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Reducing the negative valence of stressful memories through emotionally valenced, modality-specific tasks

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Background and objectives: People who perform a cognitively demanding secondary task while recalling a distressing memory often experience the memory as less emotional, vivid, or accurate during subsequent recollections. In this experiment, we tested whether the emotional valence (positive versus neutral) and sensory modality (visual, auditory, or both) of a secondary task diminishes the emotionality, vividness, and accuracy of memory of distressing videos.
Methods: Participants ($N = 156$) viewed a distressing video and were then randomized to one of six groups in a 2 (Emotional Valence: positive, neutral) × 3 (Modality: visual, auditory, combined) design. Participants were then exposed to an amusing or a neutral clip that was visual, auditory, or audiovisual. They were asked to recall the distressing video during exposure to the clip. Participants rated the emotionality and vividness of their memory of the distressing video, and completed recognition tests regarding its visual and auditory details before and after exposure to the secondary clip.
Results: Participants who recalled the distressing video while exposed to the amusing clip rated their memory of the distressing video as less distressing (but not less vivid or accurate) than did participants exposed to the neutral clip. Modality had no significant effects *Limitations.* Participants were not trauma survivors, and the memories targeted were stressful, but subtraumatic.
Conclusions: Inducing positive emotion during recollection of distressing memories may diminish the emotional distress prompted by subsequent recollection.

People with posttraumatic stress disorder (PTSD) experience intrusive recollections of traumatic events that are so distressingly vivid that it seems as if the events were recurring (Brewin, 2011). Accordingly, imaginal and *in vivo* exposure therapies aim to extinguish the emotionally evocative power of these memories such that sufferers can recall their trauma without seemingly reliving it (e.g., Foa et al., 2005). In their classic article about exposure therapy for fear reduction, Foa and Kozak (1986) defined emotional processing "as the modification of memory structures that underlie emotions" (p. 20). They argued that modification requires two steps: "First, the fear structure must be activated, and next, information incompatible with its pathological elements must be incorporated" (p. 21). Despite its efficacy, exposure therapy fails to help many patients and produces incomplete recovery in others (Institute of Medicine, 2007). Accordingly, clinical researchers have endeavored to develop new interventions for altering the representation of trauma in memory (e.g., van den Hout & Engelhard, 2012). These attempts to bolster patholytic emotional processing have been inspired by basic cognitive psychology research on working memory.

Accessing a memory requires the cognitive resources of the central executive component of working memory (Baddeley, 2012; Baddeley & Hitch, 1974). Therefore, performance of a concurrent task that taxes working memory during memory retrieval can divert resources from the central executive and from processing the memory undergoing retrieval. Accordingly, the cognitive load imposed by this additional task may alter the target memory prior to its return to long-term store. This mechanism may reduce the emotional potency of traumatic memories and render them less likely to intrude in everyday life. Moreover, when they do come to mind, they should be less upsetting than they were originally.

In fact, laboratory studies show that having participants perform bilateral eye movements (Barrowcliff, Gray, Freeman, &

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MacCulloch, 2004; Kavanagh, Freese, Andrade, & May, 2001; van den Hout, Muris, Salemink, & Kindt, 2001), copy a complex drawing (Gunter & Bodner, 2008), attend closely to their breathing (van den Hout, Engelhard, Beetsma, et al., 2011), perform serial subtractions (van den Hout et al., 2010), or play the computer game Tetris (Engelhard, van Uijen, & van den Hout, 2010) can reduce the vividness, negative emotionality, or both of distressing memories. At the same time, concurrent tasks such as passively listening to bilateral tones do not attenuate the vividness or negative emotionality of these memories as much as active tasks such as eye movements do. Presumably, this is because passive tasks do not tax working memory to the same extent as active tasks do (van den Hout et al., 2012).

Emotional processing theory holds that clinicians should produce an optimal level of distress in the patient when activating his or her memory of the trauma (Foa & Kozak, 1986). Too little distress signifies insufficient activation of the memory, whereas too much distress will impede incorporation of incompatible information. Therefore, working memory taxation concurrent with stressful memory activation may foster manageable levels of distress suitable for within-session habituation, thereby demonstrating to the patient that confronting one's trauma memory need not be emotionally overwhelming.

Tsai and McNally (2014) investigated whether varying the valence of the working memory task itself during activation of stressful memories would attenuate these stressful memories. They hypothesized that tasks likely to promote participants' positive affect may be especially effective in achieving this aim. To investigate the effect of tasks that induce positive emotion, Tsai and McNally (2014) had participants first view a distressing video presenting the aftermath of fatal motor vehicle accidents. Then, participants answered questions about details of the video while performing a concurrent matching-to-sample task consisting of photographs with negative, neutral, or positive valence, or while not performing any secondary task. Participants who were exposed to the positive secondary task exhibited greater decrements in memory for details of the distressing video than did participants in all other groups. This finding suggests that tasks that induce positive emotion while taxing working memory may be especially effective in reconsolidating less disturbing versions of traumatic memories. Although Tsai and McNally documented decrements in memory of the distressing video on an objective test, they did not test whether participants experienced reductions in vividness or negative emotionality associated with their memory of the video.

In addition to taxing the central executive component of working memory, tasks that require a specific sensory modality (e.g., visual versus verbal) may tax the congruent modality-specific subsystem of working memory such as the phonological loop (PL), responsible for auditory and verbal processing, or the visuospatial sketchpad (VSSP), responsible for processing visual and spatial information (Baddeley, 2012; Baddeley & Hitch, 1974). As these two subsystems are limited in capacity, concurrent visual tasks may compete with visual memories, whereas concurrent auditory or verbal tasks may compete with auditory memories (Baddeley & Andrade, 2000). This could reduce the accuracy, vividness, and emotionality of the auditory and visual features of stressful memories upon later recall. Indeed, Kemps and Tiggemann (2007) found that concurrent eye movements reduced visual memories more than verbal counting did, whereas concurrent verbal counting reduced auditory memories more than eye movements did. This was true for both happy and distressing autobiographical memories. The application of modality-specific tasks may have significant clinical implications, as traumatic memories tend to vary in modality. Though these memories are primarily visual, they may also involve sounds, smells, and bodily sensations. For instance, a car accident survivor may repeatedly hear the sound of crunching metal, and a witness of a shooting may repeatedly experience the smell of gunpowder (Ehlers et al., 2002).

Furthermore, some PTSD patients re-experience multimodal memories, sensations or thoughts (Ehlers et al., 2002). Patients who experience intrusive flashbacks consisting of both visual images and sounds, for example, may benefit from performing concurrent tasks that are simultaneously audio and visual. Targeting multimodal memories through cognitively demanding tasks may be possible due to a component of working memory called the episodic buffer (EB). The EB is a temporary storage system presumed to integrate information of various sources into coherent episodes (Baddeley, 2000). For example, this could entail the integration of visual information, primarily processed in the VSSP, with audio or verbal information, primarily processed in the PL. Similarly to the VSSP and the PL, the EB is controlled by the central executive and is limited in capacity. However, it also has a substantial role in transmitting and retrieving information into and from the long-term memory. Additionally, the EB may be the core mechanism mediating the modality effect by which one's available working memory capacity increases when one concurrently performs two tasks of different modalities rather than of the same modality (Allport, Antonis, & Reynolds, 1972). Indeed, participants exhibited enhanced learning when presented with simultaneous auditory and visual instructional materials than with only visual material (Mousavi, Low, & Sweller, 1995; Tindall-Ford, Chandler, & Sweller, 1997).

No study has addressed the effects of multimodal working memory tasks on distressing memories. Accordingly, in this study we tested whether multimodal (audiovisual) tasks would reduce the accuracy, emotionality, and vividness of audiovisual distressing memories more effectively than would tasks tapping a single modality (audio or visual). Past studies suggest that tasks that are too cognitively demanding might require all working memory resources rather than compete for these resources with distressing memories (Gunter & Bodner, 2008; Engelhard, van den Hout, & Smeets, 2011). However, other studies indicate that the EB has its own dedicated capacity; therefore, this subsystem's role in the performance of multimodal tasks could increase the overall functional capacity of working memory (Mousavi et al., 1995; Tindall-Ford et al., 1997) and enable increased working memory taxation. Similar to Kemps and Tiggemann (2007), we tested whether tasks tapping a single modality would most effectively reduce the accuracy, vividness, and emotionality of congruent single-modality distressing memories more than of incongruent ones. We hypothesized that visual tasks would most effectively attenuate visual memories, whereas auditory tasks would most effectively attenuate auditory memories.

Additionally, to extend the work of Tsai and McNally (2014), we tested whether concurrent tasks provoking positive emotion would be more effective in attenuating the accuracy, vividness, and emotionality of distressing memories than would emotionally neutral concurrent tasks. We explored the interaction between the modality and the valence of concurrent tasks, predicting that a positive task would be especially effective in attenuating a distressing memory under conditions of modality congruence.

Finally, to address two unanswered questions remaining from the (main) experiment, we conducted two small experiments. In the first addendum experiment, we assessed the extent to which the audio, visual, and audiovisual versions of the two film clips taxed working memory. In the second addendum experiment, we tested a control group in which subjects completed a protocol identical to that of the main study but which did not apply a film clip as a working memory task.

1. Method

1.1. Participants

Participants were recruited via the Harvard University Study Pool, comprising mainly undergraduate students and residents of Cambridge, Massachusetts, and via student e-mail lists. To be eligible, participants had to be at least 18 years old, native English speakers, and never to have had treatment for mental health problems.

One hundred and fifty six participants (90 women, 66 men) between the ages of 18 and 61 ($M = 26.8$, $SD = 11.7$) completed the study. The self-identified ethnic proportions were Caucasian (55.1%), Asian or Asian-American (14.1%), African or African-American (15.4%), Hispanic (8.3%), Native American (.6%), and “multi-ethnic” (6.4%).

We excluded seven participants from the sample after they completed the study because they failed to follow instructions ($n = 5$) or had difficulty communicating in English ($n = 2$). We recruited seven participants to replace them such that our final sample size was 156 (26 per group).

1.2. Procedure

The protocol and consent form were approved by the Harvard University Committee on the Use of Human Subjects, and participants chose either a $5 cash payment or 0.5 psychology course credit for participation in the 30-min experiment.

Upon arriving at the lab, participants read and signed the consent form and then provided their year of birth, sex, and ethnicity on the demographic information form. Information about their level of education was later obtained from the online enrollment database (less than high school; high school graduate; college graduate; completed graduate degree). Next, they viewed a video comprising five public service announcements (PSAs) that were previously used by trauma researchers to produce moderate distress in nonclinical participants (Holmes, James, Coode- Bates, & Deeprose, 2009; Lang, Moulds, & Holmes, 2009). The PSAs had originally appeared on British television to warn the public about human disasters; the scenes depicted a house fire in a home without a smoke alarm (24 s), a child suffering an electric shock (25 s), a child pedestrian struck by a car (23 s), a man drinking and drowning (22 s), and a car killing a pedestrian who was sending a text message while crossing a road (41 s). The first author used iMovie software to edit the scenes, combining them into one video lasting 2 min 15 s. After showing participants how to adjust its volume, the first author instructed participants to pay close attention to the video.

After watching the video, participants completed a 90-s distracter task designed to prevent participants from rehearsing the video's contents in their minds before they completed the first recognition test. The task was a paper-and-pencil Sudoku puzzle, taken from an online logic-problem database and ranked level “easy”. Participants received oral and written instructions urging them to complete as much of the puzzle as possible until a stopwatch beeped, informing them to stop. To diminish any stress, the experimenter told participants that they were not expected to complete a large portion of the puzzle within the given time frame.

Next, participants were asked to “take a moment to recall the PSAs” and then complete the first recognition test on the study's online Google account. There were two versions of the recognition test; their formats were identical, but the questions on them were different. Each version consisted of 20 true-or-false questions about audio (10) and visual (10) details of the PSAs, among which were 4 questions (2 audio and 2 visual) about each of the five PSAs. To ensure that audio, visual, and audiovisual questions did not result in floor or ceiling effects, 28 pilot participants completed the recognition tests prior to the study. The mean percentage of correct answers reassuringly ranged between 67% and 71% across all tests. To control for differences in the questions, we randomly assigned participants to complete either version 1 or version 2 during the first recognition test, and the other version during the second recognition test.

After completing the first recognition test, participants were asked to replay the whole PSA series in their minds as if they were watching it again, and to complete two rating scales on the study's online Google account: a vividness scale, ranging from 1 (*not clear at all*) to 9 (*extremely clear*), and an emotionality scale, ranging from 1 (*not distressing at all*) to 9 (*extremely distressing*). Participants were instructed, “When you are ready, click one number on each of the following ratings scales to rate the memory that comes to your mind for the entire PSA series.” Both rating scales were modeled after scales used in previous studies (van den Hout et al., 2001; Gunter & Bodner, 2008).

Experimental groups. The experimenter used a random number generator in Microsoft Office Excel 2008 to assign participants to one of six groups ($n = 26$ per group): positive audiovisual, positive audio, positive visual, neutral audiovisual, neutral audio, or neutral visual. The group assignment occurred immediately after participants completed the first recognition test and two rating scales. It determined the clip to which each participant was exposed while he or she held the memory of the PSAs in mind. Participants were instructed, “Next you will watch (listen) to a scene from the film *When Harry Met Sally*. As you watch (listen) to the clip, try to hold the PSAs in your mind at the same time, to the best of your ability.” To ensure that participants attended closely to the clips, the experimenter told them that they would be asked to rate their emotional response to the clips immediately afterwards.

Participants in the positive groups were exposed to the “Restaurant Scene” in which Sally fakes an orgasm while dining in a restaurant (Reiner, Scheinman, & Reiner, 1989). This scene was ranked as the most amusing among 250 scenes in a study on the induction of emotions via film (Gross & Levenson, 1995). Participants in the neutral groups were exposed to the scene “Going to NY” in which Harry and Sally drive to New York from Chicago. This scene was edited to eliminate Harry's frequent wisecracks. The first author edited the clips further to render their duration similar (83 s and 81 s, respectively).

Positive audiovisual group. Participants in the positive audiovisual group simultaneously watched and listened to the “Restaurant Scene.”

Positive audio group. Participants in the positive audio group listened to an audio recording of the “Restaurant Scene”.

Positive visual group. Participants in the positive visual group watched a silent recording of the “Restaurant Scene.”

Neutral audiovisual group. Participants in the neutral audiovisual group simultaneously watched and listened to the scene, “Going to NY.”

Neutral audio group. Participants in the audio neutral group listened to an audio recording of the scene, “Going to NY.”

Neutral visual group. Participants in the neutral visual group watched a silent recording of the scene, “Going to NY.”

After undergoing the manipulation, all participants were asked to recall the scene to which they were exposed and rate how happy or unhappy it made them feel on a scale ranging from 1 (*unhappy*) to 9 (*happy*; Lang, Bradley, & Cuthbert, 2008) on the study's Google account. Participants then spent the next 90 s working on the Sudoku puzzle before completing the second recognition test. Participants who previously answered version 1 of the recognition test now answered version 2 and vice versa. Then they rated their memory of the PSAs on the vividness and emotionality rating scales. Finally, participants were debriefed about the purpose and hypotheses of the study and referred to relevant resources for further information.

2. Addendum experiment #1

As we were completing this experiment, the third author ran a small study at Utrecht University to assess the degree of working memory taxation of the three positive and three neutral secondary recordings.

2.1. Method

2.1.1. Participants

Thirty-six individuals between the ages of 19 and 28 ($M = 22.06$, $SD = 2.33$; 21 women) were recruited from Utrecht University and the nearby community via e-mail lists and snowball sampling. They received a small financial honorarium for their participation. To be eligible, participants had to be native English speakers ($n = 33$) or non-native speakers who predominantly spoke English ($n = 3$). There were 35 students and one musician. Their nationalities were: British ($n = 10$), American ($n = 7$), Irish ($n = 4$), Canadian ($n = 3$), Australian ($n = 2$), New Zealand/British ($n = 1$), Botswanan ($n = 1$), or other ($n = 8$). Four participants had a dual nationality that included one for an English-speaking country, and we report only this nationality for them.

2.1.2. Procedure

To assess the extent of working memory taxation of the six film clip version, we used the Random Interval Repetition (RIR) task (cf. van den Hout, Engelhard, Rijkeboer, et al., 2011). In this task, a tactile stimulus was repeatedly administered through two electrodes attached to the participant's index and middle finger of the non-dominant hand. Participants were instructed to press a green button on a response box with the index finger of the dominant hand as quickly as possible to each stimulus. The RIR task was done in four conditions: one single-task condition (without a concurrent task) and three dual-task conditions (i.e., while attending to the audio, visual or audiovisual recording). The degree to which participants' reaction times increase during the dual task, relative to the single task, is a measure of working memory taxation.

The tactile stimulus was a mild electric shock of 50 ms. In a work-up procedure, it was set at a level that the participant could clearly feel but did not find annoying or painful. The electric shock ranged from 0.6 to 1.7 mA ($M = 1.00$; $SD = 0.27$; possible range: 0.2–4.0), and was generated by a Coulbourn Transcutaneous Aversive Finger Stimulator (E13-22) that used a 9-V dry cell battery attached to an adjustable step-up transformer.

After arriving at the lab, participants read and signed the consent form and then provided their age, sex, nationality, primary language, and year of study or profession on the demographic information form. They were randomly assigned to one of two groups. The positive group ($n = 19$; 11 women) completed the RIR task while attending to the three versions of the "Restaurant Scene." The neutral group ($n = 17$ participants; 10 women) completed the RIR task while attending to the three versions of the "Going to NY" scene. Then participants determined the stimulus level in the work-up procedure, and put on the headphones to determine the volume of a practice clip. This was followed by a 52-s practice phase of the RIR task, in which 40 stimuli were administered. After a 30-s break, the RIR task was presented in the four conditions in random order, with 60-s breaks between them. Each condition took 80.8 s, in which 64 stimuli were administered. Half of the interstimulus intervals (ISIs) were 900 ms and half were 1500 ms. The order of the ISIs varied quasi-randomly with no more than four consecutive identical ISIs. Reaction times were calculated after stimulus onset. Next, participants were asked to recall each scene version to which they had been exposed and rate how happy or unhappy it made them feel on a scale ranging from 1 (unhappy) to 9 (happy). Finally, they were debriefed.

3. Addendum experiment #2

This experiment enabled us test whether clips with positive valence reduce negative emotionality relative to no clips at all.

3.1. Method

After completing data collection for the main experiment, the first author ran another group through the protocol. However, this group was not exposed to any clips from *When Harry Met Sally*.

3.1.1. Participants

There were 26 participants (19 women, 7 men) between the ages of 18 and 61 ($M = 24.42$, $SD = 10.12$). The self-identified ethnic proportions were Caucasian (61.5%), Asian or Asian-American (26.9%), African or African-American (3.8%), and Hispanic (7.7%).

3.1.2. Procedure

During the period in which participants in the main experiment were exposed to the clips from *When Harry Met Sally*, participants in this addendum experiment performed the Sudoku puzzle filler task for an additional 1 min and 20 s. That is, after viewing the stressful PSA video, this group worked on the Sudoku puzzle task for 2 min and 50 s.

4. Results

4.1. Main experiment

The six groups did not differ in age, $F(5, 150) = 0.31$, $p = .91$; sex, $\chi^2(5, N = 156) = 4.10$, $p = .54$; ethnicity, $\chi^2(25, N = 156) = 19.22$, $p = .79$; or level of education, $\chi^2(15, N = 156) = 13.58$, $p = .56$. Moreover, the groups did not differ on their baseline recognition memory for audio details, $F(5, 150) = 0.83$, $p = .53$; recognition memory for visual details, $F(5, 150) = 0.20$, $p = .96$; vividness ratings, $F(5, 150) = 0.66$, $p = .66$; or emotionality ratings, $F(5, 150) = 0.32$, $p = .90$.

Participants' emotionality ratings after exposure to the clips from *When Harry Met Sally* confirmed that the emotional manipulation was successful. Across all groups, happiness ratings were significantly higher for participants exposed to the amusing clip ($M = 6.41$, $SD = 1.64$) than for participants exposed to the neutral clip, ($M = 5.64$, $SD = 1.62$), $t(154) = 2.95$, $p = .004$, $d = 0.47$. Moreover, within each valence group (positive versus neutral), emotionality ratings did not differ significantly among the audio,

Table 1
Means of study participants' emotionality ratings for the six clip versions from When Harry Met Sally.

Means for study ratings				
Scene/version	Audio-visual	Visual	Audio	All modalities
Positive	6.00 (1.74)	6.54 (1.27)	6.69 (1.83)	6.41 (1.64)
Neutral	6.27 (1.70)	5.50 (1.70)	5.15 (1.43)	5.64 (1.62)

Note. Standard deviations are shown in parentheses. $N = 156$. Study ratings may be less reliable than pilot ratings as they may have been affected by participants' prior exposure to the study's distressing stimulus.

visual, and audiovisual groups, $F(2, 155) = 0.21$, $p = .813$, $\eta^2_p = .00$. Table 1 summarizes the emotionality ratings for the six film clips.

4.1.1. Data analysis

To test the effects of the manipulation on memory for the PSAs, we created four change scores by subtracting each participant's post-manipulation score from his or her baseline score for visual accuracy, auditory accuracy, vividness, and emotionality. As there were 10 questions about visual details and 10 questions about auditory details on both the baseline recognition test and the post-manipulation recognition test, the range for auditory and visual change scores was 0–10. As the range for the vividness and emotionality scales was 0–9 for both the baseline and post-manipulation measures, the range for vividness and emotionality change scores was 0–9.

We submitted these four change indices to Pearson correlational analyses. The correlations between change in memory of visual details and the other variables were: change in memory of auditory details, $r(154) = .03$, $p = .68$; change in vividness, $r(154) = .12$, $p = .14$; and change in emotionality, $r(154) = -.16$, $p = .04$. The correlations between change in auditory details and change in vividness and change in emotionality were $r(154) = -.06$, $p = .42$ and $r(154) = -.16$, $p = .047$, respectively. The correlation between change in vividness and change in emotionality was $r(154) = .05$, $p = .57$. In summary, the associations among the four dependent variables were small and negative, or nil. Accordingly, we submitted each variable to a 2 (Valence) × 3 (Modality) analysis of variance (ANOVA). The means and standard deviations appear in Table 2.

There were no significant effects for change in recognition memory for auditory details as a function of valence, $F(1, 150) = 0.25$, $p = .62$, $\eta^2_p = .002$; modality, $F(2, 150) = 0.86$, $p = .43$, $\eta^2_p = .011$; or their interaction, $F(2, 150) = .25$, $p = .78$, $\eta^2_p = .003$. Hence, participants who were exposed to the auditory (or combined) version of the concurrent clip did not recall auditory details of the PSAs less accurately than did other participants.

There were no significant effects for change in recognition memory for visual details as a function of valence, $F(1, 150) = 0.52$, $p = .47$, $\eta^2_p = .003$; modality, $F(2, 150) = 0.70$, $p = .50$, $\eta^2_p = .009$; or their interaction, $F(2, 150) = 0.95$, $p = .39$, $\eta^2_p = .013$. Hence, participants who were exposed to the visual (or combined) version of the concurrent clip did not recall visual details of the PSAs less accurately than did other participants.

There were no significant effects for change in vividness as a function of valence, $F(1, 150) = 0.10$, $p = .76$, $\eta^2_p = .001$; modality, $F(2, 150) = 0.004$, $p = .996$, $\eta^2_p = .000$; or their interaction, $F(2, 150) = 0.62$, $p = .54$, $\eta^2_p = .008$. However, there was a significant effect for change in emotionality as a function of valence, $F(1, 150) = 4.65$, $p = .003$, $\eta^2_p = .03$. The effect of modality, $F(2, 150) = .05$, $p = .96$, $\eta^2_p = .001$; and the Valence × Modality interaction were nonsignificant, $F(2, 150) = 0.55$, $p = .58$, $\eta^2_p = .007$. Hence, participants who were exposed to any version of the amusing concurrent clip (auditory, visual, or audiovisual), reported a greater reduction in emotional distress (but not in vividness) when recalling the PSAs (Fig. 1)

Table 2
Mean reduction scores for emotionality, vividness, overall accuracy, audio accuracy, and visual accuracy for the six experimental groups.

Memory reduction Variable	Group	Neutral M (SD)	Neutral 95% CI	Positive M (SD)	Positive 95% CI
Emotionality	AV	.54 (1.80)	[−.10, 1.20]	.73 (1.18)	[1.00, 1.36]
	V	.31 (2.02)	[−.33, 1.17]	1.16 (1.57)	[.52, 1.79]
	A	.35 (1.85)	[−.33, .94]	1.00 (1.23)	[.37, 1.63]
	Total	.40 (1.87)		.96 (1.32)	
Vividness	AV	.92 (1.20)	[.42, 1.42]	.77 (1.18)	[.27, 1.27]
	V	.65 (1.40)	[.15, 1.16]	1.04 (1.40)	[.54, 1.54]
	A	.84 (1.41)	[.35, 1.35]	.81 (1.13)	[.31, 1.31]
	Total	.81 (1.33)		.87 (1.23)	
Audio accuracy	AV	.04 (2.01)	[−.78, .70]	−.35 (1.79)	[−1.09, .39]
	V	.15 (1.57)	[−.59, .89]	.31 (1.93)	[−.43, 1.05]
	A	.04 (2.05)	[−.78, .70]	−.35 (2.04)	[−1.09, .39]
	Total	.03 (1.87)		−.13 (1.92)	
Visual accuracy	AV	.31 (1.85)	[.42, 1.04]	.39 (1.83)	[−.35, 1.12]
	V	−.04 (2.11)	[−.77, .77]	.40 (1.54)	[−.70, .77]
	A	.81 (1.88)	[.08, 1.54]	.00 (2.06)	[−.73, .73]
	Total	.36 (1.95)		.14 (1.81)	

Note. AV, V, and A denote audiovisual, visual and audio group, respectively. For each experiment group $n = 26$. CI = confidence interval. The reduction range was 0 to 9 for emotionality and vividness, and 0 to 10 for audio and visual accuracy.

5. Addendum experiment #1

5.1. Results and discussion

Participants' happiness ratings after exposure to the clips tended to be higher for participants exposed to the amusing clip ($M = 6.26$, $SD = 1.07$) than for participants exposed to the neutral clip ($M = 5.75$, $SD = 1.00$), $t(33) = 1.46$, $p = .075$ (one-tailed), $d = 0.49$. Though falling just short of significance, this effect size is nearly identical to the one for participants tested at Harvard reported above (i.e., $d = 0.47$). For the reaction times, a 4 × 2 (Condition vs. Valence) repeated measures ANOVA showed a main effect for condition, $F(3, 102) = 4.63$, $p = .004$, $\eta^2_\rho = .12$, but not for valence, $F(1, 34) = 1.93$, $p = .173$ (see Fig. 2). There was no valence × condition interaction, $F < 1$. Follow-up ANOVAs showed that, compared to the RIR task alone, the dual-task conditions had significantly increased reaction times, $F(1, 35) = 12.59$, $p = .001$, $\eta^2_\rho = .26$, and that reaction times were comparable across the three dual-task groups, $F < 1$. Therefore, regardless of sensory modality, positive clips and neutral clips were comparably taxing.

6. Addendum experiment #2

6.1. Results and discussion

As there were no modality effects in the main experiment, we collapsed the audio, video, and audiovisual groups into a positive

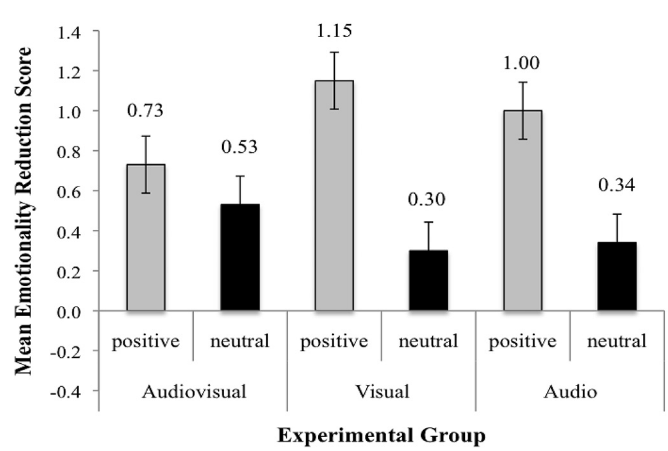

Fig. 1. Emotionality Reduction. This figure presents the mean emotionality reduction scores for all experimental groups. The possible range for emotionality reduction was 0 to 9. The positive groups (collapsed) showed significantly greater emotionality reduction than the neutral groups (collapsed). Error bars represent the standard error of the mean.

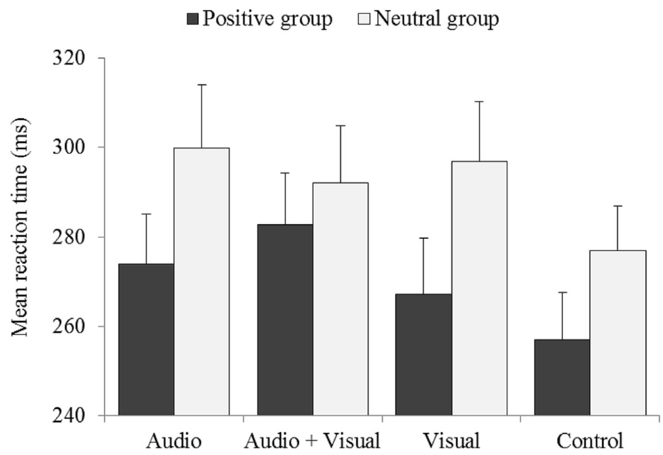

Fig. 2. Reaction Times. This figure presents the mean reaction times during the RIR task for all experimental conditions. The three dual-task conditions (collapsed) showed significantly greater reaction times than the single-task control condition. There was no significant difference between positive and neutral dual-task conditions. Error bars represent the standard error of the mean.

valence group and into a negative valence group. The means and standard deviations for the positive, neutral, and new control group for the emotionality reduction variable were 0.96 ($SD = 1.32$), 0.40 ($SD = 1.87$), and 0.92 ($SD = 1.09$). An ANVOA on the emotionality reduction scores fell just short of conventional statistical significance, $F(2, 179) = 2.84$, $p = .06$, and posthoc Least Significance Differences tests confirmed the obvious, but unexpected conclusion: the positive group was no more effective in reducing emotionality than was control group that continued to work on the Sudoku puzzles ($p = .91$). This control group was nonsignificantly more effective at reducing negative emotionality than was the neutral group ($p = .14$). Although the positive group was more effective than the neutral group in reducing negative emotionality ($p = .025$), it was surprisingly not more effective than the group that continued to work on the Sudoku puzzles. Taken together, these data suggest rather than being merely a filler task, the Sudoku puzzles wound up being sufficiently taxing as to attenuate the negative emotionality provoked by recollection of the PSA stress video. In fact, our filler task may have been inadvertently cognitively demanding for some participants as the first author observed them endeavoring to solve the puzzles while she timed them with a stopwatch.

7. Discussion

Whereas a neutrally valenced task had no effect on participants' recollection of a distressing stimulus, a positively valenced task significantly reduced the emotionality with which they recalled the stimulus. The findings from the RIR task suggest that these tasks do not differentially tax working memory. Therefore, it is unlikely that the positively valenced task had stronger effects because it taxes working memory to a larger degree as the neutrally valenced task does. These findings suggest that the positive emotion elicited by the amusing scene counteracted the otherwise negative emotion provoked by recollection of the distressing PSAs video. Accordingly, tasks that provoke positive emotion during recall of a distressing memory may diminish the negative emotion it provokes, and perhaps thereby rendering it less distressing during subsequent recall (Tsai & McNally, 2014).

However, the positive concurrent task did not attenuate the vividness of the PSAs' recollection more effectively than the neutral concurrent task did. This is surprising as ratings of vividness and negative emotionality often decline in tandem (Gunter & Bodner, 2008; Kavanagh, Fresse, Andrade, & May, 2001; Kemps & Tiggemann, 2007). Moreover, the positive concurrent task did not attenuate the accuracy of the PSAs' recollection more effectively than the neutral concurrent task (cf. Tsai & McNally, 2014). It is unclear why we failed to replicate the decrement in accuracy reported by Tsai and McNally. Indeed, the pattern of results in groups exposed to positive clips was strikingly inconsistent (see Table 2), and the lack of significant differences not attributable to differences in statistical methods (i.e., ANOVA versus focused contrast analyses).

Hence, it appears that secondary tasks that evoke positive emotion can counteract the otherwise negative emotion produced by retrieval of a distressing memory. This may diminish the emotional intensity of subsequent memory recollection without diminishing its vividness or accuracy. From a clinical point of view, suffice it to say, diminishing the negative emotionality of a distressing memory is more important than diminishing its vividness or its accuracy.

Although initially surprised by the results of Addendum Experiment #2, we suspect that our filler task in which participants performed the Sudoku puzzle, and were urged to complete as much of the puzzle as possible within 90 s, functioned as another procedure that taxed working memory. Taken together, the data suggest that inducing positive emotion or challenging participants with such puzzles may attenuate the emotionality of stressful memories to an approximately similar extent.

Despite the indication that inducing positive emotion while participants access a distressing memory renders the memory less distressing upon subsequent recall, it is possible that subjects' emotionality ratings were influenced by a prolonged positive state induced by the amusing clip rather than by attenuation in the emotional distress elicited by the memory itself. Accordingly, our confidence in this interpretation of the results would be bolstered if the negative evocative power of the memory remained attenuated long after the positive mood induced by the clip has passed.

As an experimental psychopathology study, ours has its strengths and limitations. On the one hand, we standardized the stimuli that formed the basis of the distressing memory, and these PSAs successfully induced negative emotion in previous research (e.g., Holmes et al., 2009). Likewise, the film scene that we used to induce positive emotion had been validated as highly amusing in previous research (Gross & Levenson, 1995). Furthermore, we used objective measures of memory accuracy as well as standardized subjective, measures of emotionality and vividness. On the other hand, our study is an analog study; we endeavored to attenuate negative emotional memories, not traumatic ones, and our participants were not people with PTSD. That said, our findings do suggest that taxing working memory with procedures that induce positive emotion may render its subsequent recollection less distressing.

Finally, our results invite comparison with research on memory reconsolidation. Until the seminal work of Nader, Schafe, and LeDoux (2000), behavioral neuroscientists studying animals believed that memories consolidated into long-term storage remained stable (McGaugh, 2000) — a belief curiously at odds with that of cognitive psychologists studying autobiographical memory in people (e.g., Loftus & Loftus, 1980). Yet the work of Nader et al. on fear conditioning in rats, widely corroborated by other animal researchers (For a review, see Nader & Hardt, 2009), indicated that activation of a memory renders it labile and subject to modification, and that interventions occurring post-recollection can alter the memory prior to its reconsolidation into long-term store. Reconsolidation studies concerning attenuation of stressful memories in animals have captured the interest of experimental psychopathologists keen to reduce fear-related memories in people suffering from PTSD and anxiety disorders (e.g., Kindt, in press; Kindt, Soeter,

& Verliet, 2009). Indeed, the hypothesis that treatment of these syndromes requires therapists to activate a fear memory in the patient, provide information incompatible with it, and reconsolidate a less distressing version of the memory is strikingly similar to Foa and Kozak's (1986) emotional processing model of fear reduction.

However, researchers must adhere to strict temporal guidelines if they wish to interpret their experimental findings in terms of reconsolidation (Agren, 2014; Schiller & Phelps, 2011). For example, they must ensure that the processes of consolidation, reactivation, and reconsolidation occur in certain temporal windows such that 24 h separates each of them. Whereas Gunter and Bodner (2008) found that the effects of memory taxation via eye movements did persist for one week, findings from single-session experiments (e.g., Finn & Roediger, 2011; Tsai & McNally, 2014; the current experiment) cannot plausibly be attributed to reconsolidation because insufficient time has elapsed between each of the experimental phases. In future research, psychologists who study working memory taxation as a means of modifying stressful memory should attend to these temporal parameters if they wish to interpret their results in terms of reconsolidation. For example, they could expose participants to a stressful film on Day 1, reactivate the memory and insert the intervention (e.g., amusing film) 24 h later on Day 2 and then test for memory change for the stressful film 24 h later on Day 3. If feasible, testing the stability of the memory change one week (or later) would be especially desirable. This would enable ruling out of temporary interference effects arising from application of the working memory load.

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