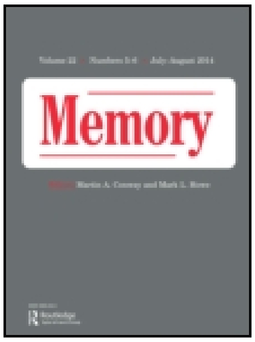

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Overcoming fixation with repeated memory suppression

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Fixation (blocks to memories or ideas) can be alleviated not only by encouraging productive work towards a solution, but, as the present experiments show, by reducing counterproductive work. Two experiments examined relief from fixation in a word-fragment completion task. Blockers, orthographically similar negative primes (e.g., ANALOGY), blocked solutions to word fragments (e.g., A_L_ _GY) in both experiments. After priming, but before the fragment completion test, participants repeatedly suppressed half of the blockers using the Think/No-Think paradigm, which results in memory inhibition. Inhibiting blockers did not alleviate fixation in Experiment 1 when conscious recollection of negative primes was not encouraged on the fragment completion test. In Experiment 2, however, when participants were encouraged to remember negative primes at fragment completion, relief from fixation was observed. Repeated suppression may nullify fixation effects, and promote creative thinking, particularly when fixation is caused by conscious recollection of counterproductive information.

Keywords: Fixation; Memory inhibition; Creative thinking.

Memory inhibition of competing responses has been argued to be an important factor in facilitating target retrieval (Anderson, 2003; Storm & Levy, 2012). In the present study, we examined whether inhibition can also alleviate fixation in solving word fragments. Using the creative cognition approach (Smith & Ward, 2012), parallels can be drawn between cognitive processes, such as memory inhibition, and processes used in tasks that require creative solutions. The mental work involved in overcoming fixation in word-fragment completion mirrors the mental work involved in overcoming mental blocks in creative problem-solving, design and idea generation.

Creative mental processes allow one to go beyond one's current state of knowledge to create innovative ideas (Smith & Ward, 2012). Fixation can prevent innovation by blocking new ideas with counterproductive known or primed ideas, sometimes called "blockers" (e.g., Jansson & Smith, 1991; Smith, 1995, 2003; Smith & Blankenship, 1991). We investigated a method for overcoming fixation (or "blocking") in word-fragment completion, a simple problem-solving task (Smith & Tindell, 1997). Specifically, we examined whether an active, intentional, memory suppression mechanism might nullify the effects of fixating blockers by having participants repeatedly suppress the blockers using the Think/No-Think paradigm (Anderson & Green, 2001). We hypothesised that the memory inhibition of blockers would nullify their blocking effect on word-fragment completion problems.

Mental blocks in problem solving

Creative problem-solving studies have frequently used Remote Associates Test (RAT) problems

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(Mednick, 1962), in which the problem solver must find a solution related to three seemingly unrelated words (e.g., *bass*, *complex*, and *sleep*). To solve a RAT problem, the participant must give a solution word (e.g., *deep*) that is associated with each of the three problem words. While searching for the correct "remote associate", however, other associates can come to mind. For example, one might associate *guitar* with the word *bass*, *hard* with *complex* and *rest* with *sleep*. Focusing on these incorrect associates can prevent the answer, *deep*, from coming to mind, creating a mental block; thus, these problems have been used to show reliable fixation effects (e.g., Smith & Blankenship, 1991; Vul & Pashler, 2007).

A simpler method for inducing fixation involves priming incorrect solutions (or presenting "negative primes") for word-fragment completion problems (Smith & Tindell, 1997). Smith and Tindell found impaired completion rates, or memory-blocking effects (e.g., Leynes, Rass, & Landau, 2008), on word fragments (e.g., A_L_ _GY) following exposure to negative primes (e.g., ANALOGY) that were orthographically similar to the solutions (e.g., ALLERGY). In the present study, we used word-fragment completion problems with unique solutions, each associated with one blocker word, because we wanted to reduce accessibility to specific blockers to nullify fixation effects.

Overcoming mental blocks

There are many ways that researchers have studied overcoming fixation, such as focusing participants on abstract representations of problems (McCaffrey, 2012), training participants to use various heuristics (Ansburg & Dominowski, 2000), providing incidental hints (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995) and forgetting fixation (Smith & Blankenship, 1989). Here we focus on forgetting fixation; whereas abstraction, heuristics and incidental hints can bring the problem solver closer to a known solution, forgetting fixation focuses on eliminating counterproductive work.

Forgetting fixation

According to the *forgetting fixation* hypothesis, initial fixation can be overcome if fixating information is forgotten. Smith and Blankenship (1989), for example, induced fixation by presenting incorrect answers alongside rebus problems during initial problem solving. They found better resolution rates after an incubation interval (i.e., a break from problem solving), as compared with immediate attempts to resolve problems. Therefore, it was concluded that the incubation period (i.e., 15 minutes of a music perception task) allowed participants to forget incorrect answers, or blockers. This conclusion was supported by their finding that recall of blockers was worse after the incubation task. The improved resolution of initially unsolved problems after a delay is typically called an *incubation effect*, which Smith and Blankenship (1989, 1991), along with other laboratory studies (e.g., Vul & Pashler, 2007) have found only when participants are primed with incorrect answers.

Consistent with the forgetting fixation hypothesis, Wiley (1998) presented "baseball misleading" RAT problems (e.g., *plate broken shot*) to baseball experts and novices and retested problems after a delay. Because experts were more likely than novices to think of baseball-related blockers (e.g., *home*), there was greater fixation for experts. Novices showed an incubation effect for these RAT problems, but experts did not. Although episodically primed blockers may be forgotten during a relatively brief incubation interval, as in experiments by Smith and Blankenship (1989, 1991) and Vul and Pashler (2007), semantic knowledge (e.g., knowledge about baseball) is unlikely to be forgotten over such a brief interval. Wiley predicted that forgetting fixation, especially for highly accessible misleading information, would require actively suppressing blockers. The present investigation is a test of that hypothesis.

Memory inhibition

Retrieval-induced forgetting

One approach to forgetting blockers may be through memory inhibition, which can be defined as the inaccessibility that results from the suppression of competing or contextually inappropriate information (Anderson, 2003). One instantiation of memory inhibition is that of retrieval-induced forgetting (RIF; Anderson, Bjork, & Bjork, 1994; Bäuml, 2002), which occurs for items in memory related to a retrieval cue that compete for access when that cue is used to guide retrieval of other items (for a review, see Storm & Levy, 2012).

Storm and Angello (2010) tested whether the memory inhibition underlying retrieval-induced forgetting could also reduce memory of blockers or incorrect associates to RAT problem words, thereby nullifying the negative effects of blockers. They reasoned that individuals showing higher levels of RIF should be better at solving RAT problems negatively primed with incorrect associates. Consistent with this conjecture, a positive correlation between RIF and RAT problem solving was observed, indicating that proficiency in memory inhibition during a memory retrieval task is associated with the ability to overcome fixation during creative problem solving (see also, Koppel & Storm, 2013; Storm, 2011). Subsequent research has found that participants who forget incorrect associates following problem solving are also better at overcoming fixation and correctly solving negatively primed RAT problems (Storm, Angello, & Bjork, 2011).

Suppression-induced forgetting

An active and intentional way to nullify the negative effects of blockers might be possible with the Think/No-Think paradigm, another task that is believed to reflect the consequences of memory inhibition (Anderson & Green, 2001). The Think/No-Think method tests the effects of repeated suppression on a cued-recall test. During the initial learning phase, participants study cue-response pairs (e.g., *ordeal-roach*). Then, during the Think/No-Think phase, participants are presented with a subset of the cue words. For some of these cue words, participants are asked to think of the corresponding response words (think items). For other cue words, however, participants are asked to not think of the corresponding response words (no-think items). More specifically, for no-think items, participants are instructed to keep the response words from even coming to consciousness. Following these trials, participants are given a cued-recall test for all initially learned responses using either the original cue (e.g., *ordeal-*) or an independent probe (e.g., *insect-r*). Results from both tests show significant levels of forgetting for suppressed responses compared with baseline responses that were neither suppressed nor thought about during the Think/No-Think phase (for a review, see Anderson & Huddleston, 2011).

Forgetting blockers

A way to nullify the negative effects of blockers was found by Koppel and Storm (2012), who demonstrated reduced memory blocking on word-fragment completion. In that study participants solved word fragments following listwise directed forgetting of negative primes, a different methodology that, like the Think/No-Think procedure, might also produce memory inhibition (Bjork, 1989). Similarly, Leynes et al. (2008) proposed a type of executive process that may inhibit activation of negative primes. In the present study, we experimentally tested the notion that such an executive process, using active suppression of blockers, would alleviate the memory-blocking effect.

Explicit and implicit mental blocks

Memory-blocking effects have been found when participants were not informed of the relation between negative primes and word-fragment solutions (Smith & Tindell, 1997). However, memory-blocking effects have also been observed when participants were specifically forewarned that the primes would consist of wrong answers, and they should avoid thinking of those primes. These results indicate that negative primes can negatively influence word-fragment completion implicitly or explicitly, and regardless of whether participants are aware of the relationship between the primes and the fragments. Interestingly, Smith and Tindell also found that memory-blocking effects can be *increased* when participants are encouraged to explicitly recall the negative primes, suggesting that conscious recollection of negative primes can exacerbate the memory-blocking effect. The present study aimed to test whether repeated suppression of negative primes could alleviate fixation and reduce the memory-blocking effect, either with or without instructions to consciously recollect primes on the word-fragment completion test. This extends the investigation by Koppel and Storm (2012), in which participants were encouraged to recollect primes; in Experiment 2 of the present investigation participants were likewise encouraged to recollect primes, whereas in Experiment 1 instructions at word-fragment completion did not mention the primes.

Participants studied negative primes (e.g., BRIGADE), which were orthographically similar to word-fragment solutions (e.g., BAGGAGE), before completing single-solution word fragments (e.g., B _ G _ A _ E). During study, each negative prime was associated with an unrelated hint word (e.g., PLANET), which served subsequently as a cue on a No-Think trial for half of the studied negative primes. The remaining studied negative primes were not assigned to No-Think trials. Following Think/No-Think trials, participants attempted to solve the critical word fragments. Consistent with prior research on the memory-blocking effect (e.g., Leynes et al., 2008; Smith &

Tindell, 1997), we predicted that blocking would occur in both experiments for standard negative primes; that is, we predicted poorer fragment completion rates for items corresponding to negative primes that had not been inhibited. Would memory inhibition nullify the effects of blockers? We asked this question for two types of word-fragment completion tasks, one that minimised the influence of recollection of primes (Experiment 1), and another that encouraged recollection of primes (Experiment 2). In both experiments, we tested whether repeated No-Think trials would inhibit memory of blockers, thereby alleviating their negative effects on word-fragment completion. Furthermore, if memory of blockers can be inhibited, are the effects seen regardless of whether participants try to remember the blockers?

GENERAL METHOD

Materials and design

Fifty-five unrelated hint-response pairs (e.g., PLANET-BRIGADE) were used. The hint words (e.g., PLANET) were taken from Anderson and Green (2001), with care taken to ensure they did not share orthographic similarity with negative primes and fragment solutions. Of the 55 response words, 15 critical seven-letter response words, used as negative primes (e.g., BRIGADE), were taken from Koppel and Storm (2012). The remaining 40 filler seven-letter response words were created so that they did not start with the same letter as, nor share orthographic similarity with, the negative primes and fragment solutions. Filler responses were randomly assigned to Think and No-Think trials.

Of the 15 negative primes, 10 were assigned to one of two within-subjects conditions: five were assigned to *16 No-Think trials* and 5 were assigned to *0 No-Think trials*. The remaining five critical response words were not studied and thus were assigned to the third within-subjects condition: *control*. Negative primes were counterbalanced between subjects.

Fifteen critical word fragments, taken from Koppel and Storm (2012), along with 15 filler fragments from Leynes et al. (2008), were tested. Ten filler fragments were tested first, followed by five blocks of four fragments. Each block contained three critical fragments (e.g., B _ G _ A _ E) and one filler fragment. Of these critical fragments, one fragment's negative prime was repeatedly suppressed (No-Think fragment), one fragment's negative prime was not previously suppressed (blocked fragment) and one *control* fragment was not negatively primed.

Procedure

Participants studied 50 hint-response word pairs for five seconds (see Figure 1) and were instructed to form a connection between them to prepare for the immediately following cued-recall test, in which hint words served as cues for response words for four seconds each with corrective feedback. Incorrectly recalled response words were tested in a new round of testing, and testing continued until all responses were correctly recalled. A final single-round cued-recall test without feedback was then administered.

Participants completed 13 practice Think/No-Think trials for five filler pairs. For green hint words, they were told to "think of the response word and keep it in mind the entire time that the hint is on the screen". For red hint words, they were told to pay attention to these words while avoiding thinking about the associated response word while it is on the screen and after the hint word has left the screen. Participants were also given the strategy presented in Bergström, de Fockert, and Richardson-Klavehn (2009) to block the response word from coming to mind without replacing it with other thoughts. To facilitate

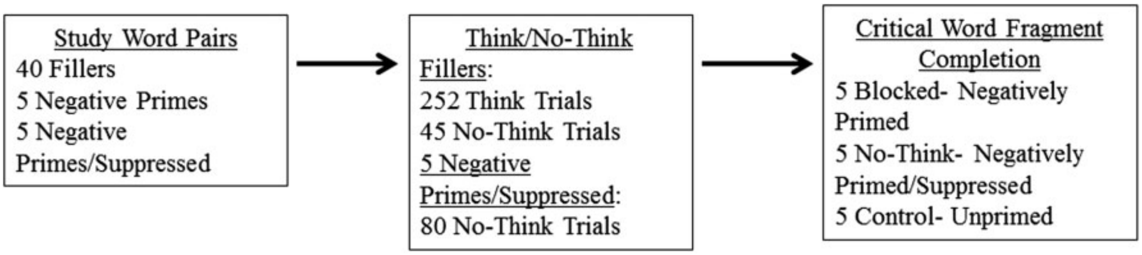

Figure 1. Schematic of general procedure in Experiments 1 and 2.

Think/No-Think performance, participants were shown a green or red cross for two seconds prior to each trial to signal the type of trial that would occur next (Hanslmayr, Leipold, & Bäuml, 2010). Each hint word was presented for four seconds following this warning.

Participants were then presented with a questionnaire to check for compliance with instructions, followed by 13 practice trials in a new semi-random order. Then, the experimental trials (see Figure 1) were presented, following a brief reminder of instruction, in a semi-random order such that no more than two No-Think trials occurred successively, no more than five Think trials occurred successively and no items were repeated in succession. The ratio of Think to No-Think trials, as well as total number of trials, was based on the values used by Anderson and Green (2001). In the final phase, participants completed word fragments: 15 fillers and 15 critical fragments, one at a time for four seconds each. Participants verbally provided one answer, while warned to avoid guessing. A post-experiment questionnaire was then administered. Participants who indicated that they were unable to comply with the Think/No-Think instructions were removed from analyses.

EXPERIMENT 1

Participants

Fifty-six undergraduates volunteered for credit in an introductory psychology course. Eight participants were unable to participate in the Think/No-Think phase because they could not recall the minimum required 50% of response words during the cued-recall test before Think/No-Think trials (Anderson & Green, 2001). One participant quit during the initial test with feedback, and three participants were excluded because they failed to comply with the Think/No-Think instructions.[1] The remaining 44 participants' (M_{age} = 19) data were used in the reported analyses.

[1]One participant fell asleep, one participant spoke aloud and one participant reported that he was never able to avoid thinking of the response words during No-Think trials.

Results and discussion

The control, blocked and No-Think problems differed in solution rates according to a one-way repeated-measures ANOVA, $F(2, 86) = 3.34$, $MSE = .12$, $\eta_p^2 = .07$, $p < .05$. As shown in Figure 2, control problems were solved more often than No-Think problems, $t(43) = 2.35$, $d = .49$, $p < .025$, and marginally more often than blocked problems, $t(43) = 1.99$, $d = .43$, $p = .05$. Blocked and No-Think solution rates did not significantly differ, $t(43) = 0.13$, $d = .00$, $p > .05$.

The results of Experiment 1 demonstrate memory blocking without encouraging conscious recollection of primes, as has been reported by Smith and Tindell (1997) and others. Thus, the present materials and procedure were sufficient for showing the standard memory-blocking effect. Interestingly, we did not find reduced memory blocking after blockers had been repeatedly suppressed. It is possible that forgetting might not be observed in the Think/No-Think paradigm on an indirect memory test (i.e., a test in which no reference is made to the target items, thought to test primarily implicit memory; see Richardson-Klavehn & Bjork, 1988), an issue left unclear by research published to date. Algarabel, Luciano, and Martinez (2006), for example, failed to observe response slowing on a lexical decision test for items repeatedly suppressed, and Meier, König, Parak, and Henke (2011) failed to find forgetting effects with a presumably indirect free association test.

On the other hand, Hertel, Large, Stück, and Levy (2012) did find suppression-induced forgetting using free association to homograph cues, an indirect measure of memory. It is difficult to interpret this finding, however, because they tested implicit memory for homograph cues rather than memory for the responses themselves. Another finding inconsistent with the idea that memory suppression effects are not found on indirect memory tests was reported by Kim and Yi (2013), who found that participants were poorer at naming pictures when the pictures had been repeatedly suppressed. However, all of the pictures used at test had been primed, without the use of unprimed fillers, possibly allowing explicit contamination (Barnhardt & Geraci, 2008). Given the inconsistent results of these few studies, it is unclear whether forgetting caused by the Think/

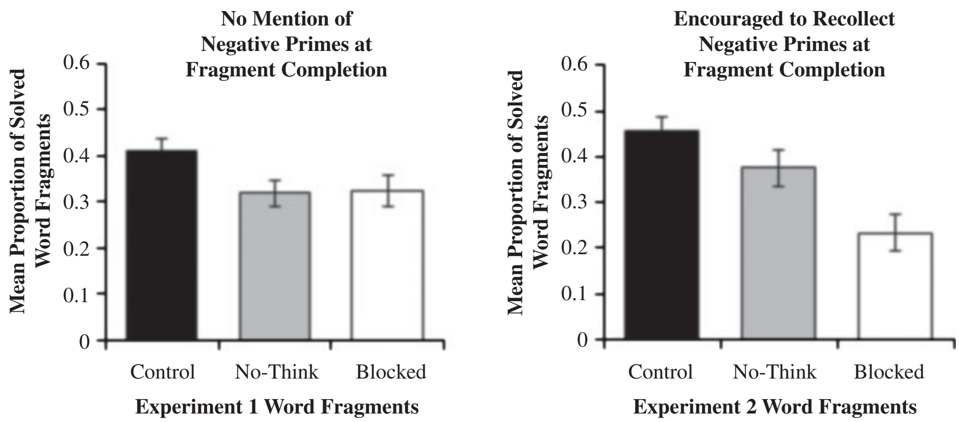

Figure 2. Mean proportion of word fragments solved as a function of type of word fragment and instructions at test for Experiments 1 and 2. Error bars represent ± 1 SEM.

No-Think paradigm is observed with indirect memory measures.

Experiment 1 failed to find that suppression-induced forgetting reduced memory-blocking effects when fragment completion was treated as an indirect test. Can fixation be reduced by suppression when it is caused by explicit recollection of blockers? Suppression-induced forgetting effects are generally observed on direct memory tests that rely heavily on conscious recollection (Anderson & Huddleston, 2011). Experiment 2 tested for relief from blocking on a word-fragment completion test whose instructions encourage explicit recollection of blockers.

EXPERIMENT 2

Participants

Thirty-one undergraduates volunteered for credit in an introductory psychology course. Four participants were unable to participate in the Think/No-Think phase because they could not recall the minimum required 50% of response words during the cued-recall test before Think/No-Think trials. One participant quit during the initial test with feedback, and two participants were excluded because they failed to comply with the Think/No-Think instructions.[2] The remaining 24 participants' (M_{age} = 18) data were used in the reported analyses.

Method

The materials and design were the same as those in Experiment 1, except for the additional instruction provided prior to word-fragment problem-solving: *Some of the words that you have studied may or may not help you complete these word fragments*.

Results and discussion

The control,[3] blocked and No-Think problems differed in their solution rates according to a one-way repeated-measures ANOVA, $F(2, 46) = 11.47$, $MSE = .31$, $\eta_p^2 = .33$, $p < .001$. As shown in Figure 2, participants solved significantly more control problems than blocked problems, $t(23) = 5.33$, $d = 1.39$, $p < .001$. The difference between control and No-Think problems neared, but did not reach, statistical significance, $t(23) = 1.79$, $d = .49$, $p > .05$. The more important finding was that participants solved significantly fewer blocked problems than No-Think problems, $t(23) = -2.66$, $d = -.79$, $p < .025$, thus indicating that the blocking effect was significantly reduced after participants repeatedly suppressed the negative primes.

[2]Two participants reported that they were never able to avoid thinking of the response words during No-Think trials.

[3]Cross-experiment comparison shows that numerically the means of the control conditions are different. However, according to an independent samples t test, the baseline level of recall in Experiment 1 (M = .409, SE = .029) was not significantly smaller compared to the baseline level of recall in Experiment 2 (M = .458, SE = .028), $t(66) = -1.105$, $d = -.294$, $p > .05$.

GENERAL DISCUSSION

Two experiments tested relief from negative priming when participants repeatedly suppressed negative primes prior to solving word fragments. In Experiment 1, when instructions made no mention of primes, repeated suppression of primes using a Think/No-Think procedure failed to nullify their effects on word-fragment completion. In Experiment 2, however, when participants were encouraged to explicitly recollect primes at test, memory-blocking effects were significantly reduced by repeated suppression of primes. Reduced memory-blocking effects were found only when conscious recollection of primes was encouraged[4] (Experiment 2), thus suggesting a means to actively counter certain types of fixation. Specifically, memory inhibition through repeated suppression may nullify fixation effects caused by conscious recollection of counterproductive information.

Fixation can have both implicit and explicit components (Smith & Tindell, 1997). Implicit fixation may be particularly difficult to overcome because, by definition, problem solvers are unaware of the cause of fixation. For example, Smith, Ward, and Schumacher (1993) indicated that *conformity effects* in creative idea generation could be caused by implicit memory of examples. Conformity occurs when participants' supposedly creative responses have features of the presented examples. Jansson and Smith (1991) found conformity effects with engineering design students and professional designers, a phenomenon also known as *design fixation*, even when they were warned to avoid replicating certain example features in their designs. Smith et al. found conformity effects when participants drew imaginary creatures even when participants were instructed to "generate ideas as different as possible from the examples given". When participants were encouraged to generate ideas similar to examples, conformity effects increased, presumably due to conscious recollection of features of the examples. A similar pattern was observed in the current study. Instructions to explicitly recollect negative primes led to a significantly larger memory-blocking effect in Experiment 2 (M = .23; d = 1.39) than in Experiment 1, where the memory-blocking effect was presumably primarily implicit (M = .09; d = .43), $t(66) = 2.08$, d = .56, $p < .05$.

It is interesting that the size of the memory-blocking effect observed in Experiment 1 was nearly identical to the effect observed in Experiment 2 for items that had been repeatedly suppressed (M = .08; d = .49). These results suggest that suppressing items via No-Think trials can reduce the explicit component of the memory-blocking effect while leaving the implicit component intact. One reason the implicit component of the memory-blocking effect may be immune to suppression is because of the representational mismatch between the word-fragment completion task and the way in which negative primes are inhibited in the Think/No-Think paradigm. According to Anderson (2003), the functional representation of an item in memory is inhibited and forgetting results when the cues at test attempt to access the item via the same inhibited representation. In our study, participants learned to associate cue words with negative primes, creating conceptual representations of negative primes (Roediger, Srinivas, & Weldon, 1989). Then, during No-Think trials, participants suppressed the negative primes when presented with cue words, thereby encouraging inhibition of those conceptual representations. In contrast, word-fragment completion is disrupted primarily by the perceptual representations of negative primes (Smith & Tindell, 1997). Thus, inhibition targeting the conceptual representation of items may be incapable of reducing the implicit, perceptually based fixation. Only in Experiment 2, when participants were encouraged to recollect negative primes, and may have therefore attempted to retrieve conceptual representations of those primes, did inhibition reduce their effect on the fragment-completion task. It is possible, however, that inhibition might reduce the implicit component of the memory-blocking effect as well, as long as the perceptual representations of negative primes are also targeted by suppression (see, Bajo, Gómez-Ariza, Fernandez, & Marful, 2006).

Finally, it should be noted that using a different suppression paradigm—the "White Bear" paradigm (Wegner, Schneider, Carter, & White, 1987)—Kozak, Sternglanz, Viswanathan, and Wegner (2008) found that having participants attempt to directly suppress thoughts of negative

[4]The reduction of the memory blocking effect for blocked fragments (difference between control and blocked fragment solution rates) caused by repeated suppression of blockers in Experiment 1 (M = −.005, SE = .036) was significantly smaller compared to Experiment 2 (M = .141, SE = .053), $t(66) = -2.318$, d = −.582, $p < .025$.

primes actually exacerbated memory-blocking effects, rather than nullifying them or leaving them intact. One potential explanation of these seemingly contradictory results is that we asked participants to suppress the *memory* of the negative prime via an associated cue, whereas Kozak et al. presented participants with the negative prime and asked them to suppress *thoughts* of that prime directly. It is possible that fixation caused by negative primes can be alleviated following memory suppression, but enhanced by rebound from thought suppression. As discussed by Anderson and Huddleston (2011), memory suppression and thought suppression differ in many important ways, and their effects on mental fixation appear to be one such difference.

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