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Effects of emotionally valenced working memory taxation on negative memories

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ABSTRACT

Background and objectives: Memories enter a labile state during recollection. Thus, memory changes that occur during recollection can affect future instances of its activation. Having subjects perform a secondary task that taxes working memory while they recall a negative emotional memory often reduces its vividness and emotional intensity during subsequent recollections. However, researchers have not manipulated the emotional valence of the secondary task itself.

Methods: Subjects viewed a video depicting the aftermath of three fatal road traffic accidents, establishing the same negative emotional memory for all subjects. We then tested their memory for the video after randomly assigning them to no secondary task or a delayed match-to-sample secondary task involving photographs of positive, negative, or neutral emotional valence.

Results: The positive secondary task reduced memory for details about the video, whereas negative and neutral tasks did not.

Limitations: We did not assess the vividness and emotionality of the subjects' memory of the video.

Conclusions: Having subjects recall a stressful experience while performing a positively valent secondary task can decrement details of the memory and perhaps its emotionality.

Traumatic events trigger intense negative emotion that facilitates encoding of the central features of the experience, sometimes producing the syndrome of posttraumatic stress disorder (PTSD; McNally, 2003). Victims who develop PTSD experience involuntary, highly distressing reactivations of the traumatic memory whose vivid sensory features make it seem as if the event were recurring. Efficacious psychological treatments for PTSD entail the activation and modification of the traumatic memory so that its emotionality and vividness diminish, thereby attenuating its distressing intrusiveness (Bisson et al., 2007).

Inspired by theory and research on working memory (Baddeley, 2001; Baddeley & Hitch, 1974), clinical investigators have asked subjects to access negative emotional memories while performing a secondary task that taxes working memory (e.g., Gunter & Bodner, 2008; Kavanagh, Freese, Andrade, & May, 2001; van den Hout, Muris, Salemink, & Kindt, 2001). Reactivation requires working memory resources, and the concurrent performance of effortful secondary tasks, such as bilateral eye movements, draws on the same pool of resources. Accordingly, taxing working memory during reactivation should impair the vividness of the traumatic memory, thereby diminishing its negative emotional valence. Hence, the memory should be less vivid and less distressing when it undergoes reconsolidation into long-term store.

Laboratory studies indicate that concurrent tasks that tax working memory reduce the self-reported vividness and negative emotionality associated with distressing memories and aversive visual images (For a review, see van den Hout & Engelhard, 2012). Moreover, secondary tasks that target the visuospatial sketchpad (VSSP) of working memory are more effective than secondary tasks that target the phonological loop (PL) when the memory is visual, and vice versa when the memory is auditory (Kemps & Tiggemann, 2007). However, the magnitude of taxation imposed by the secondary task must neither be too great nor too little (Engelhard, van den Hout, & Smeets, 2011). If the secondary task is too demanding, the subject cannot activate the memory sufficiently. If it is too undemanding, it will fail to decrement the vividness and emotionality of the memory.

To the best of our knowledge, researchers have yet to vary the emotional valence of secondary tasks. Accordingly, we exposed subjects to three filmed scenarios depicting the immediate aftermath of road traffic incidents. We later administered multiple-choice questions testing subjects' memory for the potentially stressful film footage. However, prior to doing so, we randomly

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assigned subjects to undergo the memory test under one of four conditions. Subjects in the *control* group completed the test without performing a secondary task. Subjects in the other three groups answered the memory questions while performing a secondary task designed to tax the VSSP. The secondary task was a visual match-to-sample task whereby subjects viewed a photograph followed by an array of four photographs, the target photograph plus three similar distracter photographs. The subject's task was to identify the photograph in the array that matched the target photograph. Importantly, the emotional valence of the pictures differed across the three groups. Subjects in the *positive* group performed a match-to-sample task comprising pictures of *positive* valence (e.g., smiling babies); subjects in the *negative* group performed the same task with negative pictures (e.g., snakes), and subjects in the *neutral* group performed the same task with neutral pictures (e.g., chairs).

We tested several hypotheses. First, subjects in the neutral task should exhibit more memory impairment than should those in the control group. Second, if the emotional character of the secondary task (irrespective of valence) further consumes resources, then the positive and negative groups should exhibit more memory impairment than the neutral group. Third, on the other hand, positive and negative secondary tasks may have opposing effects on memory for the distressing film. That is, the positive task may be especially potent in reducing memory for the distressing film, not only because it consumes resources, but also because its valence is opposite to that of the film. Yet the valence of the negative task may counteract any memory-decrementing effects that a secondary task might otherwise produce. In sum, our chief aim was to test whether a secondary task having positive valence would be especially potent in decrementing the details of a distressing memory.

1. Method

1.1. Subjects

Subjects were recruited through emails distributed to Harvard University undergraduate students and students affiliated with the Massachusetts Institute of Technology's Student Financial Services, through notices distributed through the Boston University Student Employment Office, through craigslist postings in the "Volunteers" section, and through fliers posted throughout the greater Boston area. Subjects were also recruited through the Harvard University study pool, most of whom were community members, not undergraduates. Recruitment notices requested subjects who were 18 years or older and who had never received treatment for a mental health problem.

A change in procedure compelled us to exclude the first nine subjects (five male) as pilots. Among 37 men and 46 women who completed the final protocol, we excluded one man and one woman who were inattentive, and one woman who struggled to follow the instructions properly. Hence, we analyzed the data from 36 male and 44 female subjects whose mean age was 29.7 years old ($SD = 12.1$). Their ethnic backgrounds were Caucasian (43.8%), Asian (31.3%), African-American (15%), Hispanic (5%), Native American (1.3%), and "other" (3.8%). Their highest levels of education were postgraduate (18.8%), bachelor's degree (26.3%), some college (41.3%), and high school diploma (5%), and some high school (3.8%). Undergraduates in Harvard's subject pool received credit for their psychology course, whereas others received $5 upon completion of the study.

1.2. Materials

The stressful stimulus comprised videotaped footage of the immediate aftermath of three fatal motor vehicle accidents drawn from a film (Steil, 1996) used by previous researchers (e.g., Stuart, Holmes, & Brewin, 2006). It lasted six minutes and nine seconds. Each episode began with blank screen during which a man's voice described the accident, followed by footage of emergency workers extricating corpses and survivors. The three accident episodes lasted 1 min and 55 s, 2 min and 17 s, and 1 min and 57 s, respectively.

After viewing the three accident episodes, subjects answered two different audiotaped sets of twelve multiple-choice questions about them (Brewin & Saunders, 2001). To answer these questions, subjects needed to recall scenes from the film. To record the questions, we used Audacity 2.0.0, a free, cross-platform sound editor software installed on a Sony VAIO S-Series laptop. Each set contained four questions per accident, testing subjects' memory for each accident sequentially. At the start of each set, subjects heard the following on the audiotape: "These questions refer to the first scene you saw." Subjects immediately heard the first question followed by the answer options, followed by 5 s of silence before subjects heard the next question in the set. Assessment of subjects' memory for the second and third accident episodes followed thereafter.

To clear the visuospatial sketchpad and prevent rehearsal of the film's contents, we had subjects complete arithmetic problems for one minute after viewing the film and then again between the first and second question set.

With the exception of subjects randomized to the control group, subjects completed a delayed matching-to-sample task (Aggleton, Nicol, Huston, & Fairbairn, 1988), programmed with E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) on a desktop PC. In each trial of this task, subjects viewed a 500 ms fixation cross, replaced by a target image that remained at center screen for 2 s. Immediately thereafter, four images appeared on the screen: the original target image, plus three similar distracter images. The subject had 2 s to identify the target from the array of four images. Subjects indicated their responses by pressing the 'u,' 'i,' 'j,' or 'k' keys on the computer keyboard; subjects were instructed that these keys respectively corresponded with images in the top left, top right, bottom left, and bottom right of the array.

Depending on their group assignment, subjects saw highly arousing positive images, highly arousing negative images, or minimally arousing neutral images. The target images were from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). To develop and validate the IAPS images, Lang et al. had raters evaluate each picture on three nine-point scales measuring arousal, valence, and dominance. The first author sorted the IAPS images by valence ratings, and then divided them into three equal parts of positive (high valence rating on the nine-point scale), neutral, and negative valence images (low valence rating on the nine-point scale). She first excluded erotic images, and those related to the September 11th terrorist attacks and motor vehicle accidents. She then selected the 50 images having the highest arousal rating among the positive and negative images, and the 50 least arousing images from the neutral images.

The positive and negative images did not differ significantly in arousal ($M = 6.11$, $SD = .48$ versus $M = 6.00$, $SD = .22$), $t(98) = 1.54$, $p = .13$, but did differ significantly in valence ($M = 7.23$, $SD = .42$ versus $M = 3.22$, $SD = .66$), $t(98) = 36.09$, $p < .001$. The positive and negative valence images together also differed significantly in arousal from the neutral valence images ($M = 2.60$, $SD = .31$), $t(148) = 56.55$, $p < .001$. Furthermore, the positive images differed significantly in valence from the neutral images ($M = 5.00$, $SD = .40$), $t(98) = 26.98$, $p < .001$; likewise, the negative images differed significantly in valence from the neutral images, $t(98) = 16.20$, $p < .001$.

For each target image, the first author identified three distracter images from the IAPS and Google's online image search. She resized each target image and its three distracters so that the images together filled a 400 × 400 pixel square.

The delayed match-to-sample task included 50 trials, and all subjects within a group viewed the identical sequence of images, available from the first author, randomly generated via Microsoft Excel 2003. The location of each image in the test array was likewise randomly generated.

1.3. Procedure

Subjects read and signed the informed consent form, approved by Harvard University's Committee on the Use of Human Subjects, prior to completing a demographic questionnaire asking them about their month and year of birth, age, gender, ethnicity, and highest level of education.

Subjects were told that they would view a film depicting three separate road traffic accidents and that their memory for the scenes would be assessed later in the experimental session. Subjects then viewed the film on a desktop computer.

Immediately thereafter, they worked on a set of arithmetic problems for one minute; they were instructed to work quickly and accurately on these problems.

Following this distracter task, the first author randomly assigned subjects to one of four groups: control, positive, negative, or neutral. There were 20 subjects per group. These group assignments determined the conditions in which subjects then responded to the first question set that assessed memory for details from the film.

For practice, all subjects heard three audiotaped multiple-choice questions about general facts in a format similar to the subsequent experimental questions. They answered each question orally. Subjects in the positive, negative, and neutral groups also practiced four trials of the delayed matching-to-sample task. Their format was similar to the experimental trials except that the images were colored squares, not IAPS pictures. Subjects in the positive, negative, and neutral groups then heard one general knowledge multiple-choice question while performing the delayed matching-to-sample practice trials on the computer.

Following these practice trials, subjects answered the first set of audiotaped questions aloud. The control group did not perform a secondary task during these questions. The positive, negative, and neutral groups performed respectively positive, negative, or neutral delayed matching-to-sample tasks during these questions; subjects were told to divide their attention equally between the tasks and the questions.

After the memory test, the experimenter asked all subjects what percentage from 0 to 100% of the questions they guessed on because they could not recall the details from the film. In this way, we assessed subjects' confidence in their memories for the film. We assessed confidence in order to compare the effects of secondary task performance upon memory accuracy versus memory confidence.

All subjects then worked on the second set of arithmetic problems for one minute. They were again instructed to work quickly and accurately.

Finally, all subjects completed the second set of questions. Subjects did not complete secondary tasks during this final memory test.

Once again, after the memory test, the experimenter asked all subjects what percentage from 0 to 100% of the questions they guessed on because they could not recall the details from the film.

Subjects viewed debriefing information about the research and received payment or course credit for their participation.

2. Results

To compute a *memory reduction score*, we tallied the number of correct answers on the second memory test (possible range: 0–12) and subtracted this number from the number of correct answers on the first memory test (possible range: 0–12), thereby controlling for differences among subjects in their baseline encoding of the film. The larger this *memory reduction score*, the larger the decrement in memory for the trauma film attributable to the secondary task. The data appear in Table 1.

The four groups did not differ significantly in age, $F(3, 75) = .60$, $p = .62$; sex, $\chi^2(3, N = 80) = 1.62$, $p = .66$; or years of education, $F(3, 76) = .69$, $p = .56$. The proportion of ethnic minority subjects differed significantly across the groups, $\chi^2(3, N = 80) = 9.09$, $p < .05$. However, differences in the memory reduction scores of the four groups are not significantly accounted for by ethnicity, $F(1, 78) = 1.94$, $p = .17$. Furthermore, the positive, negative, and neutral groups did not differ in correct number of responses on the delayed-matching-to-sample task, $F(2, 57) = 1.24$, $p = .30$.

Because we tested several a priori hypotheses about memory-reduction effects of secondary tasks, we used one-tailed focused contrasts rather than an omnibus analysis of variance. We computed effect size r for these contrasts. Cohen's (1988) guidelines designate small, medium, and large effect sizes as $r = .10$, $r = .30$, and $r = .50$, respectively (pp. 79–81).

If adding a secondary task impairs memory for the trauma film, as previous research suggests it should, then the neutral group should have a larger memory reduction score than should the control group. The scores of the neutral and control groups were .95 ($SD = 1.85$) and .50 ($SD = 2.48$), respectively. Although the neutral group had a memory reduction score nearly twice as great as the control group's score, a one-tailed t-test comparing the memory reduction scores of the neutral and control groups showed that the difference was not statistically significant, $t(38) = .65$, $p = .26$, $r = .10$.

We next tested whether emotion, irrespective of valence, impaired memory for the trauma film by applying contrast weights of +1, +1, and −2 to the memory reduction scores of the positive ($M = 1.85$, $SD = 2.23$), negative ($M = .60$, $SD = 1.79$), and neutral groups, respectively. A one-tailed test failed to confirm this hypothesis, $t(57) = .51$, $p = .31$, $r = .07$.

If positive and negative emotions enhance and diminish memory, respectively, then the positive group should have a greater memory-reduction score than the negative group should. A one-tailed t-test revealed that the positive group had a larger memory reduction score than the negative group did, $t(38) = 1.96$, $p = .03$, effect size $r = .30$.

If a secondary task provokes negative emotion, then this may neutralize the otherwise memory-impairing effects of the secondary task. To test this hypothesis, we applied contrast weights of +2, −1, and −1 to the memory reduction scores of the positive, negative, and control groups, respectively. A one-tailed contrast confirmed this hypothesis, $t(57) = 2.17$, $p = .02$, effect size $r = .28$.

Table 1
Means and standard deviations of results of memory tests.

Group	$M_{1st\ test}$[a]	$M_{2nd\ test}$[a]	$M_{difference}$[b]
Control	7.10 (2.20)	6.40 (2.16)	.50 (2.48)
Positive	7.05 (1.76)	5.60 (1.47)	1.85 (2.23)
Negative	7.55 (1.54)	6.95 (1.73)	.60 (1.79)
Neutral	7.35 (1.60)	6.45 (1.73)	.95 (1.85)

[a] Mean number of correct responses. Possible score ranges from 0 to 12 questions answered correctly. Standard deviations are shown in parentheses.

[b] Mean *memory reduction score*. Possible differences range from −12 to 12 questions. Standard deviations are shown in parentheses.

Finally, to test for a linear function, we applied the contrast weights of +3, +1, -1, and −3 to the memory reduction scores of the positive, neutral, negative, and control groups, respectively. The one-tailed contrast analysis indicated that a positive secondary task most is more potent in decrementing memory for details of the film relative to the neutral secondary task, whereas the negative secondary task was statistically indistinguishable from the control condition, $t(76) = 2.09$, $p = .02$, $r = .49$. Accordingly, emotionally negative features of a secondary task apparently neutralize the otherwise memory-decrementing effects associated with secondary tasks, whereas the emotionally positive features of a secondary task apparently enhance the memory-decrementing effects of a secondary task, at least when the target memory has negative emotion.

The groups did not differ in their confidence for memory of details about the film. Although subjects reported a slight decline in their memory confidence from the first to the second memory test, the decline did not differ as a function of group, $F(3, 76) = .57$, $p = .64$.

3. Discussion

A secondary task involving pictures having positive emotional valence produced a larger reduction in memory for details of a distressing film than did secondary tasks involving pictures having neutral or negative valence. Indeed, the negative secondary task had minimal effect on memory for details of the distressing film. These data suggest that attempts to attenuate traumatic memories by having subjects reactivate the memory while performing a secondary task (Shapiro, 1999; van den Hout & Engelhard, 2012) may be especially effective if the secondary task produce a positive emotional response in patients. That is, emotional valence opposite to that of distressing memory may potentiate the memory-decrementing effects of taxing working memory during recollection. Hence, any such secondary task may be more therapeutically potent than emotionally neutral tasks such as bilateral eye movements.

Interestingly, we found that participants expressed similar levels of confidence in their memories for the film in all four groups; these participants expressed moderate confidence during their first instance of recollection and then showed a slight decline in this confidence during their second instance of recollection. These results indicate that secondary task performance can diminish reactivated memories without an effect upon individuals' perception of their memory accuracy.

Our study has limitations. We did not assess emotional reactions to the secondary task or to the film. However, in their validation research, Lang et al. (2005) had established that the photographs in our secondary tasks provoked positive, negative, and neutral emotional responses in subjects. Moreover, previous research involving this film indicates that subjects regard it as moderating distressing (Stuart et al., 2006).

Moreover, we did not assess the self-reported vividness and emotionality of subjects' during recollection. Rather, we used an objective test (Brewin & Saunders, 2001) to examine the memory-decrementing effects of secondary tasks varying in valence. Measures of accuracy, emotionality, and vividness each tap different aspects of memory, and hence there are strengths of weaknesses among them. Accuracy is objective, but emotionality and vividness capture the core phenomenology of traumatic memory.

We did not conduct independent tests to evaluate differences among the positive, negative, and neutral tasks in terms of their capacity to tax working memory. However, the tasks were identical except for the differences in arousal between the positive and negative tasks versus the neutral task on one hand, and for the difference in valence between the positive and negative tasks on the other hand. Accordingly, in addition to their capacity to tax working memory, tasks having positive emotional valence possess additional memory-decrementing capacity, at least for negative memories.

We controlled for materials effects by exposing subjects to the same stressful film. Yet autobiographical memories of trauma are far more emotionally disturbing than are memories of a film depicting the aftermath of serious motor vehicle accidents. Accordingly, it remains unclear to what extent our findings generalize to the modification of traumatic memories. On the other hand, neutral secondary tasks do attenuate the vividness and emotional impact of traumatic memories in PTSD patients (van den Hout et al., 2012). Hence, our data imply that secondary tasks having positive emotional valence may increase the therapeutic benefits of such interventions. A memory undergoing reactivation becomes labile and subject to modification (Finn & Roediger, 2011; Hardt, Einarsson, & Nader, 2010). Yet the aim of taxing working memory during recollection is not merely to reduce the vividness and emotionality of distressing memories during performance of the secondary task. Rather, the aim is to alter the representation of the trauma prior to its reconsolidation into the subject's autobiographical database, permanently changing it. In the case of PTSD patients, memory modification prior to reconsolidation should diminish the vividness and emotionality of the memory, thereby reducing the likelihood of subsequent intrusive, disturbing sensory recollections of the trauma. However, one study showed that although eye movements reduced the vividness and emotionality of traumatic memories during their recollection in the laboratory, vividness ratings had returned to baseline one week later (Lilley, Andrade, Turpin, Sabin-Farrell, & Holmes, 2009). Accordingly, key aims for future research are to determine whether changes in vivid memory for details and emotionality persist well beyond the reactivations in the laboratory or clinic.

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