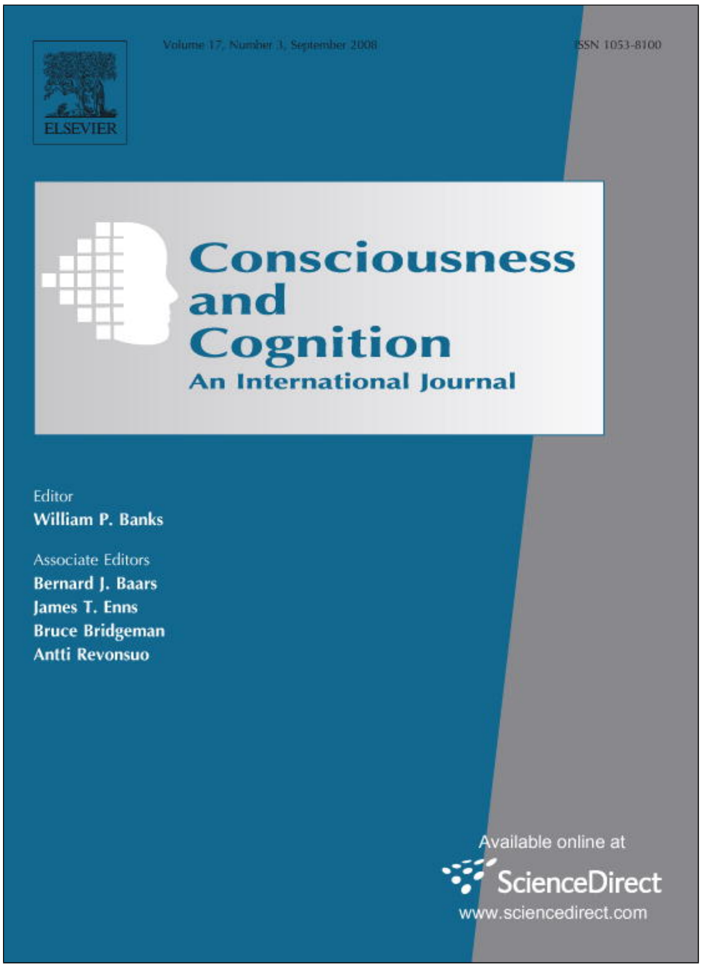
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Evidence that logical reasoning depends on conscious processing

C. Nathan DeWall [a,*], Roy F. Baumeister [b], E.J. Masicampo [b]

[a] *Department of Psychology, University of Kentucky, 201 Kastle Hall, Lexington, KY 40506-0044, USA*
[b] *Department of Psychology, Florida State University, 1107 W. Call Street, Tallahassee, FL 32306, USA*

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Abstract

Humans, unlike other animals, are equipped with a powerful brain that permits conscious awareness and reflection. A growing trend in psychological science has questioned the benefits of consciousness, however. Testing a hypothesis advanced by [Lieberman, M. D., Gaunt, R., Gilbert, D. T., & Trope, Y. (2002). Reflection and reflexion: A social cognitive neuroscience approach to attributional inference. *Advances in Experimental Social Psychology*, *34*, 199–249], four studies suggested that the conscious, reflective processing system is vital for logical reasoning. Substantial decrements in logical reasoning were found when a cognitive load manipulation preoccupied conscious processing, while hampering the nonconscious system with consciously suppressed thoughts failed to impair reasoning (Experiment 1). Nonconscious activation (priming) of the idea of logical reasoning increased the activation of logic-relevant concepts, but failed to improve logical reasoning performance (Experiments 2a–2c) unless the logical conclusions were largely intuitive and thus not reliant on logical reasoning (Experiment 3). Meanwhile, stimulating the conscious goal of reasoning well led to improvements in reasoning performance (Experiment 4). These findings offer evidence that logical reasoning is aided by the conscious, reflective processing system.

Keywords: Logical reasoning; Priming; Motivation; Consciousness; Volition

1. Introduction

Of what use or value is human consciousness? That ancient question has gained new urgency in recent decades as evidence has accumulated that much of human mental activity occurs outside of consciousness. The present investigation was designed to test one possible, partial answer proposed in a provocative article by Lieberman, Gaunt, Gilbert, and Trope (2002). Specifically, they argued on theoretical grounds that full-fledged logical reasoning is limited to what they called the "C" or reflective system, which is the home of conscious, reflective thought. The other, "X" or reflexive system, marked by automatic and nonconscious processes, does not appear to engage in such reasoning processes (or at best does so in a highly limited manner that is associated with immediate, concrete stimuli). In the present series of studies, we investigated whether

* Corresponding author. Fax: +1 859 323 1979.
E-mail address: nathan.dewall@uky.edu (C.N. DeWall).

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success at logical reasoning could be altered by stimulating or hampering these two systems. If Lieberman et al., (2002; see also Smith & DeCoster, 1999) are correct, then manipulations that affect the conscious "C" system should be able to alter performance on logical reasoning, whereas manipulations that target the nonconscious "X" system should be largely irrelevant.

The partitioning of human mental activity into two major systems or two types of processing has become deeply entrenched in psychological theorizing and is widely regarded as axiomatic. Sigmund Freud is usually credited with having taught psychologists that it is necessary to distinguish conscious from unconscious processes, and most dual process theories agree broadly that one type of thought is marked by rapid, efficient, largely nonconscious processing, whereas the other is marked by slower, more complex, possibly more flexible, and generally more conscious processing (Chaiken & Trope, 1999).

In recent years, research has been strongly focused on elucidating the power and value of the automatic rather than controlled processes. A large body of evidence suggests that many processes once thought to be the province of conscious thought can be executed just as well, if not better, by automatic processing, sometimes leaving the person consciously unaware or even seriously mistaken as to what is transpiring inside his or her mind (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Troetschel, 2001; Wegner, 2002; Wilson, 2002). Faced with this rising tide of evidence that automatic processes can do so many things better, faster, and more easily than conscious processing, some writers have begun to wonder openly whether conscious processing has any value at all (Bargh, 1997; Gazzaniga, 2003). Dijksterhuis (2005; Dijksterhuis & Nordgren, 2006) proposed that consciousness is at best useful for making trivial decisions, such as what brand of oven mitts to purchase. Thus, psychologists are left wondering what, if any, positive usefulness consciousness may have for behavior, decision-making, and other processes.

An evolutionary perspective on this trend in theorizing might suspect that consciousness is an obsolescent pattern of mental activity that has been supplanted by the more efficient and effective automatic system. However, the facts of evolution do not square easily with this approach and in fact suggest the opposite pattern of development. Most nonhuman animals seem to have mainly the automatic style of processing, whereas consciousness seems to be a relatively recent (i.e., human) adaptation. Why would evolution add a new style of cognitive processing that was essentially useless and/or counterproductive?

A rival view of the duplex mind has begun to appear. It suggests that there are certain highly useful and adaptive mental operations that require the special properties of the conscious, controlled system. Kahneman (2003) has contended that the automatic system is poor at combining and integrating information, which would suggest that the automatic system would have difficulty following the rule-based logic. Consistent with that view, Deutsch, Gawronski, and Strack (2006) showed that negating the evaluative meaning of a proposition, which they assert is a prototype of a rule-based process, did not become automatized after practice. Thus, the automatic processing excels at processing simple, discrete bits of information, whereas the conscious system may be needed for integrating larger and diverse sets of information, such as for negating the evaluative meaning of a proposition or performing a cost-benefit analysis of a complex decision with multiple options.

Other research has begun to focus on the potential benefits of the conscious system. In a study published after we had run most of the present studies, De Neys (2006) demonstrated that participants suffered impairments on syllogistic reasoning problems while their executive resources were hampered by a dot memorization task. This impairment was found for individuals with both high and low working memory capacity, which suggests that rule-based processing relies on the conscious system for all people, regardless of individual differences in working memory capacity.

In the same vein of seeking to offer consciousness some limited scope for rehabilitation, a seminal and authoritative article by Lieberman et al. (2002) proposed that the two major mental systems have different, complementary powers and functions. In their terms, the "X" or reflexive system is marked by speedy, efficient, parallel processing of information, whereas the "C" or reflective system is slower, operates in serial, does one thing at a time, follows explicitly learned rules, and possibly can perform certain large operations that would be impractical if not impossible for the piecemeal approach of the "X" system. Among these, they proposed that logical reasoning is the special preserve of the "C" system. Logical reasoning requires the person to apply socially validated rules to take one set of information and from it proceed to generate some quite different ideas (e.g., getting conclusions from premises by invoking valid forms of argument). The present investigation was directly stimulated by this aspect of Lieberman et al.'s (2002) work and sought to provide preliminary tests.

On an a priori basis, the approach of Lieberman et al. (2002) and like-minded theorists (Smith & DeCoster, 1999, 2000) seems highly plausible. Conscious processing may be biologically costly to create and execute, and plenty of creatures seem to function well without it. Why would natural selection have cultivated the capacity for this different form of thought if it were merely a feeble copy of what the mind could already do automatically? Evidence that conscious processing sometimes introduces mistakes or impairs performance (e.g., Baumeister, 1984; Wilson, 2002) does not detract from that argument but in a way intensifies it: consciousness must presumably have all the more special value in order to overcome its drawbacks. It hardly seems plausible that natural selection favored the emergence of a new mental system whose primary function was to make people choke under pressure or misperceive their own preferences.

1.1. Current research

The central hypothesis of this investigation is that logical reasoning depends heavily on conscious processing. To use the terms of Lieberman et al. (2002), only the reflective or ''C'' system has the capacity to engage in full-blown logical reasoning. (To be sure, the ''X'' system may be able to perform simple reasoning tasks if few mental operations are required and especially if prior reflective processing has shown the way.)

The ideal way to test this theory would be to have manipulations that affected only one or the other of the two processing systems and left the other untouched. Unfortunately this does not quite seem possible, especially insofar as most or all conscious thought depends on some degree of support from automatic processing (for example, to convert the sensory input of sounds or ink squiggles into meaningful words). Cognitive load manipulations, for example, preoccupy the conscious mind, but they may also alter the functioning of the nonconscious system. Still, it is possible to influence nonconscious processing in a way that can produce an effect without the person consciously recognizing what is happening or participating consciously in the process. So it is possible to compare manipulations that affect both processes against manipulations that affect mainly just nonconscious processing. Insofar as nonconscious processes are crucial for logical reasoning, then a manipulation that alters both conscious and nonconscious processes should produce the same effects as a manipulation that alters only nonconscious processes. If conscious processes are decisive, however, then those two types of manipulations should produce very different results.

Our hypothesis was that both conscious and nonconscious processes make important but different contributions to logical reasoning, and in particular the rule-based thinking of the conscious, reflective system plays the more distinctive and decisive role. The role of the automatic system would be more supportive and more robust. Hence, manipulations that affect both processes should affect logical reasoning, whereas manipulations that mainly just affect the nonconscious system should not.

It may seem contradictory for us to say that the nonconscious system plays a vital role but that manipulations to affect it alone will not alter performance on logical reasoning. All we are suggesting here (following Lieberman et al., 2002) is that rule-based logical reasoning is not one of the activities for which the automatic system was designed. In some of these studies, we sought to hamper the conscious, reflective system with cognitive load manipulations such as vigilance tasks (Experiment 1). To activate and engage the conscious system, we used manipulations of accountability and explicit goals (Experiment 4). To hamper the automatic system, we used a manipulation of nonconscious load (Experiment 1), and we sought to activate it with priming manipulations (Experiments 2(a–c) and 3).

By these manipulations, we hoped to be able to test the hypothesis that conscious or reflective processing (''C'' system, to use the language of Lieberman et al., 2002) is vital for logical reasoning. Activating and engaging conscious processing should improve logical reasoning performance, whereas hampering that system via cognitive load should impair performance. Activating nonconscious processes should increase the accessibility of logic-relevant concepts but have no influence on performance, whereas hampering the nonconscious system via a nonconscious load manipulation should not influence logical reasoning performance.

2. Experiment 1

Experiment 1 provided the first test of the hypothesis that occupying the conscious system would impair logical reasoning, whereas occupying the nonconscious system would have no impact on logical reasoning.

As noted earlier, De Neys (2006) showed that occupying the conscious system through high cognitive load caused decrements in logical reasoning. Experiment 1 was designed to address two possible alternative interpretations for these findings. First, it is plausible that cognitive load renders participants unable to encode the logical reasoning problems. If that were true, then the poor performance would not say anything about logical reasoning, because no one can solve a problem without getting it into the mind in the first place. Experiment 1 assessed the degree of successful encoding with a recognition memory test.

The other alternate explanation was that the effects of conscious load depended mainly on impairing nonconscious processing. Cognitive load undoubtedly places some demands on nonconscious processing, such as to sort through incoming information and process the meaning of words. A cognitive load thus may alter both conscious and nonconscious processing, and in principle the impairment of reasoning could be due to the impairment of the nonconscious processing, contrary to our hypothesis that conscious processing is crucial.

There are two reasons to argue against this alternate explanation. First, as already noted, the automatic system tends to operate in parallel and is therefore able to do multiple tasks at once, and so a cognitive load should be less debilitating to nonconscious processing than to conscious processing. (Serial unity characterizes the "C" system, so a cognitive load should preempt it entirely at any given moment, though it might sometimes be able to shift attention back and forth between different projects.) Hence, the nonconscious system should still (even under load) be able to make whatever its contribution is to reasoning. Dijksterhuis and Nordgren (2006) have argued that the capacity of the automatic system is incalculably vaster than that of the conscious system, and so even if it did devote some resources to a cognitive load, it should still be able to do almost everything else it normally does—unlike the conscious system, which could be fully preempted and preoccupied with a single load. Thus, in theory, the combination of vast capacity and parallel organization should render the nonconscious system relatively immune to impairments from standard cognitive load manipulations.

The second argument is empirical. Some prior work has concluded that cognitive load manipulations do not impair automatic processing such as perceptual encoding (Mulligan, 1998; Mulligan & Hartman, 1996; Sherman, Lee, Bessenhoff, & Frost, 1998). This further supports our view that the cognitive load manipulation would not interfere with the automatic processes involved in completing the logical reasoning task.

Insofar as these arguments are unconvincing, however, it seemed crucial to test the rival hypothesis that cognitive load would impair logical reasoning by virtue of its effect on nonconscious processing. One way to do this would be to find a cognitive load manipulation that only occupied conscious processing and made no demands at all on automatic processing, but to our knowledge no such manipulation exists, and it may not be possible to create one. The other procedure would be to find a manipulation that would mainly or exclusively alter nonconscious processing. Such a manipulation was developed by Wegner and Gold (1995), based on Wegner's (1994) ironic processing theory. According to ironic processing theory, thought suppression has two parts: a nonconscious monitor that scans the environment for cues that might evoke the forbidden idea, plus conscious suppression of such thoughts. Crucially, the nonconscious monitor continues vigilantly scanning for unwelcome cues even after the conscious mind turns its attention elsewhere. Wegner and Gold (1995) had participants think of a former relationship partner and then instructed them to stop thinking about him or her. As adapted for Experiment 1, this procedure frees up the conscious mind to solve logic problems while the nonconscious system is still (somewhat) busy thinking about the old flame. Experiment 1 included a postmeasure to verify that the thought of the old flame remained highly accessible after the logic problems, which would indicate that the ironic processing had continued its work all along, just as Wegner (1994) theorized.

If the impairments in logical reasoning stemming from high cognitive load (in De Neys, 2006) were mediated by the load's effect on nonconscious processing, then similar impairments should be observed in Experiment 1, because it too has a nonconscious load. In contrast, if consciousness is crucial, then loading the nonconscious system should not matter, and performance should be fine.

2.1. Method

2.1.1. Participants

Fifty-six participants (39 women) participated in this study in exchange for partial course credit.

2.1.2. Materials and procedure

Participants arrived at the laboratory individually for an experiment ostensibly concerned with performance on different tasks. After giving informed consent, participants were randomly assigned to one of three cognitive load conditions: conscious load, nonconscious load, and no load. The nonconscious load conditions were further subdivided by self-selection into hot-flame and cold-flame load (see below).

Participants in the conscious load and no load conditions completed a set of symbolic logic puzzles. For participants assigned to the conscious load condition, participants completed the logical problems while listening to a song and counting the occurrences of the word "time" in the song. We used the song "48 hours" by Negativland (1989), track 8, which has been used in previous research to induce cognitive load in participants (Baumeister, Schmeichel, DeWall, & Vohs, 2007). The song is 5 min 37 s long and contains the word "time" **16** times. It contains cacophonous sounds and features multiple layers of vocals that require close attention to follow. Participants in the no load condition did not listen to the song but were given the same amount of time (5 min and 37 s) to work on the logic problems.

Participants in the nonconscious load condition were divided into hot-flame and cold-flame load conditions. Both referred to a former relationship, and the difference had to do with whether the person continues in the present to have feelings for the person such as wishing to be reunited (hot means yes, cold means no). This division was implemented using the methods specified by Wegner and Gold (1995), who showed that participants who suppressed thoughts of a cold-flame experienced a subsequent *cognitive* rebound, whereas participants who suppressed thoughts of a hot-flame experienced a subsequent *emotional* rebound. Because the results from Wegner and Gold (1995) showed consistently that suppressing thoughts of a hot-flame did not produce cognitive rebound, we felt that it was not necessary to include an additional condition in which participants did not suppress thoughts about an old flame. The hot-flame condition should serve as an adequate comparison group to the cold-flame condition in terms of enabling us to detect a cognitive rebound effect.

All nonconscious load participants were asked to fill out a relationship questionnaire assessing feelings about an old flame. They self-selected into hot-flame and cold-flame conditions by their responses to the questions as to whether they still desired the relationship. All nonconscious load participants performed three tasks: initial expression, logical reasoning, and final expression. During the initial expression task, participants were asked to think aloud about the person they wrote about in the relationship questionnaire. For the logical reasoning task, participants were asked to avoid thoughts about the old flame and to work on the same logical reasoning problems that conscious load and no load participants completed. For the final expression task, participants were asked once again to think aloud about their old flames. Participants were given 5 min and 37 s for each of the three tasks.

Last, all participants were given a problem recognition questionnaire that presented them with ten symbolic logic problems. Five of the problems were identical to those the participant attempted to solve earlier in the study. The other five problems were new to the participant but similar to the other problems in form and content. Participants were asked to read each problem and indicate whether they recognized the problem as one from the packet given to them earlier in the study. After completing the problem recognition questionnaire participants were fully debriefed, given partial course credit, and dismissed.

2.2. Results

2.2.1. Problems solved correctly

As predicted, participants in the conscious load condition solved fewer logic problems correctly compared to participants in all other conditions. An ANOVA conducted on the number of logical problems solved correctly revealed significant variation between the four groups, $F(3, 52) = 8.91$, $p < .001$. A focused contrast confirmed that conscious load participants solved significantly fewer logic problems correctly than hot-flame, cold-flame, and no load participants, $F(1, 54) = 21.65$, $p < .001$, $d = 1.41$. Planned comparisons demonstrated that conscious load participants ($M = 2.63$, $SD = 1.26$) answered fewer logic problems correctly than no load participants ($M = 4.07$, $SD = 1.62$), $F(1, 54) = 8.64$, $p = .005$, $d = .99$. Conscious load participants ($M = 2.63$, $SD = 1.26$) also answered fewer logic problems correctly than both hot-flame load participants ($M = 4.57$, $SD = 1.40$), $F(1, 54) = 15.21$, $p < .001$, $d = 1.46$, and cold-flame load participants ($M = 5.18$, $SD = 1.08$),

$F(1, 54) = 22.41$, $p < .001$, $d = 2.17$. Thus, occupying conscious attention and awareness led to substantial decrements in logical reasoning performance.

In contrast, and more centrally to this experiment′s purpose, the nonconscious load did not impair performance. Hot-flame load participants did not differ from no load participants in terms of the number of logic problems solved correctly, $F(1, 54) = 2.00$, $p = .33$. The cold-flame load participants actually answered more logic problems correctly than participants in the no load control condition, $F(1, 54) = 4.29$, $p < .05$, $d = .81$. These findings strongly contradict the alternative theory′s prediction that nonconscious load would impair logical reasoning.

2.2.2. Recognition

ANOVA on the surprise recognition test revealed no significant variation between the four groups, $F < 1$, *ns*. Conscious load participants ($M = 9.63$, $SD = .62$) recognized a similar amount of the logic problems compared to hot-flame load ($M = 9.79$, $SD = .80$), cold-flame load ($M = 10.00$, $SD = .00$), and no load participants ($M = 9.67$, $SD = .82$). To determine whether response biases may have influenced the recognition findings, we also analyzed the recognition data using signal detection analysis (e.g., Wickens, 2002). An ANOVA revealed no significant variation in d' among the four conditions, $F < 1$, *ns*. Conscious load participants ($M = .93$, $SD = .12$) had similar performance scores as the hot-flame load ($M = .96$, $SD = .16$), cold-flame load ($M = 1.00$, $SD = .00$), and no load participants ($M = .93$, $SD = .16$). These results speak against the view that the conscious load manipulation impaired encoding compared to the nonconscious and no load manipulations.

2.2.3. Cognitive rebound via talking time

To test whether the cold-flame load manipulation produced more cognitive rebound than the hot-flame load manipulation, two research assistants (blind to condition) coded the tape-recorded stream-of-consciousness reports for the total number of seconds that participants talked about the old flame during the 5 min 37 s initial and final expression. Interrater agreement was high for the initial expression period ($r = .87$, $p < .001$) and for the final expression period ($r = .89$, $p < .001$). A difference score was computed by subtracting initial expression scores (combined across coders) from final expression scores. Higher positive difference scores would indicate greater cognitive rebound (i.e., participants spoke more about the old flame after the logic test), whereas lower positive or negative difference scores indicated less cognitive rebound. Results from an ANOVA on the difference scores demonstrated that cold-flame participants showed more cognitive rebound ($M = 11.36$, $SD = 22.03$) than hot-flame participants ($M = -33.79$, $SD = 75.36$), $F(1,26) = 4.63$, $p = .04$, $d = .81$. Thus, the cold-flame load manipulation was successful in terms of producing more cognitive rebound than the hot-flame load manipulation, and the size of effect met conventional criteria for describing large effects (Cohen, 1977).

2.3. Discussion

Some recent work has shown that cognitive load impairs performance on reasoning (De Neys, 2006). Experiment 1 replicated this effect, but its main purpose was to tease apart two explanations for that effect. One was our hypothesis that logical reasoning depends on the integrative work of the conscious, reflective system (so a cognitive load preempts that process). The other was based on the assumption that a cognitive load also places some burden on the automatic, reflexive system, and the impairments in logical reasoning could be due to that impairment, rather than to preempting the conscious system. To test that possibility, Experiment 1 added a procedure involving a nonconscious load. Specifically, participants were instructed to remember a former romantic relationship and then to suppress thoughts about that relationship while doing the logic problems. Based both on prior findings (Wegner & Gold, 1995) and on present evidence that the idea of that former relationship remained prominent in the person′s nonconscious processing, we assumed that participants in the nonconscious load conditions would direct their conscious attention to the logic problems while the suppressed thought of the former relationship would place some processing burden on their nonconscious system.

The results of Experiment 1 favored the view that the impairment of logical reasoning caused by cognitive load is due to interference with conscious (as opposed to nonconscious) processing. Participants in the nonconscious load conditions showed no impairments in logical reasoning, even though their nonconscious system continued to work on thoughts and cues regarding the former relationship (as indicated by the high accessibility later on). This was true for both hot-flames and cold-flames, that is, both for former relationships that remained appealing and for ones now regarded as unappealing. The combined findings of those two conditions showed no hint of impairment, and if anything the trend was in the opposite direction (i.e., participants under nonconscious load performed slightly better than no load controls). Thus, people can reason effectively even when their nonconscious system is actively preoccupied with an irrelevant topic, indeed one that was almost certainly more interesting to the participants than our logic problems.

The results from the nonconscious load conditions may appear to contradict previous work showing that thought suppression depletes the self′s executive resources, which in turn causes impairments on tasks that rely on executive functioning (see Muraven & Baumeister, 2000, for a review). The nonconscious load manipulation differed from standard ego depletion manipulations in that hot-flame and cold-flame participants were instructed to suppress their thoughts about their old flame and then immediately began the logical reasoning problems. In most ego depletion studies (e.g., Baumeister, Bratslavsky, Muraven, & Tice, 1998; Vohs, Baumeister, & Ciarocco, 2005), participants perform an initial task that either involves self-regulation or not, for 5–10 min, and then complete a second task that requires self-regulation. The length of the first task is crucial to depletion effects because that is the period in which the self′s executive resources are being spent on effortful regulation of responses—such as stifling the forbidden thought. Moreover, Wegner (1994) found that the thought suppression task was less onerous when participants were given something else to think about in order to distract them. Participants in the hot-flame and cold-flame conditions in Experiment 1 did not consciously suppress their thoughts for a long period of time before the logical reasoning problems and hence did not perform poorly. Instead, they were able to focus attention on the logic problems, which most likely served as highly compelling distractors. Thus, for them, little conscious effort or energy was likely needed to suppress the thought of the old flame. Instead, the core effect of the instructions to suppress would be to activate the nonconscious processes to monitor for cues or reminders of the former relationship. Consistent with Wegner′s theory, our results from the cognitive rebound measure indicated that the nonconscious system was busy scanning the environment for information relevant to the old flame even while they completed the logic problems.

A second purpose of Experiment 1 was to test the hypothesis that a failure of encoding might underlie the impairment of reasoning performance. That is, the conscious load manipulation might have lowered performance, not because it made people unable to reason logically, but because the load prevented the problems from being encoded in the first place. The recognition memory data from Experiment 1 should remove that concern. Participants under cognitive load remembered nearly all the logic problems and in fact remembered them as well as participants in other conditions. Thus, under conscious load, people were able to read and encode the problems—just not solve them correctly.

3. Experiments 2a–2c

We turn now to manipulations that directly target the nonconscious, automatic, reflexive (''X'') processing system. The purpose of Experiments 2a–2c was to test the hypothesis that logical reasoning can be facilitated through nonconscious activation of logical reasoning goals. This would be contrary to the assertion by Lieberman et al. (2002) that logical reasoning depends vitally on the conscious system. Previous research has shown that activating various goals at an unconscious level can have remarkable effects on cognition and behavior (e.g., Bargh et al., 2001; Shah, 2003). Experiments 2a–2c therefore used measures designed to activate logical reasoning (or neutral) goals. If the ''X'' system can facilitate logical reasoning, then priming logical reasoning goals should activate concepts related to logical reasoning and ultimately improve logical reasoning performance. But if logical reasoning is dependent largely upon the ''C'' system, then unconscious priming of logical reasoning goals should have little or no effect on subsequent logical reasoning performance.

In Experiments 2a–2c, we tested whether logical reasoning would improve if participants first completed a task that was designed to activate the idea of logical reasoning. For this, we used a modified version of the scrambled sentence task used originally by Srull and Wyer (1979). In the logic prime condition, about half the sentences had to be completed using words related to logical reasoning. Participants in the neutral prime condition, in contrast, completed 13 sentences using words that previous research had shown to be neutral in meaning and thus irrelevant to logic (Bargh et al., 2001).

To ascertain whether the priming manipulation was successful, participants completed a word fragment completion task. Gilbert and Hixon (1991) showed that activation of particular concepts led participants to complete word fragments with words that were relevant to the activated concept. In the current study, participants were presented with certain word fragments that could be completed either with words that were related to logical reasoning or with words unrelated to logical reasoning (e.g., L _ G _ _ could be logic or legal). If the logic prime manipulation succeeded in activating the goal concept of being logical, then participants in the logic prime condition should complete more word fragments with words that related to logical reasoning, compared to participants in the neutral prime condition.

Logical reasoning was measured by having participants complete a series of GRE analytical problems (Experiments 2a and 2c) or symbolic logic puzzles (Experiment 2b). Participants were either given a limited amount of time to complete the logical reasoning task (Experiment 2a) or were given as much time as they wanted (Experiments 2b and 2c). In Experiments 2a and 2b, participants completed the accessibility measure after the priming manipulation and then moved on to the logical reasoning test. To rule out a potential ordering effect, Experiment 2c administered the logical reasoning test first and then the accessibility measure. If the predicted results of Experiments 2a–2b were due to an order effect based on gradual attenuation of the priming manipulation, then Experiment 2c should find significant effects on the logic test and no effect on the subsequent accessibility measure. In contrast, if the findings of Experiments 2a–2c indicate that nonconscious priming has effects on accessibility but not on logical reasoning, then Experiment 2c should yield the same results despite the change in sequence of measures.

3.1. Method

3.1.1. Participants

One hundred two undergraduates (Experiment 2a: 8 men, 14 women; Experiment 2b: 11 men, 22 women; Experiment 2c: 31 women, 16 men) participated in this study in exchange for partial course credit.

3.1.2. Materials and procedure

Participants arrived at a large classroom in groups for a series of ostensibly unrelated studies concerned with language processes. Participants first completed a scrambled sentence test (Chartrand & Bargh, 1996; Srull & Wyer, 1979) that was designed to activate nonconsciously either a logical reasoning goal or no goal. In this task, all participants were presented with 13 items in which they were required to construct a grammatically correct four-word sentence from five words presented in a scrambled order. Examples from the logic prime condition were "is palm very rational Judy," "thinks logically book he always," and "document analyzed he shelves the." Examples from the neutral prime condition were "staples the paper she relaxed," "the hat big is wooded," and "green the grass is pusher." In the logic prime condition, words related to logical reasoning (e.g., rational, evaluated, intelligent, coherently, analyzed) were embedded in 7 of the items. The remaining words were neutral in terms of a logical reasoning goal.

To assess the activation of concepts related to a logical reasoning goal, participants were given a word fragment completion task modeled after those used in previous research (Gilbert & Hixon, 1991; Sinclair & Kunda, 1999; Tulving, Schachter, & Stark, 1982). Participants in the current study were provided with eight word fragments related to a logical reasoning goal that were separated by seven neutral word fragments. The word fragments related to logical reasoning (e.g., S _ _ _ _ T, _ _ I N K, R _ _ D, representing SMART, THINK, and READ) could also be completed by using words not related to logical reasoning (e.g., SHORT, DRINK, and ROAD). The full list of logical reasoning-relevant words were *smart*, *think*, *read*, *logic*, *bright*, *study*, *genius*, and *focus*. The seven neutral items (e.g., _ A L L, _ U G S) could only be completed with words not relevant to logical reasoning (e.g., TALL, BUGS). The number of logical reasoning-relevant word fragment completions served as the measure of the degree to which logical reasoning concepts were currently activated.

To measure logical reasoning performance, participants completed either GRE analytical problems (Experiments 2a and 2c) or symbolic logic puzzles (Experiment 2b). Participants in Experiment 2a worked until they had completed all of the GRE problems or until the predetermined 10 min limit had been reached, whereas participants in Experiments 2b and 2c were given an unlimited amount of time to complete the respective logical reasoning task. Participants in Experiments 2a and 2b completed the accessibility measure first and then completed the logical reasoning task, whereas participants in Experiment 2c completed the logical reasoning task first and then moved on to the accessibility measure. Finally, participants were given a brief demographic questionnaire, were probed for suspicion, and dismissed.

3.2. Results

3.2.1. Activation of logical reasoning goal

The number of logical reasoning-relevant words that participants filled in on the word fragment task was compared across prime conditions in Experiments 2a–2c using a one-way ANOVA. Across Experiments 2a–2c, results indicated that participants assigned to the logic prime condition completed significantly more word fragments that were relevant to a logical reasoning goal than participants assigned to the neutral prime condition, $F\text{s} = 8.31$ (Experiment 2a), 6.64 (Experiment 2b), and 6.06 (Experiment 2c), respectively, all $p\text{s} < .04$, $d\text{s} > .73$. The means are presented in Table 1. Thus, the priming manipulation exerted a strong influence in activating logic-relevant concepts even after a delay.

3.2.2. Experiment 2a: Logical reasoning performance

To examine the degree to which the activation of a logical reasoning goal promoted effective GRE analytical performance, we compared the number of correct problems, the number of attempts, and the proportion of correct answers between the logic and neutral priming conditions. Results from a one-way ANOVA showed that participants assigned to the logic prime condition did not differ in the number of GRE analytical problems they answered correctly, as compared to neutral prime participants, $F < 1$, *ns*. If anything, neutral prime participants showed a trend for performing better on the logical reasoning task compared to logic prime participants. Logic prime and neutral prime participants also did not differ with regard to the number of problems they attempted, or with regard to the proportion of problems they answered correctly, both $F\text{s} < 1$, *ns*. The means are presented in Table 1.

3.2.3. Experiment 2b: Logic puzzle performance

The total number of correct responses to the logic puzzles was averaged and compared across the logic prime and neutral prime conditions. Results indicated that although the priming manipulation was successful in activating logic-relevant concepts, logic prime participants did not differ in their number of correct answers to the logic puzzles compared to neutral prime participants, $F < 1$, *ns*. Results also indicated that logic prime participants did not differ from neutral prime participants in terms of the number of problems they attempted or the proportion of correct responses they had, both $F\text{s} < 1$, *ns*. Thus, these findings showed that nonconsciously activating a logical reasoning goal did not confer any advantage in performing well on a logical reasoning task.

3.2.4. Experiment 2c: GRE analytical performance

To examine the degree to which the activation of a logical reasoning goal promoted effective GRE analytical performance, we compared the number of correct problems, the number of attempts, and the proportion

Table 1
Means and standard deviations of measures used in Experiments 2a–2c

Experiment, measure	Experimental condition	Correct	Attempt	Proportion correct	Word fragment
2a: GRE analytical	Logic prime	5.10 (2.77)	8.00 (2.95)	.63 (.23)	3.00 (1.15)
2a: GRE analytical	Neutral prime	5.08 (2.15)	8.50 (1.98)	.59 (.19)	1.42 (1.38)
2b: Logic puzzle	Logic prime	5.30 (2.00)	10.90 (1.79)	.48 (.17)	3.50 (.97)
2b: Logic puzzle	Neutral prime	4.78 (1.56)	11.22 (3.38)	.45 (.18)	2.33 (1.00)
2c: GRE analytical	Logic prime	5.73 (2.01)	12.00 (.00)	.47 (.17)	3.04 (1.39)
2c: GRE analytical	Neutral prime	6.74 (1.70)	11.81 (.87)	.53 (.14)	2.09 (1.18)

Note: Data indicate average values for each measure. Standard deviations appear in parentheses.

of correct answers between the logic and neutral priming conditions. Results from a one-way ANOVA showed that participants assigned to the logic prime condition did not differ in the number of GRE analytical problems they answered correctly, as compared to neutral prime participants, $F < 1$, *ns*. If anything, neutral prime participants showed a trend for performing better on the logical reasoning task compared to logic prime participants. Logic prime and neutral prime participants also did not differ with regard to the number of problems they attempted, or with regard to the proportion of problems they answered correctly, both $F\text{s} < 1.40$, $p\text{s} > .27$. The means are presented in Table 1.

3.3. Discussion

Experiments 2a–2c provided consistent evidence that nonconsciously activating a logical reasoning goal increased the accessibility of concepts related to logical reasoning—but such priming had no discernible effect on actual logical reasoning performance. In each study, participants in the logic prime condition completed more word fragments with words related to logical reasoning (e.g., smart, logic) than participants in the neutral prime condition. These findings show that our manipulation was effective and successful at stimulating the nonconscious processing system to activate the idea of logical reasoning. But priming participants with the idea of logical reasoning did not help them perform any better than neutral prime participants on three different measures of logical reasoning. Although the studies had somewhat small sample sizes, the consistent null effects across each study provided converging evidence that the logical reasoning prime had no influence on logical reasoning performance. (Moreover, the results were not close to significance and in some cases the trends were in the wrong direction, so larger samples would hardly seem likely to produce significant support for the hypothesis.) These findings provide support for the view that unconscious priming can facilitate certain associations and behaviors, but actual logical reasoning may be dependent upon a level of processing that requires more integrative depth and flexibility, namely the ‘‘C’’ system (Lieberman et al., 2002).

Should the priming manipulation have affected logical reasoning, if logical reasoning is essentially a nonconscious process? One could suggest that the priming manipulation activated the trait construct of logicalness but without making the person behave logically. Against that view, past research has shown consistently that individuals primed with trait constructs behave in line with the trait that was primed (e.g., Bargh, Chen, & Burrows, 1996).

A more complex variation on the trait activation explanation could invoke decay over time. Bargh et al. (2001) argued that if a priming manipulation activates a goal, the effect of the priming manipulation should be strengthened after a brief delay (so as to the increase the desire to fulfill the activated goal), whereas the priming effect should be attenuated after a delay if the priming manipulation activates trait constructs instead of a goal state. If our priming manipulation merely activated trait constructs relevant to logical reasoning, then the strength of the manipulation should dissipate after a delay. The results of Experiment 2c contradict this explanation. In that study, we reversed the order of the measures yet found the same results: the priming manipulation failed to improve logical reasoning but did make logic-related concepts more accessible, even though the logical reasoning test was administered immediately after the priming manipulation.

The findings of Experiment 2c strengthen the results of Experiments 2a and 2b by showing that the priming manipulation was powerful enough and long-lasting enough to elicit significant and large effects (on accessibility) even after the participant had completed an intervening task. By implication, the priming manipulation in Experiments 2a and 2b should have still been in force during the logical reasoning test. Its failure to alter logical performance is consistent with the Lieberman et al. (2002) hypothesis that automatic, nonconscious processes are not the province of logical reasoning.

These findings also speak, albeit gently, against the hypothesis that the priming manipulation would only activate the trait construct without activating the related goal of being logical. According to Bargh et al. (2001), such a pattern would be reflected in a gradual decay of the effect of priming, which could have fit the results of Experiments 2a and 2b (a strong effect on the immediate measure of accessibility, but then no effect on the subsequent measure of reasoning). But Experiment 2c found the opposite sequence: no effect of priming on the immediate measure of reasoning performance, and then a strong effect on the later measure of accessibility. The effect on the accessibility measure was almost identical in size to what was found in Experiments 2a and 2b, and one could argue it is surprising that it occurred at all, insofar as the intervening test of logical reasoning might also have activated the idea of logical reasoning in all participants, thereby undermining any difference produced by the priming manipulation. The only apparent explanation is that the priming manipulation had a significant and durable effect on nonconscious processing. But activating the idea of logical reasoning was not enough to improve logical reasoning, as long as conscious processing was unaffected.

4. Experiment 3

Experiment 3 sought to go a step further by showing that priming the idea of logical reasoning could motivate people to perform better on a reasoning task—but only if it was simple enough that the automatic system could do it. For this, we made use of an innovative procedure developed by Markovits and Nantel (1989). Participants had to judge whether a syllogism was logically valid. In some cases, dubbed "conflict items," the argument was logically sound but the conclusion was empirically (or synthetically, in logic terms) wrong. For example, the premises "All mammals can walk" and "Whales are mammals" logically entail the conclusion that "Whales can walk," and so the syllogism is valid—but a superficial processing might be prone to reject it as invalid simply because in reality whales cannot walk. In other (congruent) cases, logical reasoning and empirical knowledge would give the same answer. The conflict items have been shown to rely on what Lieberman et al. (2002) refer to as the "C" system (De Neys, 2006), whereas the no-conflict items have been shown to rely largely on the "X" system.

Our theory has been that the automatic system does not actually conduct the rule-based thinking necessary to evaluate the logical validity of an argument independent of the person′s basic knowledge of the world. Hence, it would rely on accessing existing knowledge rather than logical thinking to evaluate the arguments. This would produce a tendency to get the congruent items correct and the high-conflict items wrong. If priming the idea of logical reasoning motivates people to pursue the goal more assiduously, then performance might actually improve on the congruent items—but (once again) it should be unable to improve performance on the high-conflict items.

4.1. Method

4.1.1. Participants

One hundred seventy undergraduates (118 women, 48 men, 4 did not specify their gender) participated in this study in exchange for extra course credit.

4.1.2. Materials and procedure

Participants completed the current study in a large classroom setting. After giving informed consent, participants were given a packet that contained all of the study materials. By random assignment, half of the participants completed the logic prime, whereas the other half of the participants completed the neutral prime. The priming materials were the same as those used in Experiments 2a–2c. When participants had finished the priming materials, participants completed eight syllogisms taken from the work of Markovits and Nantel (1989). Four of the syllogisms, termed conflict items, had conclusions in which logic was in conflict with the extent to which the conclusion was deemed believable. The other four syllogisms, termed congruent items, had conclusions in which the logical validity did not conflict with believability. The conflict and no-conflict items were presented in a random order that was kept constant across all participants. After completing the syllogisms, participants completed the word fragment measure used in Experiments 2a–2c to provide an indicator as to the extent to which the logic prime activated concepts related to logical reasoning. Participants were then debriefed.

4.2. Results

4.2.1. Manipulation check

The number of logical reasoning-relevant words that participants filled in on the word fragment task was compared across prime conditions. As in Experiments 2a–2c, participants in the logic prime condition ($M = 2.31$, $SD = 1.39$) completed significantly more word fragments than participants in the neutral prime condition ($M = 1.60$, $SD = 1.15$), $F(1, 168) = 13.52$, $p < .001$, $d = .56$. This finding suggests that the logic prime was successful in terms of activating concepts related to logical reasoning.

4.2.2. Reasoning performance

A 2(prime: neutral vs. logic) × 2(item type: congruent vs. incongruent) mixed-model ANOVA was conducted on reasoning performance scores. Results revealed a marginally significant prime × item type interaction, $F(1, 168) = 2.78$, $p < .10$. On the congruent items, participants in the logic prime condition ($M = 3.55$, $SD = .70$) completed significantly more items correctly than participants in the neutral prime condition ($M = 3.31$, $SD = .86$), $F(1, 168) = 3.88$, $p = .05$, $d = .31$. In contrast, no difference was found between logic prime ($M = 2.03$, $SD = 1.43$) and neutral prime ($M = 1.96$, $SD = 1.33$) participants in terms of the number of conflict items completed correctly, $F < 1$, *ns*. Thus, the logic prime caused improved performance on the syllogisms that relied on the "X" system, but the logic prime did not enhance performance on the syllogisms that relied on the "C" system.

4.3. Discussion

In Experiment 3, priming the idea of logical reasoning did improve performance on one test of reasoning, though not on another. The one that required more careful and disciplined thought was the one that failed, consistent with the general hypothesis that the "C" or conscious system is needed for full-blown logical reasoning. When shortcuts yield the same answer as proper logic, however, we did find that priming the idea of logic led to significant improvement in logical reasoning. This should allay any doubts that the logic prime did in fact activate the motivational goal of doing better.

In other words, when the automatic or "X" system can improve its performance on a reasoning task, then it does improve as a result of being primed with logic. Apparently, however, it can only improve sometimes, and that depends on the type of task. Tasks that required following strict rules of logic rather than relying on general knowledge and associations seem to be beyond the sphere in which the automatic system can improve by dint of the increased motivation stemming from goal priming.

The failure of the priming manipulation to improve performance on the conflict items was consistent with what we found in Experiments 2a–2c. Likewise, De Neys (2006) showed that cognitive load impaired performance on those items but did not hamper performance on the congruent, no-conflict items. These results converge to support the conclusion that conscious, "C" system processing is necessary for full-fledged logical reasoning.

5. Experiment 4

The results thus far have shown that genuine logical reasoning was neither improved nor impaired by manipulations aimed at the automatic, nonconscious system, whereas it was significantly impaired by cognitive load manipulations aimed at the conscious or reflective processing system. The one thing we have not shown yet is that reasoning can be improved by engaging the conscious, reflective processing system.

The possibility of a ceiling effect could compromise our conclusions thus far. Experiment 1 showed that conscious cognitive load impaired performance, but a nonconscious cognitive load did not impair performance. Experiments 2a–2c showed that priming the nonconscious system failed to improve it. (Experiment 3 confirmed these patterns, with some additional twists). If people are already performing at their maximum, then it is no wonder that priming fails to bring improvements.

Hence, Experiment 4 sought to improve logical reasoning performance by manipulating the conscious goal of being logical. If the manipulation of a conscious goal could succeed where the manipulation of nonconscious goal failed, this would provide strong support for the view that the conscious processing system is more relevant to logical reasoning than the nonconscious processing system.

To manipulate the conscious goal of reasoning, we adapted a procedure used by Priester, Dholakia, and Fleming (2004) to stimulate conscious thought. Specifically, they used a combination of overt framing (i.e., presenting the problems as requiring logic), explicit incentive (offering a reward for good performance), and accountability (instructing participants to be ready to explain their answers). If performance was already at a ceiling, this manipulation could not produce any improvement. But if engaging the conscious mind is able to improve reasoning, then these procedures should raise scores on the logic test.

The nonconscious goal manipulation was the same as the priming procedure as in Experiments 2(a–c) and 3, namely a scrambled sentence completion task. The results of Experiments 2(a–c) and 3 provided consistent evidence that priming logical reasoning did not cause differences on problems that required following strict rules of logic compared to participants primed with a neutral goal. Hence, the current study did away with the neutral priming condition. Exposing participants to both the conscious and nonconscious logical reasoning manipulations seemed unnecessary, since it would be difficult to determine if performance in such a condition would be due to the conscious goal manipulation, the nonconscious goal manipulation, or both. Therefore, Experiment 4 included only conditions in which the logical reasoning goal was manipulated through conscious or nonconscious means.

5.1. Method

5.2.1. Participants

Thirty-eight undergraduates (26 women) participated in this study in exchange for partial course credit.

5.2.2. Materials and procedure

Participants arrived at the laboratory individually for an experiment ostensibly investigating the psychological processes involved in completing different reading tasks. By random assignment, half of the participants were assigned to a conscious motivation condition, whereas the other half of the participants were assigned to a logic prime condition. Since no difference in performance between logic and neutral prime participants was found in Experiments 2(a–c) and 3, we felt that excluding the neutral prime condition would not alter our results. Participants in the logic prime condition first completed the version of the scrambled sentence test used to activate logical-reasoning concepts in Experiments 2(a–c) and 3. Logic prime participants then completed the set of symbolic logic puzzles used in Experiment 2b.

Participants in the conscious motivation condition, in contrast, were given instructions that were meant to frame the meaning of the symbolic logic puzzles, to provide a conscious incentive to perform well, and to place participants in a position of accountability for their responses. Specifically, the experimenter informed conscious motivation participants that the symbolic logic problems required logical reasoning to complete (i.e., task meaning), that participants would be paid $1 cash for each problem he or she answered correctly (i.e., incentive), and that participants would be asked to explain their answers to a few of the problems (i.e., accountability). To bolster the credibility of the cash incentive, the experimenter showed participants in the conscious motivation condition an enveloped filled with a large stack of $1 bills. All participants were given 20 min to complete as many of the symbolic logic problems as they could. After 20 min had elapsed, participants were fully debriefed, given partial course credit, and dismissed.

5.3. Results

5.3.1. Correct responses

Consciously motivated participants ($M = 20.56$, $SD = 6.29$) completed more logical reasoning problems correctly than did logic prime participants ($M = 14.47$, $SD = 7.63$), $F(1,36)= 7.12$, $p = .01$, $d = .87$. They also answered a significantly higher proportion of questions correctly ($M = .77$, $SD = .13$) than did logic prime participants ($M = .55$, $SD = .23$), $F(1,36)= 13.48$, $p = .001$. The size of effect for this difference was $d = 1.18$, which exceeds standard criteria used for describing large effects (Cohen, 1977).

5.3.2. Attempts

ANOVA revealed no significant difference in terms of the number of problems participants each group attempted, $F < 1$, *ns*. Conscious motivation participants ($M = 27.00$, $SD = 7.06$) attempted the same number of (or, if anything, fewer) logical reasoning problems compared to logic prime participants ($M = 28.21$, $SD = 13.69$). Thus, the superior performance of the conscious goal group cannot be attributed to their attempting more problems.

5.4. Discussion

Experiment 4 showed that it is possible to improve logical reasoning by enlisting the conscious, reflective system in the goal of being logical. These findings also ruled out the alternative explanation based on ceiling effects. Participants in the conscious goal manipulation gave more right answers and fewer wrong answers, as compared to participants in the nonconscious priming condition. Thus, the failure of the priming manipulation to improve logic performance in Experiments 2a–2c cannot be dismissed as due to a ceiling effect (i.e., that it is impossible to improve upon the logical reasoning of our participants). Participants in our sample apparently can be stimulated to think more logically and make fewer errors. But this seems to require engaging the conscious mind rather than simply activating the notion of logicalness via a nonconscious priming manipulation.

Meanwhile, the two conditions did not differ as to the number of problems attempted. Thus, as in the preceding studies, the difference between manipulations targeting conscious vs. nonconscious processes does not appear to reside in simply doing problems and producing answers. Rather, it lies in producing *correct* answers. Engaging the conscious system resulted in smarter but not faster performance.

6. General discussion

The present investigation was stimulated by the broad question of what are the special advantages and benefits of conscious processing. Lieberman et al., (2002; also Smith & DeCoster, 1999, 2000) proposed a provocative hypothesis, namely that the automatic, nonconscious processing system does not generally carry out logical reasoning operations and indeed may be largely incapable of them, in contrast to the conscious and reflective system, which can reason from one concept to another following the validated rules of logic. If adding the capacity for logical reasoning to the human mental apparatus enabled a significant increase in logical reasoning, then the result could well have proven to be a hugely adaptive rise in the ability to think, and more importantly in the ability to attain new insights—and thereby to increase the stock of knowledge—by means of thinking. Hence, there could be special value in having the conscious or reflective ("C") thinking system. Put another way, some of the value and purpose of consciousness could in principle derive from an improved ability to understand the world by means of logical reasoning.

The present investigation sought alternately to engage and stimulate or to encumber and hamper each of the two major mental domains: the conscious, reflective system and the nonconscious system. After manipulating them, we assessed performance at logical reasoning. In a nutshell, our results suggested that logical reasoning depends on conscious processing. When we engaged and stimulated conscious processing, logical reasoning improved, and when we encumbered or preoccupied it, logical reasoning got worse. In contrast, neither engaging nor encumbering the nonconscious system yielded any changes in logical reasoning performance in either direction.

Moreover, the results cannot be explained by saying that our manipulations of nonconscious processing were too weak to have any effects. Our priming manipulation increased the accessibility of the concepts of logic and reasoning, in fact by a large margin. It also clearly activated the goal of reasoning effectively, as indicated by improved performance on logic test questions that could be solved by shortcuts (invoking associative links to general knowledge) rather than rigorously following rules. Likewise, our old flame manipulation succeeded in creating a nonconscious load in the sense that there was ongoing preoccupation of nonconscious processing, consistent with Wegner's (1994) ironic process theory. We replicated the finding of Wegner and Gold (1995) that thinking about a cold-flame (i.e., a former but no longer desired romantic relationship) produced significantly more cognitive rebound than thinking about a hot-flame, again with a large effect size. Thus, the only way to argue that nonconscious processing is still responsible for our observed decrements in logical reasoning in the conscious load conditions would be to say that our manipulations of nonconscious load were somehow too weak to affect reasoning at all despite being strong enough to produce large effects on other measures. Also, such an argument would seemingly violate the prevailing assumptions about the automatic system, which is that it operates in parallel and therefore can do multiple things at once (Lieberman et al., 2002).

When the conscious processing system was preoccupied with another (cognitive load) task, logical reasoning was more than slightly impaired. We found that participants in that condition furnished correct answers at a rate that did not exceed what would be obtained by random responding. In other words, there was no sign of any successful reasoning among the participants in the high cognitive load condition. Despite their efforts to think the problems through, their rate of correct answers was tantamount to guessing.

Whereas the conscious cognitive load manipulation substantially lowered the number and rate of correct answers, it failed to alter the total number of answers (i.e., correct plus incorrect) people gave. This can be regarded as surprising in several ways. For one thing, an increase in answers (even based on random guessing) would have been an effective strategy for increasing the total number of correct answers, and so the failure to increase was noteworthy. It suggests, at least, that participants failed to realize that they were doing no better than just guessing at the problems. On the other hand, one might have expected that the cognitive load manipulation would have reduced the number of answers people gave, insofar as they were distracted by the load and hence had to work more slowly. But it did not. The combination of no change in attempts and significant change in number correct supports the view that separate systems were operating. Under cognitive load, people continued to produce answers at the same rate as before, suggesting that their pace of work and level of effort were unchanged. All that changed was the quality of their answers.

The size of the observed effects was not subtle. Preoccupying the conscious system with the load task led to more than a full standard deviation′s reduction in logical reasoning performance. A nonconscious load task did not impair (and instead slightly improved) logical reasoning performance (Experiment 1). And although priming failed to change performance, it did increase the accessibility of the concepts of logic and reason, again by over a standard deviation in most cases (Experiments 2a–2c). (Thus, the present studies contribute at least in replication to the growing body of work indicating that nonconscious priming can yield large and reliable effects on cognitive processing.) Even Experiment 4, which compared conscious vs. nonconscious pathways for stimulating better performance at logical reasoning, found large differences, with the conscious activation producing more correct answers ($d = .87$) and a higher rate of correct answers ($d = 1.18$) than did the nonconscious priming. Thus, all of our laboratory manipulations succeeded in producing large and replicable changes in mental performance. These large effects contrast sharply with the negligible changes in reasoning following the various manipulations of nonconscious process. Those generally yielded not the slightest hint of effect, instead tending to produce nonsignificant trends in the opposite direction.

6.1. Limitations

We hasten to acknowledge several limitations of our work. We are not claiming that the automatic system is irrelevant to logical reasoning, and indeed we share the widespread assumption that conscious processes generally rely on extensive support by automatic processing. As noted earlier, automatic processing was obviously necessary in order to enable participants to read the problems, and probably in other ways as well. At present, the fairest and most reasonable conclusion would seem to be that full-fledged logical reasoning requires cooperative interplay between both systems, rather than being fully executed by the conscious processing system alone.

Our results also cannot rule out the possibility that some logic operations can be executed automatically. Indeed, Experiment 3 found improved performance on ostensible logic problems, although a knowledgeable person could get those correct without actually engaging in rigorous reasoning. Simple logic problems may be solvable without conscious thought, and one can also imagine that extensive practice might enable an expert (perhaps an instructor responsible for grading a hundred final exams in a college logic course!) to spot flaws in reasoning without needing the full power of conscious thought.

Nor is it even fair to say that the conscious, reflective system is invariably more logical than the automatic system. Participants in a study by Lee, Amir, and Ariely (2006) made pairwise preference judgments either under cognitive load or while devoting full conscious attention to each choice. The logical principle of transitivity was more consistently upheld in the automatic judgments than in the conscious ones, prompting those authors to characterize the automatic responses as the more logical ones. However, the logic in those decisions depended merely on consistency of evaluative response, and it may well be that investing more conscious deliberation into one′s preferences can produce misleading or mistaken results (Wilson, 2002). One way to resolve the apparent contradiction is to suggest that automatic responses are better at repeating simple operations, which would thus yield consistent judgments of liking and preference. Conscious processing may be designed to detect and process integrative and interactive effects (interaction in the statistical sense), which is why it is powerful for combining information, as was required for doing our logic problems. This view is in accordance with Kahneman's (2003; see also Simonson, 2005) argument that automatic processes (what he refers to as System 1) is responsible for repeating simple operations, whereas conscious processes (what he refers to as System 2) function to detect and correct errors made by the automatic system.

Our goal is not to derogate the powers of automatic thought but to establish some benefits of conscious thinking. Toward that end, it is sufficient to show that on some problems and under some circumstances, conscious processing can improve performance substantially.

A last and important limitation is that our results do not speak to the question of why the conscious system is characterized by subjectively conscious experience. Our results suggest that the conscious system can sometimes succeed where nonconscious processing fails, and in that way we have supported the view that two systems with different capabilities and specialties are better than one. Diehard skeptics of consciousness might however contend that, in principle, a second nonconscious system might have existed with the full capabilities to perform logical reasoning and any other operations that characterize the human conscious processing system. We have taken the two systems as they come, more or less with one being conscious and the other nonconscious. Hence, we cannot use the present data to speculate as to whether the reflective "C" system might in principle perform just as well if it lacked the property of subjective consciousness. Nonetheless, if consciousness per se has special value, that value is likely to be found in the tasks that are in practice performed better by the conscious mental system, and so the present results may eventually prove useful in ultimately appraising whether the subjective state of being conscious has functional value.

7. Concluding remarks

A perennial question in psychology has been "What is consciousness useful for?" Early theorists such as Freud (1901/1965) and Skinner (1938) believed that most causes of human behavior could not be found within one′s conscious self or ego but were instead located within the recesses of the unconscious or externally in one′s environment. During the past 15 years, researchers have argued that most daily behaviors are determined by mental processes that operate outside of conscious attention and awareness (e.g., Bargh & Chartrand, 1999; Bargh & Ferguson, 2000). Thus, many researchers have been left wondering why evolution endowed humans with consciousness and what positive usefulness consciousness could have—if any.

The present results have pointed toward one possible conclusion about the value of, if not subjectively conscious states themselves, at least the realm of mental activity that happens to be conscious. As proposed by Lieberman et al. (2002), Smith and DeCoster (1999, 2000), and Simonson (2005), logical reasoning appears to be a peculiarly difficult form of mental activity that requires special capabilities. In the human mind, the reflective or conscious processing system is much better equipped with those capabilities than the automatic, nonconscious system. To the question of whether the conscious portion of the human mind has any special powers or usefulness, our results can hold up logical reasoning as one possible answer. And if logical reasoning has any benefits for survival and reproduction—an assumption we hold but that goes far beyond the present data—then natural selection might well have favored individuals whose minds permitted conscious processing over those whose did not.

A last point is that we have treated consciousness as the property of one segment of the individual mind, but in the long run an interpersonal dimension of consciousness may be required for a full understanding. The value of logical reasoning may depend in part on the fact that people can share an understanding of its rules and therefore correct each other′s mistakes. Three decades ago, a seminal article by Nisbett and Wilson (1977) argued that people are often unaware of their inner cognitive processes and hence do not know why they have the feelings, beliefs, or attitudes that they do. This revolutionary insight attuned subsequent researchers to the extent and importance of nonconscious processing. Nisbett and Wilson (1977) also noted that when pressed for explanation, people would often resort to a priori theories which did not correspond to the actual inner process. Although we accept their conclusions generally, we acknowledge that logical reasoning may be an important exception. Among others, Strack and Deutsch (2004) have suggested that logical reasoning and other reflective processes can be inspected, because they follow rules that are explicitly known. Perhaps the conscious system has learned to think according to rules because those rules are accepted by others and hence the thought processes that use them can be discussed and debated. As Nisbett and Wilson (1977) suggested, it may not matter *why* a person likes a particular pair of nylon stockings, because in a sense there is no right answer and no basis by which one person can persuade somebody else that one color or texture is better than another. Hence, there may be no need to discuss and dissect the inner process that produced the preference. But if two people disagree as to whether a particular conclusion is correct, they can invoke shared (indeed, universal) principles of logic to ascertain whether the evidence justifies that conclusion, and by those rules they can resolve their dispute.

Determining the truth-value of conclusions and the logical validity of arguments may be a special style of thinking that required a special set of mental capabilities. Because logical reasoning can be inspected and corrected, consciousness—including the ability to explain one′s thinking to others and find out whether they concur that the premises entail the conclusion—may help people learn to think more logically and ultimately to reach correct answers more often. In our studies, conscious thinking appears to have improved people′s ability to reach correct answers.

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