Empirical Article

ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

Clinical Psychological Science
2017, Vol. 5(2) 316–324

DOI: 10.1177/2167702616687292
www.psychologicalscience.org/CPS
SAGE

Stress Enhances the Memory-Degrading Effects of Eye Movements on Emotionally Neutral Memories

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Abstract

Eye movement desensitization and reprocessing is an effective treatment for posttraumatic stress disorder. It uses a dual-task approach: Patients retrieve traumatic memories while making lateral eye movements. Laboratory studies have consistently shown that this dual-task component decreases the vividness of emotional memories, whereas neutral memories appear insensitive to the intervention. Hence, emotional arousal might play a crucial role in the (re)consolidation of the degraded memory. This study investigated whether boosting arousal levels would induce degradation of neutral memories by dual tasking. A total of 67 participants, 32 with performance anxiety, selected two vivid, neutral autobiographical memories, which were subjected to dual tasking or recall only. Half of the participants first underwent the Trier Social Stress Task to increase arousal. Only participants with performance anxiety in the arousal condition showed reduced vividness after the dual tasking relative to recall only. Thus, adding arousal to neutral memories makes them susceptible to the degrading effects of dual tasking.

Keywords

dual tasks, arousal, EMDR, Trier Social Stress Task, autobiographical memory

Received 6/3/16; Revision accepted 11/20/16

A well-established psychological treatment for posttraumatic stress disorder (PTSD) is eye movement desensitization and reprocessing (EMDR). This treatment uses a dual-task approach: Patients focus on traumatic memories while simultaneously making lateral eye movements (EM; Shapiro, 2001). An abundance of research demonstrates that EMDR is effective (e.g., Bisson et al., 2007; Bradley, Greene, Russ, Dutra, & Westen, 2005; Chen et al., 2014), and that this dual-task approach has significant additional value, over and above mere exposure to the traumatic memory (Lee & Cuijpers, 2013). Together with cognitive behavioral therapy, EMDR serves as treatment of choice in clinical guidelines for PTSD (Bisson et al., 2007; Bradley et al., 2005; Shapiro, 2001).

Despite its proven effectiveness, EMDR has long been the focus of extensive debate and skepticism, particularly related to its poor theoretical rationale (see Engelhard, 2012). A number of theories have been formulated to explain how EMDR works (see van den Hout & Engelhard, 2012, for an overview), and, to date, most evidence has been obtained for the working memory (WM) account (Andrade, Kavanagh, & Baddeley, 1997; Gunter & Bodner, 2008; Maxfield, Melnyk, & Hayman, 2008; van den Hout & Engelhard, 2012). WM is a collection of multiple components, including a supervisory component (central executive) and at least three slave systems that are responsible for the temporary storage of visuospatial information (visuospatial sketch pad), auditory information (phonological loop), and the integration and chronological ordering of this information (episodic buffer; Baddeley, 2000). WM is crucial for the execution of a wide range of cognitive tasks, including memory recall (van Veen et al., 2015). However, its capacity is limited. Therefore, all tasks that occupy WM, including EM (van den Hout et al., 2011), interfere with elaborated recall of

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autobiographical memories, resulting in a less vivid and emotional memory recollection. This effect appears to be maximal when the same slave system is taxed (Andrade et al., 1997; Kemps & Tiggemann, 2007; but see Tadmor, McNally, & Engelhard, 2016). Because during recall memories become alterable by interference (Nader & Hardt, 2009), this less vivid and emotional or “desensitized” memory may be reconsolidated into long-term storage. Indeed, the effects of recall + EM on memory vividness and emotionality have been observed to last beyond the experimental session (Gunter & Bodner, 2008; Leer, Engelhard, & van den Hout, 2014).

As predicted by the WM account, ample research has demonstrated that not only EM but also other tasks that tax WM (e.g., playing Tetris, counting backward, drawing a complex figure) that are performed while thinking of an emotional memory lead to reduced vividness and emotionality when the memory is later recalled again (e.g., Engelhard, van Uijen, & van den Hout, 2010; Gunter & Bodner, 2008; van den Hout et al., 2010). Furthermore, negative memories are degraded by dual tasks, but so are positive memories, as well as future-oriented mental images about threat or substance use (negative and appetitive flash-forwards: e.g., Engelhard et al., 2012; Littel, van den Hout, & Engelhard, 2016). Moreover, the degree of memory degradation is correlated with WM capacity: The smaller the WM capacity, the larger the effects (e.g., Gunter & Bodner, 2008; van den Hout et al., 2010; but see van Schie, van Veen, Engelhard, Klugkist, & van den Hout, 2016). Finally, dual tasks that are barely taxing (e.g., listening to sounds) or extremely taxing (complex counting), which reduce competition with holding the memory in mind, have little effects on emotional memories (Engelhard, van den Hout, & Smeets, 2011).

However, in a recent study by van den Hout, Eidhof, Verboom, Littel, and Engelhard (2014), an anomaly to the WM account was observed. In this study, the effects of EM during recall of emotional memories (vs. recall only) were compared with the effects of EM during recall of nonemotional memories (vs. recall only) that were matched in terms of vividness. Although the typical decline in vividness was observed for the emotional memories, no such effects were found for the neutral memories. After recall only *and* recall + EM, neutral memories remained highly vivid.

Why do emotionally neutral memories remain unaffected by simultaneously performing an EM task? There are at least two possible explanations: (a) neutral memories do not sufficiently tax WM, which prevents competition with the dual task and, hence, hampers memory degradation; or (b) neutral memories are degraded while engaging in a dual task, but emotional arousal is necessary for making effects last, that is, for the (re)consolidation of the degraded memory. Inspired by this second explanation, the main goal of the current study was to increase insight in the possible modulating role of emotional arousal in the effectiveness of dual task interventions to degrade memory representations.

During emotional arousing experiences, adrenal stress hormones are released from the adrenal glands, which in turn stimulate noradrenaline neurotransmission in the brain. Noradrenaline strengthens memory-related synaptic plasticity, allowing memories to be formed and maintained in a more intense and enduring manner, also known as the emotion-superiority effect (Joels, Fernandez, & Roozendaal, 2011; Sara, 2009). Pharmacological studies have shown that noradrenaline blockage selectively impairs the memory enhancement in response to emotional arousal (see, for overviews, Chamberlain, Muller, Blackwell, Robbins, & Sahakian, 2006; van Stegeren, 2008), whereas arousal inducing agents, including (nor)adrenaline agonists, increase memory for emotional or neutral material (Chamberlain et al., 2006; Wingenfeld et al., 2013). Similar noradrenaline modulating effects have been observed with regard to memory *re*consolidation. For example, blocking noradrenaline by administration of propranolol after memory reactivation abolishes emotion-superior memory reconsolidation (Schwabe, Nader, Wolf, Beaudry, & Pruessner, 2012). It is interesting that not only pharmacological interventions but also more naturalistic experiences can change the strength and content of previously consolidated memories. For instance, inducing arousal with a mild stressor such as the cold pressure test (Bos, Schuijer, Lodestijn, Beckers, & Kindt, 2014; Coccoz, Maldonado, & Delorenzi, 2011) or with emotionally laden scenes (Anderson, Wais, & Gabrieli, 2006; Finn & Roediger, 2011) after memory reactivation has been demonstrated to enhance the reconsolidation of neutral and emotional material (but see Schwabe & Wolf, 2010, for a memory impairing effect of arousal).

Strong, emotionally arousing memories play an important role in many psychopathologies (Hackmann & Holmes, 2004), and lie at the core of PTSD. Recalling these memories triggers emotional arousal, which naturally promotes superior (re)consolidation of the memories and facilitates their persistence (Forcato, Fernandez, & Pedreira, 2014; Wichert, Wolf, & Schwabe, 2011). During EMDR treatment, patients also display high levels of emotional arousal, especially during the first trauma recalls. Yet, memories become *less* vivid and emotional. Could emotional arousal be beneficial here? And if so, does it lead to a superior reconsolidation of the *degraded* image (degraded by performing a dual task during recall)? If these hypotheses are correct, adding temporary arousal to the retrieval of neutral memories would make neutral memories susceptible to the degrading effects of EM, which is exactly what we sought to investigate in the present study. If arousal has beneficial effects on a dual task intervention, this will be informative to other techniques and interventions that aim to alter emotional memories, such as imagery rescripting (Holmes, Arntz, & Smucker, 2007) or cognitive behavioral therapy (Ehlers & Clark, 2000).

To determine whether neutral memory recall + EM becomes effective under the influence of induced arousal, a laboratory model is needed. By changing one variable, holding others constant, and assessing the effect, one can draw conclusions about causality. There are lab models that are well suited to examine clinical phenomena. In research on dual tasking, the model looks like this (Engelhard et al., 2012; van den Hout & Engelhard, 2012). Healthy participants recall autobiographical (aversive) memories and rate them in terms of vividness and emotionality. Then, the memories are recalled while tracking a moving dot on a computer screen, which induces horizontal EM (dual taxing), or memories are recalled while keeping the eyes still (no dual taxing). Afterward, participants recall both memories again and rate their vividness and emotionality.

In the current study, participants recalled *neutral* memories while they made EM (recall + EM) or kept their eyes stationary (recall only). Prior to the task, half of the participants were told to prepare for a public speaking task to induce anticipatory arousal (Kearns & Engelhard, 2015; Kudielka, Hellhammer, & Kirschbaum, 2007). Because it was uncertain whether this task would be stressful enough to cause adrenal stress responses in everyone, half of the participants were selected based on high levels of performance anxiety. We predicted that, in contrast to the participants in the nonarousing control condition, participants in the arousal condition would report significant reductions in the vividness of neutral memories after recall + EM compared to recall only.

Methods

Participants

A total of 74 female students participated.[1] Exclusion criteria were any current psychiatric disorder, visual impairments, use of medication affecting memory, heart rate, or blood pressure, and familiarity with the potential working mechanism of EMDR. All participants were recruited from Utrecht University via advertisements posted across the campus and an online participant system. They signed up by filling out an online version of the Public Speaking subscale of the Personal Report of Communication Apprehension (PRCA-24). Participants who completed the questionnaire were assigned to two experimental conditions (low arousal, high arousal) in such way that differences in performance anxiety were minimized. Data from participants with pretest vividness scores deviating −3 *SD* from the mean, and pretest emotionality or difficulty scores deviating +3 *SD* from the mean were excluded from the analyses (n = 7; Ratcliff, 1993). This resulted in a final sample of 67 women (*M* age = 21.22, *SD* = 2.70), of whom 32 had high levels of performance anxiety (scores ≥ 23) and 35 low levels of performance anxiety (scores < 23). Ethnicity was not assessed. Participants received either financial compensation or course credit for participation. The study was approved by the local ethics committee of the Faculty of Behavioral and Social Sciences. All participants provided written informed consent.

Materials

To simulate the EM component of EMDR, a computerized EM task was used (cf. Engelhard, van den Hout, Janssen, & van der Beek, 2010; van den Hout, Muris, Salemink, & Kindt, 2001). A white dot was presented on a black screen and moved from side to side with 1 s per cycle or remained stationary during 4 intervals of 24 s with 10-s breaks. Participants sat at a 30 cm distance from the computer screen. During both conditions participants recalled one of the selected memories. Before (pretest), directly after (posttest), and 10 min after the EM Task (delayed posttest) participants rated their memories on vividness using 10-cm visual analogue scales (VASs) ranging from 0 (*not vivid*) to 10 (*very vivid*). At pretest they also rated their memories on difficulty to recall using a VAS ranging from 0 (*not difficult to recall*) to 10 (*very difficult to recall*) and emotionality using a VAS ranging from 0 (*not emotional*) to 10 (*very emotional*). The EM task and VASs were presented using E-prime 1.2.

An adaptation of the Trier Social Stress Task (TSST) was used for arousal induction. The TSST is a standardized and validated protocol for the experimental induction of psychological stress (Kudielka et al., 2007). In the original test, participants enter a room with a panel of judges, a video camera, and an audio recorder. They are instructed to prepare a short presentation, within a brief period of time (e.g., 5 min). During the presentations the judges maintain neutral facial expressions and give no comments. The presentation is immediately followed by a mental arithmetic task, in which participants have to count backward from a large number in steps of multiple numbers. If they make an error, they have to start over. Numerous studies have indicated that the TSST increases subjective tension, but also induces objective physiological and neuropsychological responses like increases in heart rate, blood pressure, and noradrenergic levels (Kudielka et al., 2007).

Prior to the current study, a pilot study (N = 14) was conducted to determine at which stage of the TSST procedure participants display increased arousal levels, but are still capable of retrieving their memories vividly. Heart rate, self-reported tension (VAS), and emotionality and vividness of neutral and negative memories were measured upon entrance, during the preparation phase, directly after the speech, and 6 min after the speech. During the preparation phase, just before the actual presentation, subjective tension and heart rate were significantly higher than at pretest, whereas the vividness and emotionality of the memories remained unchanged. In the ultimate experiment, we therefore decided to conduct the EM task during the preparation phase, and to terminate the TSST afterward. This means that we did not induce actual stress but anticipatory stress.

In the current study, subjective tension and heart rate were measured three times: before the adapted TSST, after the adapted TSST, and approximately 15 min after the adapted TSST (10 min after the EM task). For subjective tension, a 10 cm VAS ranging from 0 (*not tense at all*) to 10 (*very tense*) was used. Heart rate was measured with a blood pressure monitor (Braun, Bp 4900ph-We).

The Dutch translation of the Public Speaking subscale of the PRCA-24 was used to measure fear of public speaking or performance anxiety. The PRCA-24 is composed of 24 statements (e.g., "I feel relaxed when giving a speech") and is scored on a 5-point Likert-type scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The PRCA-24 has adequate psychometric properties (McCroskey, 1982).

Procedure

After obtaining written informed consent, participants filled out a questionnaire on demographics. Then, they all drank a glass of syrup to raise blood glucose because very low blood glucose might result in an absent response to the TSST (Kudielka et al., 2007). Participants recalled two unique, vivid, but relatively neutral memories, for example, "buying a Hawaiian pizza in the supermarket." In line with the Dutch EMDR protocol, participants were asked to play the memories in their minds and make a "screen shot" of the most vivid moment. They had to write down keywords of the resulting image for referencing purposes. During the pretest, both neutral memories were scored on difficulty to recall, vividness, and emotionality using VASs. Afterward, blood pressures and heart rate were measured, and participants reported how nervous they felt (subjective tension).

Then participants were randomly assigned to the arousal or control condition and the TSST started. Participants in the arousal condition had to think of a realistic job for which they would like to apply. They were explained that they had 3 min to prepare for a job interview, consisting of a 4-min monologue, recorded by a microphone and two large cameras and with the female experimenter taking notes. Participants in the control condition were asked to wait for 3 min and do nothing. After 3 min of preparation (arousal condition) or waiting (control condition), blood pressure and heart rate were measured for a second time and subjective tension was assessed.

After the preparation phase, participants in the arousal condition were told that before their monologue started, they had to perform one extra task: the EM task. During this task, one memory was recalled while making EM and one without EM (recall only). Immediately after the interventions, memories were scored on vividness. Both the order of EM and recall only and the assignment of the two memories to either EM or recall only were counterbalanced. Participants in the control condition performed the EM task after the waiting period.

After the EM task, participants in the arousal condition were told that they were actually in the control condition and did not have to give a monologue. All participants waited 10 min. Then the two memories were recalled and scored on vividness for a third time. Also, subjective tension, blood pressure, and heart rate were measured. Subsequently, participants were debriefed and received their reward.

Design and statistical analyses

There were two groups (high and low performance anxiety), two arousal conditions (high and low arousal), and two intervention conditions (recall + EM, recall only). Heart rate and subjective tension were assessed three times: at the beginning of the experiment, during preparation of the TSST (or during the wait period in the low arousal condition), and 10 min after the EM intervention. Hypothesized effectiveness of the arousal manipulation was checked with two $3 \times 2 \times 2$ mixed model ANOVAs, with time (pretest, preparation TSST/wait, delayed posttest) as the within-subject factor, and arousal condition (arousal, control) and performance anxiety group (low, high) as between-subject factors.

Assessment of memory vividness took place at three times: at the beginning of the experiment (before the TSST and EM intervention; pretest), immediately after the EM intervention (posttest), and 10 min later (delayed posttest). Hypothesized effects of arousal on memory vividness after EM versus recall only were assessed with $3 \times 2 \times 2 \times 2$ mixed model ANOVAs. Time (pretest, posttest, delayed posttest) and intervention condition (EM, recall only) served as within-subject factors. Between-subject factors were arousal condition (arousal, control) and performance anxiety group (low, high). Post hoc pairwise comparisons with Bonferroni correction were computed for all significant interaction effects. Wherever sphericity assumptions were violated as indicated by Mauchly's test, Greenhouse–Geisser corrections were

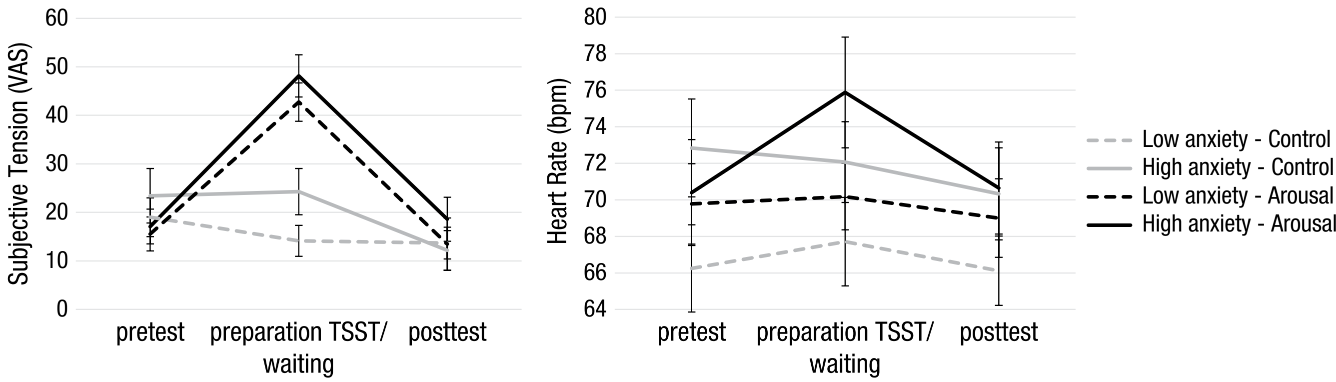

Fig. 1. Subjective (mean ± *SEM*) tension levels and heart rates for participants with high and low levels of performance anxiety in the arousal and control conditions measured before, directly after, and 15 min after the Trier Social Stress Task (TSST) or waiting period. bpm = beats per minute; VAS = visual analogue scale.

applied to adjust the number of degrees of freedom for within group effects. An alpha level of .05 was used for all statistical tests.

Results

Randomization check

Participants in the two arousal conditions did not significantly differ in age, $t(65) = 0.05$, $p = .96$, the number of hours they were awake at the time of testing, $t(65) = .81$, $p = .42$, or whether they drank coffee in the hours before the experiment, $\chi^2(1) = 2.21$, $p = .14$. Furthermore, participants in the two arousal conditions did not differ in heart rate and subjective tension at the beginning of the experiment, both *t*s < 1.14, both *p*s >.26. Their selected memories did not differ in difficulty to recall, emotionality and vividness at pretest, all *t*s < 1.18, all *p*s > .24. There were also no significant differences on the previously mentioned variables within each performance anxiety group, all *t*s < 1.70, all *p*s > .10. Across participants, there were no significant differences in difficulty to recall, emotionality, and vividness between memories in the recall only condition and the EM condition, all *t*s < 0.98, all *p*s > .33.

Manipulation check

Subjective tension. A significant Time × Condition interaction was observed for self-reported tension, $F(2, 122) = 31.53$, $p < .001$, $\eta^2 = .34$, demonstrating that changes over time depended on condition. Figure 1 (left) shows the self-reported tension scores, and changes over time can be observed in the arousal condition. Pairwise comparisons confirmed that the increase of tension from the pretest to the TSST preparation phase was significant ($p < .001$), indicating that the arousal induction was successful. Pairwise comparisons also showed that the decrease of tension from the preparation phase to the posttest was significant ($p < .001$), and that in the control condition (low arousal), tension significantly decreased from pretest to posttest ($p = .015$). Changes were not dependent on performance anxiety, Time × Condition × Group, $F(2, 122) = .81$, $p = .45$.

Heart rate. No significant Time × Condition interaction was observed for heart rate, $F(2, 124) = 1.95$, $p = .15$. However, a significant Time × Condition × Group interaction was found, $F(2, 124) = 3.83$, $p = .027$, $\eta^2 = .06$. Thus, changes in heart rate over time where dependent on both arousal condition and performance anxiety group. As can be seen in Figure 1 (right), heart rate increased from the pretest to the preparation phase, but only in the arousal condition for participants with high levels of performance anxiety. Pairwise comparisons confirmed that this was the only significant increase ($p < .001$). The decrease from the preparation phase to the posttest was also significant ($p < .01$). These findings indicate that, when using a physiological index of stress, the arousal manipulation was successful in participants with high performance anxiety only.

Memory vividness

There was a significant main effect for time, $F(2, 126) = 8.44$, $p < .001$, $\eta^2 = .12$, and condition, $F(1, 63) = 6.21$, $p = .02$, $\eta^2 = .09$. As can be seen in Figure 2, vividness decreased from the pretest to the posttest ($p < .01$) and from the pretest to the 10-min delayed posttest ($p < .01$) across all groups and conditions, and, overall, vividness was lower in the recall + EM condition than in the recall only condition ($p = .02$). There were no significant main effects for group, $F(1, 63) = 2.30$, $p = .13$, or performance anxiety, $F(1, 63) = 2.08$, $p = .15$. Two- and three-way

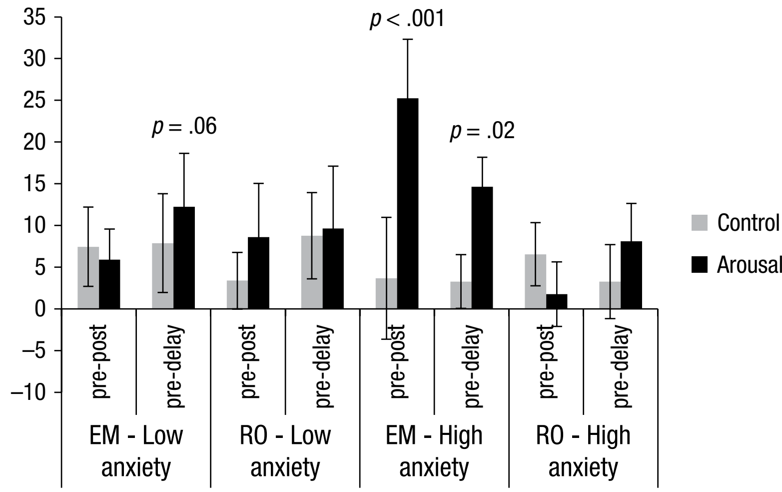

Fig. 2. Decreases (mean ± *SEM*) in vividness scores from pretest (pre) to posttest (post), and pretest to delayed posttest (delay), for participants with high and low performance anxiety in the arousal and control conditions after recall + eye movements (EM) and recall only.

interaction effects were also not significant, all *F*s < 1.73, all *p*s > .19. The absence of the Time × Condition interaction crucially indicates that, across groups, vividness for neutral memories did not decrease more after recall + EM than recall only.

The only significant interaction was the crucial Time × Condition × Group × Performance anxiety interaction, $F(2, 126) = 4.53$, $p = .02$, $\eta^2 = .07$. Figure 2 (third panel) shows that participants with high performance anxiety showed a steep and highly significant decline in vividness after recall + EM when stressed ($p < .001$). This effect remained over time: At 10-min delayed posttest, the vividness scores were still significantly lower than at pretest ($p = .02$). Participants with low performance anxiety who were stressed also showed a trend toward a significant decrease from pretest to 10-min delayed posttest after recall + EM ($p = .06$; see first panel). None of the other decreases in vividness were significant (all *p*s > .19).

Discussion

The present study was designed to test whether boosting arousal levels would induce degradation of neutral memories by EM. Previous studies have shown that recall + taxing dual tasks renders emotional memories less vivid (van den Hout & Engelhard, 2012), whereas equally vivid neutral memories are insensitive to these desensitizing effects (van den Hout et al., 2014). We confirmed this finding in the present study: In the absence of arousal, neutral memory vividness did not decrease after recall + EM relative to recall only.

To test our main hypothesis regarding the role of arousal, half of the participants underwent an adaptation of the TSST (Kudielka et al., 2007). In anticipation to this stress induction task subjective arousal (self-reported tension) was significantly increased in all participants. Objective arousal (heart rate) was increased in participants with high levels of performance anxiety. Results of the subsequent EM task showed that, after stress induction, the vividness of neutral memories significantly decreased from pretest to posttest after recall + EM relative to recall only in participants with high levels of performance anxiety. These effects were still present 10 min after the EM task, when subjective and objective arousal measures had returned to baseline. Interestingly, participants in the arousal condition with low levels of public speaking fear also showed a trend toward reduced memory vividness in response to recall + EM versus recall only after the 10-min delay. None of these effects were observed in the nonarousal control group. This indicates that adding arousal to neutral memories made them susceptible for the memory-degrading effects of recall + EM, especially in participants who were most sensitive to the arousal induction, namely participants with high levels of performance anxiety.

Memory vividness decreased across time in all participants regardless of arousal and intervention condition. This finding has been reported before (see, e.g., van den Hout, Bartelski, & Engelhard, 2013) and may be caused by decay over time.

Only female participants were included. This criterion was applied because males and females might experience different levels of stress in response to the anticipatory evaluation of their performance by a *female* jury member. Furthermore, we aimed to control for possible confounding effects of sex-specific neuroendocrine stress responses, which have been observed in response to full stressor tasks (Kudielka et al., 2007; Stroud, Salovey, & Epel, 2002). Although sex differences in *anticipatory* stress response have also been reported before (Kudielka et al., 2007), it is unclear whether males and females would have actually exhibited different stress responses to the modified version of TSST used in the present study.

The present results suggest that emotional arousal is a prerequisite for the effectiveness of recall + EM. The neurobiological explanation holds that arousal causes increased noradrenaline neurotransmission in the brain, which in turn strengthens the reconsolidation of memories that are degraded by recall + EM. Alternatively, adding arousal to recall + EM could have increased the overall amount of WM taxation, thereby increasing competition for WM resources. In addition, adding arousal could have temporarily decreased WM capacity, especially in participants with high performance anxiety, resulting in more competition for WM resources (Sorg & Whitney, 1992). It can, however, be questioned whether this increased WM taxation/competition would actually increase neutral memory degradation. Although a dose-response relationship between WM taxing and memory degradation might be logically inferred from the WM explanation of EMDR, research indicates that the relationship between WM taxing and reduced emotional intensity of the memory is best represented by an inverse U curve (Engelhard et al., 2011). Adding arousal to a task that is already taxing (EM) would therefore not benefit the retrieval or holding in mind of low taxing neutral memories (Gunter & Bodner, 2008).

Thus, results of the current study suggest that dual task interventions that target memory representations benefit from high levels of arousal. It, however, remains inconclusive how arousal exerts these beneficial effects. To disentangle the roles of WM taxation and neurobiological aspects of arousal, a critical next research step would be to directly manipulate noradrenaline levels in the brain during memory recall + taxation. Here no additional task is necessary, there are no confounding participant characteristics, and WM taxation can be held relatively constant. If our neurobiological hypothesis is correct, then the administration of noradrenaline agonists (e.g., yohimbine) should make neutral memories susceptible to memory degradation. And the other way around, administering noradrenaline antagonists (e.g., propranolol) should block the beneficial effects of arousal and decrease or abolish the degrading effects of a dual task on memory vividness and emotionality. Currently, two studies are conducted in our lab that test these specific hypotheses.

Results of the current study contribute to delineate boundary conditions of the dual task paradigm. The effectiveness of dual tasks not only depends on WM taxing properties of the dual task and memory retrieval, but also on the amount of arousal a person experiences during these tasks. In addition to these theoretical implications, results of the current study have several potential clinical implications. First of all, the findings suggest that the effectiveness of EMDR/dual task interventions might, if circumstances allow, be further boosted with arousal-inducing tasks or agents. Furthermore, EMDR/dual-task interventions (a) may be less effective for low arousing memories, (b) may become less effective over time as a consequence of decreasing arousal levels, and (c) may be less effective for patients using arousal blocking medication (e.g., beta blockers). The other way around, arousal-inducing tasks or agents may be used to strengthen reconsolidation of certain existing memories. Patients with PTSD, but also patients suffering from depression, not only have highly accessible negative memories, but also have great difficulty accessing positive memories (McNally, Litz, Prassas, Shin, & Weathers, 1994). Inducing arousal prior to the retrieval of positive memories might strengthen these memories and make them more accessible during future recall.

To summarize, results of the current study indicate that arousal is a prerequisite for the effectiveness of dual task interventions. Neutral memories appear insensitive to the blurring effects of EM. However, when sufficient arousal is added, EM become effective in decreasing the vividness of neutral memories. These results expand our knowledge about the underlying working mechanism of EMDR. Moreover, the observed modulating effects of arousal in recall + EM are relevant to other techniques and interventions that aim to alter memory strength or content.

Author Contributions

M. Littel and M. Remijn developed the study concept and study design. Testing and data collection were performed by M. Remijn and A. M. Tinga. M. Littel performed the data analysis and interpretation. M. Littel drafted the manuscript, and I. M. Engelhard and M. A. van den Hout provided critical revisions. All authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding

This study was supported with a TOP-grant (40-00812-98-12030) from the Netherlands Organization for Health Research and Development (ZonMw) awarded to M.A.V. I.M.E. is supported with a Vici grant (453-15-005) from the Netherlands Organization for Scientific Research (NWO).

Note

1. Because males and females might experience different levels of stress in response to the anticipatory presence of a female jury member during the Trier Social Stress Task, we decided to test female participants only. This also controls for possible confounding effects of sex differences in neuroendocrine stress responses, which have been observed in response to full stressor tasks (for an overview, see Stroud, Salovey, & Epel, 2002).

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