprehension test.

After completing both the nonsense words task and the GRE task, participants completed a postexperimental questionnaire. Thus, the study used a $2 \times 2 \times 2$ mixed-factors design in which attention control versus no-control instructions and order of completing the tasks (i.e., nonsense words task first vs. GRE reading problems first) were between-subjects factors and task type (nonsense words vs. GRE problems) was the within-subjects factor.

Results

Manipulation checks. We conducted a *t* test to confirm that the difficulty of the video-watching task varied by condition. This expectation was confirmed: Attention control participants rated their task as more difficult (on a scale ranging from 1= *not at all difficult* to 10 = *very difficult*) than participants in the no-control condition, $t(33) = 3.66$, $p < .001$, $d = 1.25$ (*M* attention control = 4.17, *SD* = 2.92 vs. *M* no-control = 1.47, *SD* = 0.87). Thus, the manipulation was successful in varying the degree of regulatory exertion.

Test for order effects. Tests of order effects (nonsense words task first or reading comprehension first) revealed no significant differences in either dependent measure of cognitive processing, nor did test order predict either subscore on the PANAS (Fs < 2.25, *ns*). Thus, the sequence of the tests does not appear to have been a factor in determining performance.

Cognitive performance: GRE reading comprehension. Our primary prediction was that having to control one's attention would lead to poorer reasoning ability, as evidenced by lower scores on the GRE reading comprehension test. We computed an ANOVA with condition (attention control or no-control) and task order (within-subjects factor: reading comprehension first or nonsense words first) as predictors of GRE scores. This analysis revealed the predicted cognitive impairment effect of attention control instructions, $F(1, 35) = 8.50$, $p < .001$, $d = 0.98$. Engaging in attention control while watching the videotape led to worse performance on the subsequent GRE reading comprehension test relative to participants who did not control attention during the video (see Table 3). There were no other main effects or interactions in predicting GRE scores (Fs < 2.25, *ns*), suggesting that the order of the two tasks following the attention control manipulation did not influence reading comprehension test performance. Because the GRE was timed, we were again able to compute speed (i.e., attempted questions) and accuracy (i.e., proportion of correct answers, which takes into account number of attempts). An ANOVA revealed that although participants in the ego depletion condition attempted the same number of problems ($F < 1$, *ns*, $d = 0.28$), they were much

Table 3
Cognitive Performance by Condition (Experiment 3)

	GRE reading						Nonsense syllables	
	No. correct		No. attempts		Prop correct		Prop correct	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attention control	4.56_a	1.04	8.06	2.92	0.57_a	0.18	0.40	0.18
No-control	5.72_b	1.49	7.39	1.33	0.78_b	0.11	0.45	0.15

Note. Means in the same column with different subscripts are different at $p < .05$. GRE = Graduate Record Exam; Prop correct = proportion of correct answers for questions attempted.

more inaccurate on those they did attempt, $F(1, 34) = 17.66$, $p < .001$, $d = 1.45$, compared with the no-control participants. Hence, there were robust performance impairments on the complex, higher order cognitive task, thereby helping to confirm the results of Experiments 1 and 2.

Cognitive performance: Nonsense syllables task. Next, we conducted a parallel analysis on performance on the nonsense syllable recall task. An ANOVA using the same predictors (condition and task order) found no effect of attention control condition on memory for the nonsense words, $F(1, 35) = 1.27$, *ns*, $d = 0.39$, no main effect of task order, $F(1, 35) = 2.60$, *ns*, $d = 0.56$, nor an interaction between task order and attention control condition ($F < 1$). Attention control participants and no-control participants recalled approximately the same number of nonsense syllables, consistent with our predictions (see Table 3). This finding is a conceptual replication of the results of Experiment 2, in which simple information processing was unaffected by ego depletion.

The nonsignificant main effects of task order and attention control condition on nonsense syllable recall deserve further attention because it is possible that these effects would have been statistically significant in a larger sample of participants. We conducted post hoc tests to assess whether the effect of the attention control manipulation on nonsense syllable performance was more reliable among participants who took the reading comprehension task first (attention control $M = 4.88$, $SD = 1.73$ vs. no-control $M = 6.40$, $SD = 2.72$) or among those who did the nonsense syllable task first (attention control $M = 6.80$, $SD = 2.40$ vs. no-control $M = 7.13$, $SD = 2.80$). Although tests of depletion condition within task order conditions failed to reach significance (ts < 1.40, *ns*), the resource depletion effect on nonsense syllable recall was in fact larger when participants had performed the reading comprehension task first ($d = 0.67$) than when participants had taken the nonsense syllable task first ($d = 0.13$).

This pattern of results implies that the attention control manipulation alone did not have a large impact on nonsense syllable recall, but that performing the GRE reading comprehension test in addition to the attention control task did have some negative impact on subsequent recall performance. If one allows that the nonsense syllable test does require some guidance by the central executive of WM, such as in the initiation of rehearsal of these syllables (Baddeley, 1986), then it is reasonable that performing both the reading comprehension test and the attention control task would impair recall performance, but that the attention control task alone would not impair recall because this single task is less depleting than the combination of tasks. However, the reading comprehension task clearly required more central executive activity than the nonsense syllable task, which is presumably why reading comprehension was reliably impaired by the attention control manipulation whereas the nonsense syllable task was not.

Cognitive performance: Direct comparisons of cognitive tests. The full test of our hypothesis involved showing that the manipulation of ego depletion affected one kind of task more than the other. To do this, we computed a mixed-factor ANOVA with attention control condition and task order as between-subjects factors and performance on each type of test (using proportion of correct answers on the GRE vs. proportion of nonsense syllables correctly recalled) as a within-subjects factor. This analysis yielded a main effect for attention control, $F(1, 31) = 11.76$, $p < .01$, $d = 1.23$, indicating that the initial exercise in attention control reduced performance quality overall, and no main effect of task order, $F(1, 31) < 1.81$, *ns*, $d = 0.47$. The main effect of condition was qualified by an interaction between condition and type of test, $F(1, 31) = 4.08$, $p < .05$, partial eta squared (ηp^2) = 0.12. As the preceding analyses indicate, the main effect of the attention control condition was observed almost entirely on the reading comprehension task. The significant interaction constitutes the most direct support for our hypothesis that ego depletion impairs complex cognition but not simple information processing.

Tests of possible mood effects. We expected that the attention control task would not affect mood states as measured by the PANAS (Watson et al., 1988), a prediction that was supported by an ANOVA with attention control condition as the predictor. Scores on the PA subscale ($F < 1$, $d = 0.04$) and the NA subscale ($F < 1$, $d = 0.43$) were similar in the attention control (positive $M = 21.13$, $SD = 5.38$, negative $M = 11.10$, $SD = 6.32$) and no-control (positive $M = 21.35$, $SD = 6.48$, negative $M = 13.42$, $SD = 4.34$) conditions. As in Experiments 1 and 2, we also focused on the three PANAS items that directly relate to fatigue and lethargy. Again, the two groups did not differ on these items. Participants in the attention control and no-control conditions gave similar responses on the “alert” ($M = 3.72$, $SD = 0.83$ vs. $M = 3.89$, $SD = 0.90$), “active” ($M = 2.89$, $SD = 0.90$ vs. $M = 3.00$, $SD = 1.09$), and “attentive” ($M = 3.56$, $SD = 0.62$ vs. $M = 3.44$, $SD = 0.92$) items, respectively (all ts < 1, ds $< .16$). Consistent with Experiments 1 and 2, the ego depletion manipulation did not result in more self-reported fatigue or lethargy.

We again explored whether mood states in the two conditions were differentially related to performance. We found no difference in the magnitude of the correlation between NA and GRE performance in the control condition and the attention control condition ($z = 0.68$, *ns*). The correlation between PA and GRE performance was also similar in both groups ($z = 0.66$, *ns*). In fact, none of the correlations between PA and NA and the two cognitive tasks was significantly different between the two conditions (all zs < 0.80, all ps $> .40$). Correlations between mood and GRE performance were as follows: PA did not correlate with GRE performance in the attention control, $r(18) = -.11$, *ns*, or the no-control, $r(18) = -.13$, *ns*, conditions. Similarly, NA did not correlate with GRE performance in the attention control, $r(18) = -.17$, *ns*, or no-control, $r(18) = -.06$, *ns*, conditions, respectively. Once again, mood did not appear to influence performance on the cognitive tasks.

Discussion

The findings of Experiment 3 provided further evidence that ego depletion affects some cognitive performances and not others. After participants watched a video during which they either did or did not have to regulate their attention, all participants performed two different cognitive tasks. Participants who had regulated their attention showed poorer performance than other participants on the reading comprehension task, but there was no difference on the nonsense syllable memory task. This pattern of findings is a conceptual replication of the results in Experiment 2, and they fit the overarching hypothesis that ego depletion impairs the self’s ability to reason actively and manage its cognitive activity, whereas simple information processing is unaffected. The results of Experiment 3 also indicate that ego depletion impairs complex reading comprehension, a task that relies on the involvement of the central executive in WM (Baddeley, 1996).

These results provide valuable corroboration of the results of Experiment 2 in several respects. First, the same pattern of results was obtained in both studies despite different manipulations of resource depletion and different measures of intellectual performance. Second, Experiment 3 counterbalanced the order of the tasks and showed that there were no significant order effects, thus ruling out one possible alternative explanation for the findings of Experiment 2. Third, Experiment 3 showed impairment on a timed task, whereas Experiment 2 showed it on an untimed task, and so the same result emerged regardless of whether participants performed at their own pace or against a time limit. Fourth, there has been no evidence that the results were due to mood or emotion.

General Discussion

Self-regulation refers to the self's ability to manage its own responses and processes. This ability appears to be essential when the self makes difficult choices, manipulates and elaborates on information, or develops implications through logical reasoning. Thus, self-regulation may be especially relevant to some kinds of cognitive processes but not others. More specifically, simple information processing may not depend on active guidance by the self, whereas complex, logical reasoning that requires executive operations likely does require the self to play an active role.

The present investigation began with the assumption that self-regulation depends on a limited resource, akin to strength or energy, that is consumed when the self actively regulates its responses or engages in other acts of volition. After such an act, the self is in a state of ego depletion. This state is signified by a reduction in the amount of resources the self has available to use for further acts of self-regulation and volition. Ego depletion can be inferred by impaired performance on such acts. When depleted, the self does not function as well, as effectively, as otherwise.

The present investigation manipulated ego depletion by having some participants engage in an initial act of self-regulation. Participants were instructed to regulate their attention (Experiments 1 and 3) or their emotional responses (Experiment 2); then performance on various cognitive tasks was measured. Some of these cognitive tasks involved higher order processes that presumably required the self to take an active, decisive role, whereas the other (simpler) tasks could seemingly proceed without active guidance by the self.

The results of these three studies consistently showed that ego depletion led to poorer intellectual performance—but only on the higher order, more complex tasks (such as logical reasoning) that presumably required active self-control and executive functioning. Impairments of this kind were found in all three studies. In Experiment 1, ego depletion led to poorer performance on logical reasoning questions from the GRE Analytical test. In Experiment 2, depletion led to poorer performance on the CET, which required participants to estimate unknown answers by extrapolating from existing knowledge. In Experiment 3, depletion caused poorer performance on a reading comprehension test from the GRE Verbal test, in which participants had to mentally manipulate information to answer thought-provoking questions.

In contrast to the pattern of impaired performance involving higher order cognitive processing, simple information processing was unaffected by the same manipulations in the same studies. In Experiment 2, ego depletion failed to impair performance on a simple test of vocabulary and other general knowledge. In Experiment 3, ego depletion had no impact on performance on a nonsense syllable recall task. It is important to note that the same set of participants completed both the higher order and basic processing tasks within each of the latter two studies. Thus, even when the self's resources have been expended, the person can still learn new information and retrieve it from memory. The depleted person can also follow well-learned rules (such as in basic arithmetical computations) but cannot engage more advanced forms of cognitive operations (such as logical reasoning).

The broad implication is that the conscious, active self is vital for some mental acts but not others. When the self is depleted by previous regulatory exertions, one set of mental processes is impaired, but another set is unaffected. In the terms of Baddeley's (1986, 1996) WM model, ego depletion hinders the controlled functioning of the central executive, but depletion does not interfere with the automatic functioning of the slave systems in WM. The involvement of the human self in cognitive processes thus appears to have expanded the power and range of thinking, but these added powers are fragile in that these cognitive abilities are reduced when resources are depleted.

Alternative Explanations

The present results correspond well with predictions arising from the view that self-regulation and executive functioning draw on a limited resource that can be depleted. However, it is useful to consider these results from other perspectives and to address potential alternate explanations.

As already noted, the findings of Experiment 2 were possibly confounded by the procedure of administering the two main cognitive tests in the same order. Explaining the different findings on the basis of order effects seems less plausible given that there was no effect of the manipulation on the first task (the GMAT) but a significant effect on the second task (the CET). Order effects most commonly reflect diminishing effects of manipulations over time, so an order effect would have most likely produced the opposite pattern from what we found. In any case, Experiment 3 counterbalanced the order of the two tasks, and order did not significantly impact performance on either task.

We have interpreted the null findings on the general knowledge test (Experiment 2) and the nonsense syllable task (Experiment 3) as arising because these tasks do not require active guidance by the self. However, good performance on these tests, particularly the nonsense syllable recall task in Study 3, probably does require the central executive in WM to some small degree, although it is safe to assume that the recall task was considerably less reliant on the central executive than the reading comprehension task (and the complex tasks used in Experiments 1 and 2). In total, ego depletion effects were most evident on the most complex tasks and there was some evidence that the simpler recall task was also susceptible to ego depletion. It appears that the magnitude of the ego depletion effects was positively related to the degree of active cognitive control required by the different cognitive tasks. To state this in continuous terms, the greater the executive requirements of a task, the more it was impaired by ego depletion.

Also, the absence of significant effects of ego depletion on the simple cognitive tasks may have been due to floor or ceiling effects, a restricted range, or lack of statistical power. The present data speak against those explanations. Mean scores on the simple tests in Experiments 2 and 3 indicated both room for improvement and for impairment, so neither a floor nor a ceiling effect seems to have obtained. Also, there was substantial within-cell variance on both of those measures, which speaks against an explanation based on restricted range or insensitivity. Additionally, the notion that there may not have been enough statistical power to detect reliable effects is negated by the fact that within the same studies that revealed null effects, there were also significant results on the predicted (more complex) cognitive measures. The results of the mixed-measures tests used in Experiments 2 and 3 also mollify this concern. Last, our findings were obtained with both timed and untimed tests. Therefore it does not appear that time pressure or time management is responsible for our results.

Previous findings on ego depletion and regulatory depletion have sometimes been interpreted as possibly reflecting a reduced willingness by participants to exert themselves on the second task. The present findings speak against such an interpretation, because any motivational deficit or reluctance to cooperate with the experimenter would presumably be the same regardless of the experimental task, whereas the present studies found effects on some tasks and not others. Furthermore, the effort to explain ego depletion findings on the basis of a motivational deficit or a perception that one's obligation has already been filled would presumably predict order effects, and the present investigation found either no order effects (Experiment 3) or order effects in the opposite direction (Experiment 2).

In all three experiments we thoroughly explored the role that mood may have played in mediating or influencing the impact of ego depletion on cognitive performance. To the extent that the depletion manipulations engendered a negative mood state, it may have facilitated effortful, systematic processing (e.g., Schwarz, 1990; Schwarz, Bless, & Bohner, 1991; see also Isen, 1993). According to this view, negative mood resulting from the depletion manipulations should have improved performance on cognitive tasks to the extent that performance on these tasks benefits by systematic and effortful processing. Indeed, our predictions about the detrimental effects of ego depletion centered on cognitive tasks that require this type of processing. Across three studies, however, we demonstrated that relationships between mood and performance did not differ between the depleted and nondepleted conditions. The results of these studies, along with prior work using a variety of ego depletion manipulations (Baumeister et al., 1998; Muraven et al., 1998; Vohs & Heatherton, 2000), strongly suggest that depletion manipulations do not influence mood states; therefore, mood does not appear to be a mediator of resource depletion effects.

Last, it is important to note that the effects demonstrated in the current experiments were observed using two contiguous tasks and not concurrent demands. In these studies, as in previous research on ego depletion, the effects of engaging in self-regulation were demonstrated on subsequent (not simultaneous) performance and therefore reflect an aftereffect of using some of the self's precious executive resources. Regarding the central executive in WM, these experiments suggest that central executive resources are taxed not just in the coordination of dual-task performance (Baddeley, 1986, 1996), but central executive operations may also suffer by the contiguous performance of complex cognitive tasks.

Implications and Conclusions

Most previous investigations involving ego depletion have shown significant decrements on all performance measures. Although those results were consistent with the hypothesis of resource depletion, they could also suggest sweeping deficits in motivation or ability. The present results constitute a vital extension of research on ego depletion because they show a selective impact: Specifically, depletion of the self's resources affects tasks that require active control by the self, but it does not impair performance on other tasks.

In published data, there are precious few hints that depletion effects are limited to some specific patterns (e.g., for specific people or under certain conditions). Probably the first such hint was provided by Vohs and Heatherton (2000), who demonstrated that only chronic dieters, and not nondieters, were depleted by resisting the temptation to eat forbidden foods. Presumably, overriding the desire to eat tempting foods only required the self to be actively engaged among dieters, who need to constantly override impulses to achieve their shape and weight goals. The role of individual differences in depletion effects demonstrated by Vohs and Heatherton (2000) dovetails nicely with the current studies, in which resource depletion was shown to impair within-person abilities on some tasks (i.e., those requiring the active self) and not others. In tandem, these two approaches advance our understanding of the processes underlying resource depletion by demonstrating specificity in depletion effects both across people and across tasks.

More broadly, these patterns fit the view that the self (as controller of only some inner processes) is needed for some tasks but not others. Active guidance by the self may be difficult and costly, and so the human psyche develops many procedures for processing information that do not deplete the self's limited resources.

The specificity of the present findings raises an apparent contradiction. We have found that ego depletion produced no visible decrement on cognitively simple tasks. Prior work, however, has found ego depletion to produce decrements on cognitively simple tasks such as squeezing a handgrip (Baumeister et al., 1998). The explanation is revealing as to the nature of executive control and the expenditure of a limited resource. Squeezing a handgrip does not require active control by the self over any cognitive operations, but it does require control over other responses. As one's hand becomes fatigued, the person will feel increasingly strong impulses to release the grip so as to ease tension in the hand and forearm and bring an end to the muscular discomfort. In order to persist, the person must override those impulses and force the muscles to continue squeezing. What this has in common with the cognitively complex tasks in this investigation—yet in sharp contrast to the cognitively simple tasks in these studies—is the need for the self to override some responses and exert a controlling, executive influence over what the person does. Thus, ego depletion may affect either simple or complex tasks, as long as these require central executive control over which responses are enacted, and regardless of whether these responses consist of cognitions or muscle movements.

Put more simply, what is depleted is the capacity for volition and self-control (in the sense of overriding responses). Cognitive tasks that depend on executive control will be impaired, and in the current research the more complex tasks were impaired precisely because they required the self to exert executive control. Squeezing a handgrip does not require executive control to manage the cognitive demands, which are quite simple, but it requires control in order to keep squeezing even when the muscular fatigue becomes aversive to the point of painful.

The present findings are consistent with dual-process models of information processing. For example, Lieberman et al. (2002) distinguished between conscious, reflective cognitive processes and automatic, reflexive processes, and they proposed that logical reasoning is mostly limited to the former. Logical reasoning is an important adaptation and indeed one of the most distinctly human abilities, and so it is highly plausible that logical reasoning may be limited to the most conscious and costly operations in the human brain and mind. Our findings support that view by showing logical reasoning to be especially impaired when the self has already expended some of its resources in a prior, seemingly unrelated act of self-regulation (such as stifling one's emotional distress or keeping attention away from extraneous stimuli).

Although human intellectual performance has been studied extensively, particularly in connection with intelligence tests, relatively few researchers have examined any influence of the self on such performance. One exception has been the work by Steele and colleagues showing that feeling oneself to be the target of stereotypes and expectations can result in poorer intellectual performance (Steele, 1997; Steele & Aronson, 1995, 2000). The precise intrapsychic mechanisms responsible for cognitive impairments in those studies remain elusive, however, insofar as one assumes that people are not actively trying to perform poorly so as to confirm the low expectations of intellectual ability that others might hold regarding them. We suggest that perhaps coping intrapsychically with other people's stereotypes may drain the self's executive and regulatory resources. If so, the present findings confirm that such depleted resources could indeed lead to poorer performance on cognitive tests.

Human life has achieved a level of sociocultural complexity that is far beyond that of any other species. Undoubtedly, multiple traits have facilitated the evolution of human culture. Prominent among these traits are having a self with extensive powers for executive functioning and self-regulation, and being capable of elaborate, intelligent thought. Given the undeniable value of these traits, one might well ask why nature has not given us more of both, and indeed it is easy to surmise that if we were all smarter and better at self-control, then we would all fare very much better. The most likely answer to this question is that these abilities are quite costly. Dunbar (1998) has observed that the human brain is an extremely expensive organ, accounting for only 2% of body mass but exhausting 20% of the body's caloric energy consumption. Hence we should not be surprised by the existence of severe limits on both self activity and intelligent thought. The present findings indicate that those two are intertwined, and that when the capacity for self-regulation is reduced by expenditure of resources, the most sophisticated, and therefore most costly, forms of intelligent reasoning suffer as well.

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