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Changing negative autobiographical memories in the lab: a comparison of three eye-movement tasks

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ABSTRACT
There is strong evidence that executing eye-movement (EM) tasks that load working memory (WM) while thinking of an emotional memory reduces the emotionality and vividness of this memory. According to WM theory, EM tasks that load WM more should be more effective to devalue emotional memories. In this study, we compared three EM tasks: dot tracking, letter identification, and a combination of dot tracking and letter identification. First, participants completed a reaction time (RT) task to assess the WM load of the three EM tasks relative to a control task (viewing a black screen). Then, participants were asked to think of a negative autobiographical memory while executing one of these EM tasks and asked to recall another negative memory while executing the control task. Before and after each task, participants rated emotionality and vividness of the memory. All EM tasks slowed down RTs relative to the control task, and the letter identification task induced the largest RTs. Reductions of vividness relative to the control task, however, were comparable across the EM tasks, and there were no reliable reductions of emotionality. We discuss these findings in light of the WM theory and alternative theories for the effects of dual-task interventions.

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KEYWORDS
WM taxation; memory degradation; WM theory; EMDR

Negative emotional memories can have a detrimental impact on psychological well-being. This is most clearly demonstrated in patients suffering from post-traumatic stress disorder (PTSD), who often suffer from intrusive memories of a traumatic event (e.g., Engelhard, Arntz, & van den Hout, 2007; Michael, Ehlers, Halligan, & Clark, 2005). Intrusive emotional memories occur in a range of other psychological disorders as well, including obsessive-compulsive disorder, bipolar disorder, and agoraphobia (e.g., Brewin, Gregory, Lipton, & Burgess, 2010; Holmes & Mathews, 2010). Not only patients with PTSD, but also healthy people report such memories (Engelhard et al., 2007; Radomsky et al., 2014). Hence, there is a pressing demand for effective techniques that can reduce the negative impact of intrusive emotional memories.

One effective approach to counter the negative effects of an emotional memory involves recalling the memory while executing a demanding secondary task. This procedure is successfully applied in eye movement desensitisation and reprocessing (EMDR) therapy (Shapiro, 2018), which is an efficacious psychological treatment for PTSD (Bisson et al., 2007; Bisson, Roberts, Andrew, Cooper, & Lewis, 2013; Cloitre, 2009; Novo et al., 2016). It is suggested (APA, 2017) or recommended as a PTSD treatment in practice guidelines (e.g., National Collaborating Centre for Mental Health, 2005; World Health Organization, 2013). The key element in EMDR therapy is that patients keep a distressing memory in mind while simultaneously following the index finger of the therapist that moves horizontally and induces lateral eye movements (EM) (Shapiro, 2018). A large number of laboratory studies have found that keeping a distressing emotional memory in mind while executing EM reduces the emotionality and vividness of this memory (e.g., Lee & Cuijpers, 2013).

These effects are most consistently explained by the working memory (WM) account (Gunter & Bodner, 2008; van den Hout & Engelhard, 2012). According to this account, recalling an aversive memory taxes the limited-capacity resources of WM (Baddeley & Andrade, 2000). When someone simultaneously performs a dual-task (like making EM), both tasks compete for limited resources, leaving less capacity available for memory recall. This will impair memory retrieval (Andrade, Kavanagh, & Baddeley, 1997), and result in immediate decreased vividness and emotional intensity of the memory before the memory is restored into long-term memory (Engelhard, 2012; van den Hout & Engelhard, 2012).

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WM theory is a well-accepted mechanistic explanation for the effects of EM and other dual-tasks on memories, and generates predictions regarding the optimal tasks to use during memory recall. One prediction is that tasks that are more cognitively demanding should interfere more with the emotional memory than less taxing tasks (see van den Hout & Engelhard, 2012). Indeed, in a study of van Veen et al. (2015), faster EM of 1.2 Hz (number of left-right movements per second) were superior to slower EM of 0.8 Hz in making the memory less emotional, less vivid, and more difficult to retrieve (see also Maxfield, Melnyk, & Hayman, 2008; van Schie, van Veen, Engelhard, Klugkist, & van den Hout, 2016). Measured with a reaction times (RT) task, the fast EM were more demanding than the slow EM (van Veen, Engelhard, & van den Hout, 2016), which could suggest a linear relationship between the degree of memory taxing and the reduction of memory emotionality and vividness. However, also based on the WM theory, Gunter and Bodner (2008) proposed an inverted U-curve hypothesis, according to which taxing WM is most efficacious when memory recall and the dual-task use a similar amount of WM resources. Accordingly, too little or too much taxing have little or no effect: the former leaves too many resources for vivid and emotional memory recall, while the latter requires all resources for the dual-task, leaving too little room for recall. There is preliminary evidence for this hypothesis by a study in which three tasks were compared that increasingly taxed WM, showing that the most complex task had less effect on memory than the simple or intermediate task (Engelhard, van den Hout, & Smeets, 2011).

Another prediction of WM theory is that not only the *amount* of WM load of a task is important to interfere with recalled memories, but also whether there is a *modality overlap* between the task and the recalled memory. Particularly, according to the highly influential WM model of Baddeley and Hitch (1974), WM is composed of two substructures: the phonological loop, which is responsible for processing verbal information, and the visuo-spatial sketchpad, which is responsible for processing visuo-spatial information. According to this WM model, the effect of dual-tasks on long-term memories should be particularly pronounced when the dual-task overlaps in modality with the primary modality of the recalled memory. Indeed, several studies, but not all (e.g., Matthijssen, Verhoeven, van den Hout, & Heitland, 2017; Tadmor, McNally, & Engelhard, 2016), have demonstrated that a visual dual-task interferes more with a visual memory and an auditory dual-task interferes more with an auditory memory, rather than vice versa (e.g., Baddeley & Andrade, 2000; Kemps & Tiggemann, 2007; for related work in craving, see, e.g., May, Andrade, Panabokke, & Kavanagh, 2010). Nonetheless, despite this potential role for modality-specific interference, all WM models emphasise the importance of general (modality non-specific) load (Baddeley, 2012). Indeed, non-visual, taxing dual-tasks, such as attentional breathing, auditory shadowing, or counting backwards also degrade visual, negative memories. In contrast, tasks that barely tax working memory (e.g., listening to beeps) are not effective (see van den Hout & Engelhard, 2012).

Currently, several EM tasks to degrade emotional memories are often used in laboratory studies. One common task, developed by Gunter and Bodner (2008) and based on the paradigm developed by van den Hout, Muris, Salemink, and Kindt (2001), simply involves visually tracking a dot that moves horizontally from side to side across a computer screen. This task is based on the eye movement component of EMDR. The optimal speed has previously been determined at 1.2 Hz by Maxfield et al. (2008) and van Veen et al. (2015). Another common task, designed by Andrade et al. (1997), involves eye movements induced by the alternate appearance of a letter on the left and right side of a computer screen, which is sometimes randomly replaced by a target letter to which participants have to respond by saying a word or pressing a computer key. Furthermore, alternating black and white stripes are presented in the background of the computer screen. This task was designed to maximise interference with the visuo-spatial component of WM (Andrade et al., 1997; Homer, Deeprose, & Andrade, 2016). Despite that these two EM tasks are often used in laboratory research, no study has previously compared them. We think that such a comparison is useful given that there is room for further improvement of the effects of EM tasks on emotional memories. Specifically, while the effects of EM tasks in the laboratory are quite robust (i.e., Cohen's $d = 0.74$, 95% confidence interval = [0.57, 0.91]) the effects of eye-movements interventions in EMDR therapy are less robust (i.e., Cohen's $d = 0.27$ (after removal of two possible outliers)–0.41 (all studies included), 95% confidence interval = [0.07–0.13, 0.47–0.70]; Lee & Cuijpers, 2013). Furthermore, despite quite large effects, EM tasks do not completely reduce the emotionality and vividness of emotional memories (i.e., the post-intervention ratings usually remain within a range of 60–75 on a 100-point scale; e.g., van Schie et al., 2016). Hence, there is considerable room for the improvement of the effects of EM tasks.

In this study we aimed to provide such a comparison. Furthermore, we designed a third EM task that combined features of the tasks by van den Gunter and Bodner (2008) and Andrade et al. (1997) to explore whether the effectiveness of the dual-tasks could be further improved. In this new task, participants had to identify a target letter between distractors and had to visually track a dot that moved between the target and distractor letters. First, we established WM load of these three EM tasks by using a secondary reaction time (RT) task (cf. Engelhard, van Uijen, & van den Hout, 2010; van den Hout, Engelhard, Rijkeboer, et al., 2011). Next, we assessed the effects of these EM tasks on memory emotionality and vividness by having participants recall a negative autobiographical memory while executing one of the EM three tasks and recall another negative autobiographical memory while executing a passive viewing control task. Before and after recalling these memories while executing one of these EM tasks, participants were asked to rate the emotionality and vividness of their memories. Prior to conducting the study, we did not have strong predictions with regard to which EM task would be most effective to change emotional memories. However, based on the WM theory introduced above, it may be expected that the EM task developed by Andrade et al. (1997) and our combined task would be more effective to reduce the emotionality and vividness of emotional visual memories than the task developed by Gunter and Bodner (2008), due to their presumably greater interference with the visuo-spatial component of WM.

Method

Pre-registration

The sample size (using a power analysis), design, procedure, and data analyses steps were determined prior to conducting the study and registered on the Open Science Framework after the first 10 participants had been tested (https://osf.io/yanqz/).

Participants

Prior to data collection, the required sample size was determined based on a power analysis using GPower (Faul, Erdfelder, Lang, & Buchner, 2007). For the RT task in our experiment, GPower (using the within-subjects ANOVA option with 1 group, 4 measurements and $N = 96$) indicated a statistical power for detecting a small effect ($f = .10$) of .63 and a power for detecting medium ($f = .25$) and large ($f = .40$) effects of >.99. For the autobiographical task, GPower (using the between-subjects ANOVA[1] option with 3 groups and $N = 96$) indicated a statistical power of .13, .57, and .94 to detect small, medium, and large effects, respectively. We decided beforehand that we would continue testing until a target sample size of 96 participants with valid data was reached for the autobiographical memory task (see *Data reduction and analysis* section for information regarding the exclusion of data). Participants were recruited through advertisement (posters, handouts, and social media) at Utrecht University and Utrecht University of Applied Sciences (Hogeschool Utrecht). By means of an online questionnaire, all participants were screened for prior knowledge about EMDR, participation in previous EMDR-related studies, diagnoses of a psychiatric illness, and for the use of medication that affected memory or concentration. Based on this initial screening, 108 individuals were excluded from further participation. The final number of participants who completed the experiment was 100 (23 male, 77 female) with an average age of 21.65 ($SD = 3.52$; range = 18–44). Participants received course credits or financial reimbursement (€10) for their participation.

Materials

Participants were tested individually in a dim, soundproof room. During each computer task, participants were seated at a fixed distance of approximately 60 cm in front of a computer screen (23 inch HP EliteDisplay E231; screen resolution of 1920 × 1080). A webcam (Logitech C920) was used to check whether participants performed the tasks correctly and a Sennheiser PC 131 headset was used to present auditory cues and to register reaction times to these cues. All EM tasks were programmed using Presentation software (Version 18.3, Neurobehavioral Systems, Inc., Berkeley, CA, USA, www.neurobs.com). Emotionality and vividness ratings were completed on slips of paper with 100 mm Visual Analog Scales (VAS; emotionality: "How unpleasant did you find the image of the memory that you just recalled?", 0 = *not at all unpleasant*, 100 = *very unpleasant*; vividness: "How clear did you find the image of the memory that you just recalled?", 0 = *not at all clear*, 100 = *very clear*).

Procedure

General procedure and design

The experiment consisted of two parts. The first part of the experiment was completely within-subjects. All participants performed an auditory RT task while performing four different tasks: (1) control, (2) dot tracking (Gunter & Bodner, 2008), (3) letter identification (Andrade et al., 1997), or (4) dot tracking + letter identification. The second part of the study was a pretest-posttest design with three between-subjects conditions to which participants were randomly allocated. In each of the conditions, participants recalled one negative autobiographic memory while performing a control task (passively viewing a black screen) and they recalled another negative autobiographic memory while performing one of the three EM tasks (see below).

EM tasks and control task

Each of the tasks consisted of one practice block and four experimental blocks of 24 s, separated by 10-second breaks. These intervals match those used in prior studies with the same paradigm (e.g., Engelhard et al., 2012; Gunter & Bodner, 2008; van Veen et al., 2015). In the control task, participants were informed to look at a black computer screen. In the dot tracking task, participants were instructed to follow a dot moving horizontally by making eye-movements, while keeping their head still. The dot moved with 1.2 Hz across the screen along a visual angle of approximately 40 degrees, corresponding with 1.2 left-right movements per second (cf. van Veen et al., 2015). In the letter identification task, letters, rather than a dot are used to induce eye movements (Andrade et al., 1997). These letters (q, m, q, w, or c) repeatedly appeared on alternate sides of the computer screen. The background of the screen consisted of alternating vertical black and white stripes. Twice during each trial, the letter was randomly replaced by a target letter (d, n, p, v, e, respectively) to which participants had to respond by pressing the space bar. Each letter was presented for

300 ms with a 200 ms interval. Finally, in the dot tracking + letter identification task, the same procedure was followed as in the letter identification task, only now the eyes were lead to the letters by a horizontal moving dot (moving at 1.2 Hz; this speed resulted in an interval of approximately 415 ms between the letters) and the vertical black and white stripes were no longer presented (so the moving dot could be shown; see Figure 1 for a schematic illustration of all three EM tasks).

Reaction time task

In the first part of the experiment, the degree of WM taxation of the different tasks was assessed with an RT task using auditory cues (cf. van den Hout, Engelhard, Rijkeboer, et al., 2011). Participants were instructed to say "Yes" loud and clearly after hearing a beep through the headphones. The inter-trial interval of the auditory cues varied between 2 and 2.8 s, resulting in 10 cues per 24 s block. Participants completed five such blocks for each task, of which the first block was a practice block to familiarise participants with the task. Auditory cues were approximately 65 dB in intensity. Reaction times (voice onset) to the auditory cues were registered as the outcome measure.

Autobiographical memory task

Before the start of the second part of the experiment, participants were again screened for prior knowledge about EMDR: they were asked whether they were familiar with three treatments, including EMDR, and, if so, whether they could describe them. This was done to ensure that participants had not familiarised themselves with EMDR between the initial screening and the actual experiment (none of the participants indicated that they had). The procedure of the autobiographical memory task was adapted from the procedure designed by van den Hout et al. (2001) and modified and used in various other studies (e.g., Engelhard, van den Hout, Janssen, & van der Beek, 2010; Gunter & Bodner, 2008; van Veen et al., 2015). Participants were instructed to select two vivid, negative memories of at least one week old that still had emotional impact on them (e.g., loss of a loved one or witnessing a serious accident) and to write down key words about each memory on two paper strips. For each memory, participants rated emotionality on a scale of 0 (*not at all unpleasant*) to 100 (*very unpleasant*). If this score was not in the range of 60–90, participants were asked to select a different memory, to avoid the memory being not aversive enough or too upsetting. Next, for each memory, participants were asked to describe it globally, and to choose the most aversive and emotion-provoking image of the memory (i.e., "target image"). If needed, the experimenter asked the participants questions to make sure that they were able to visualise a clear still image (e.g., what exactly do you see?). For each target image, a relatively neutral label was chosen (e.g., "cycling" referring to a cycling accident), which served as a reference to the image throughout the experiment. Then, participants performed a pre-rating, a task and a post-rating for each memory. Based on counterbalancing, participants started with the least or the most unpleasant memory. One memory was assigned to the control task

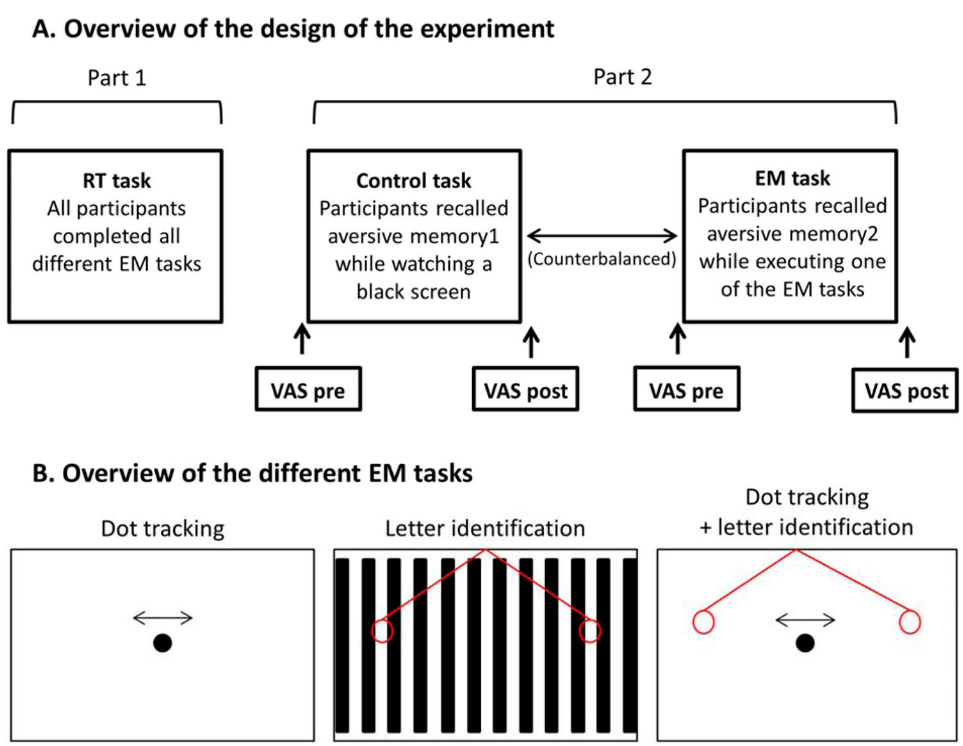

Figure 1. Schematic illustration of the design of the experiment (A) and the different eye-movement tasks (B): Red circles indicate where the letters appear and the black arrow indicates the horizontal movement of the dot. Note also that the colors were inversed (i.e., a white dot/letters on a black computer screen).

and the other memory was assigned to the EM task (i.e., one of the EM tasks described above: dot tracking, letter identification, or dot tracking + letter identification).

In the pre-rating, participants were presented with the label and asked to vividly recall the image for 10 s (i.e., "You will now have to recall the image of [label memory] as it is CURRENTLY stored in your mind"; this phrasing is based on the Dutch EMDR protocol; see also: van Schie et al., 2016; van Veen et al., 2015) and then to rate the emotionality and vividness of the image on the VASs. Before the EM and the control task, and at the end of every break, participants were asked to recall the image (i.e., "Concurrently recollect the memory which you selected just before. Do you have the image clear?"). Participants executed the EM and control task for four trials of 24 s separated by 10-second breaks (cf. Engelhard et al., 2012; van Veen et al., 2015), while following the instructions belonging to the assigned task. Immediately thereafter, participants completed a post-rating, which had an identical procedure as the pre-rating. The pre-rating, task and post-rating were then repeated for the second memory. The experiment ended with a questionnaire in which participants were asked about their quality and hours of sleep, the extent to which the images of the two memories intermingled, which strategy they used to make eye movements and visualise the image at the same time, and what their hypotheses were about the study. This questionnaire was included for exploratory reasons and will not be discussed further (i.e., we did not have any a priori hypotheses regarding the items of this questionnaire, see our preregistration). Finally, participants were debriefed about the purpose of the experiment.

Data reduction and analysis

To test the WM taxation of the three EM tasks relative to the control condition, a repeated measure analysis of variance (ANOVA) was performed with EM Task (control, dot tracking, letter identification, dot tracking + letter identification) as a within-subjects factor and average Reaction Time (RT) to the auditory cues as the outcome measure. In this analysis, data of 5 participants were removed due to incompleteness (i.e., more than 70% of the trials had missing data). Furthermore, all RTs from the practice trials were removed from the analysis, as well as RTs above 1500 ms and below 200 ms, including non-responses (7.57% of all trials). Note that these exclusion criteria for the RT data were not included in the pre-registration document (but are based on accepted practices in the literature; see Whelan, 2008).

To test the effectiveness of the interventions in changing emotionality and vividness of two negative autobiographical memories, two mixed three-way ANOVAs were conducted with Time (pre-test, post-test) and Condition (control, EM task) as within-subjects variables and Type of EM Task (dot tracking, letter identification, dot tracking + letter identification) as a between-subjects factor. Emotionality and vividness VAS ratings constituted the outcome measures of the two ANOVAs. Two participants were removed from this analysis because they could not come up with two negative memories (their emotionality rating was <60) and two other participants were excluded due to not following the instructions of the experimenter (i.e., misinterpretation of the VAS and inattention). Note that exclusion of participants based on emotionality ratings was part of our preregistration. The exclusion of the two other participants was not part of our preregistration, but was decided during testing (i.e., prior to any statistical analyses). An overview of the mean pre- and post-test VAS ratings for the different EM tasks is provided in the Supplementary Materials.

Finally, we tested whether the degree of WM taxation due to the experimental task (indexed by the increases in RT in the experimental task relative to the control task) correlated with the pre–post changes in emotionality and vividness during the experimental task relative to the control task. Statistical analyses were carried out using SPSS Statistics 24. An alpha level of .05 was applied for all the analyses.

Results

Reaction time task

An overview of the average RT of responses to auditory cues for all tasks is given in Figure 2. The ANOVA showed that RTs varied significantly across conditions, $F(3, 282) = 151.54$, $p < .001$, $\eta_p^2 = .62$. Paired *t*-tests further revealed that all EM tasks had significantly higher RTs compared to the control task, with the letter identification task having the highest increase in RT, $t(94) = 17.08$, $p < .001$, Cohen's $d_z = 1.75$, followed by dot tracking + letter identification, $t(94) = 16.78$, $p < .001$, Cohen's $d_z = 1.72$, and dot tracking, $t(94) = 7.29$, $p < .001$, Cohen's $d_z = 0.75$. In addition, follow-up tests showed that both letter identification, $t(94) = 11.47$, $p < .001$, Cohen's $d_z = 1.18$, and dot tracking + letter identification, $t(94) = 10.03$, $p < .001$, Cohen's $d_z = 1.03$, had significantly higher RTs than dot tracking. Finally, letter identification had higher RTs compared to dot tracking + letter identification, $t(94) = 2.43$, $p = .017$, Cohen's $d_z = 0.25$[2].

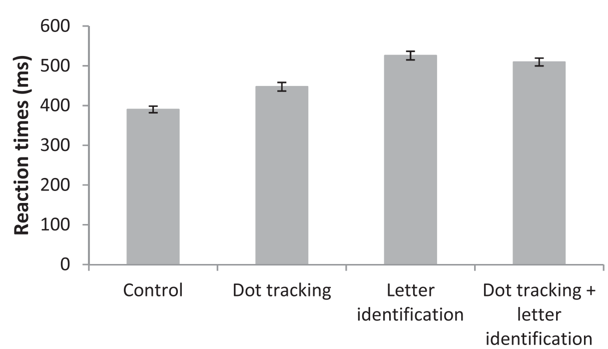

Figure 2. Mean reaction times on the secondary reaction time task for the different eye-movement tasks and the control task. Error bars reflect standard error.

Autobiographical memory task

Emotionality ratings

For emotionality ratings, no main effects of Condition, $F(1, 93) = 1.64$, $p = .203$, $\eta_p^2 = .02$, or Task, $F(2, 93) = 0.71$, $p = .493$, $\eta_p^2 = .02$, were observed. Furthermore, the two-way interaction between Time and EM Task, $F(2, 93) = 0.05$, $p = .953$, $\eta_p^2 < .01$, Condition and Task, $F(2, 93) = 0.64$, $p = .531$, $\eta_p^2 = .01$, and between Time and Condition, $F(1, 93) = 1.24$, $p = .269$, $\eta_p^2 = .01$, were not significant, nor was the three-way interaction between Time, Condition and EM Task, $F(2, 93) = 1.62$, $p = .203$, $\eta_p^2 = .03$. The only effect that did reach significance was the main effect of Time, $F(1, 93) = 4.99$, $p = .028$, $\eta_p^2 = .05$, which reflected higher emotionality ratings pre- ($M = 66.69$, $SD = 13.23$) compared to post-intervention ($M = 64.32$, $SD = 15.63$; see Figure 3).

For exploratory reasons, we looked at the interaction between Time and Condition for the different EM tasks individually. Note, however, that no statistical inferences regarding differences between the EM tasks can be drawn from these interactions because the overall three-way interaction between Time, Condition and EM Task was not statistically significant (Nieuwenhuis, Forstmann, & Wagenmakers, 2011). Bonferroni-corrected *p*-values are reported. This interaction between Time and Condition was not significant for any of the EM tasks, dot tracking: $F(1, 31) = 1.32$, $p = .777$, $\eta_p^2 = .04$; letter identification: $F(1, 31) = 2.27$, $p = .426$, $\eta_p^2 = .07$; and dot tracking + letter identification: $F(1, 31) = 0.58$, $p = 1$, $\eta_p^2 = .02$. A graphic illustration of changes in emotionality for the EM tasks and the control task is given in Figure 3.

Vividness ratings

For vividness ratings, the two-way interaction between Time and Condition was significant, $F(1, 93) = 5.00$, $p = .028$, $\eta_p^2 = .05$. Follow-up paired samples *t*-tests showed that while the pre–post changes in the control condition were

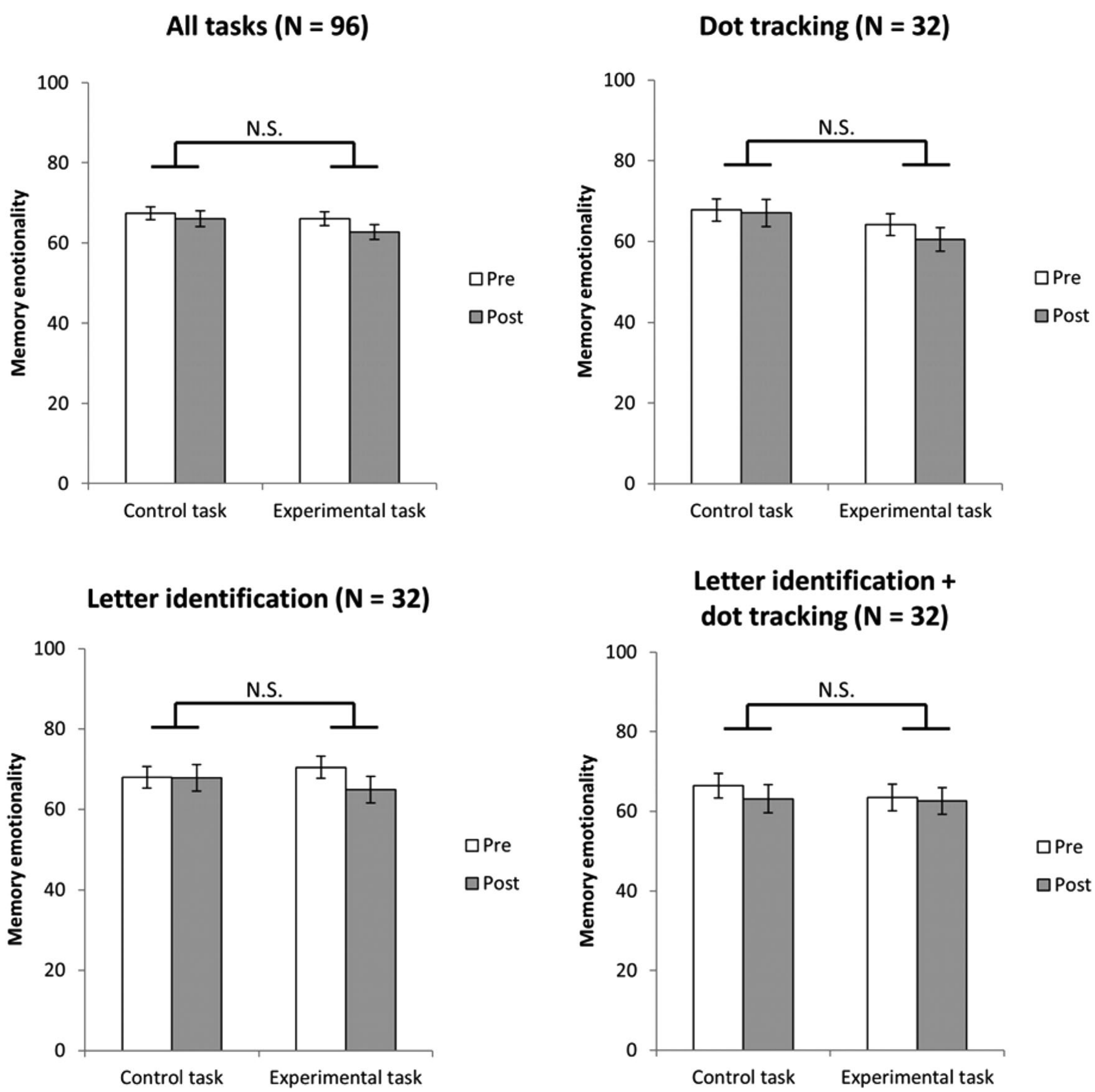

Figure 3. Pre- and post-intervention emotionality scores of the negative autobiographical memory. Means (and standard errors) are presented for all different eye-movement tasks combined (top left), and the different tasks specifically.

not significant, $t(95) = 0.02$, $p = .985$, Cohen's $d_z < 0.01$, the reduction of the score in vividness from pre to post was significant for the EM task (i.e., all different EM tasks combined), $t(95) = 2.56$, $p = .012$, Cohen's $d_z = 0.26$ (see Figure 4). Furthermore, a significant main effect of Condition, $F(1, 93) = 4.34$, $p = .040$, $\eta_p^2 = .05$, and a significant interaction between Condition and EM Task, $F(2, 93) = 4.91$, $p = .009$, $\eta_p^2 = .10$, were observed. These main and interaction effects were due to higher vividness ratings in the control condition, particularly for the letter identification task (see Figure 4). Finally, the main effects of Time $F(1, 93) = 2.68$, $p = .105$, $\eta_p^2 = .03$, and EM Task, $F(2, 93) = 1.22$, $p = .300$, $\eta_p^2 = .03$, the interaction Time and EM Task, $F(2, 93) = 0.50$, $p = .610$, $\eta_p^2 = .01$, and the three-way interaction between Time, Condition and EM Task, $F(2, 93) = 0.22$, $p = .803$, $\eta_p^2 = .01$, were not significant.

As for the emotionality ratings, we have looked at the interaction between Time and Condition for the different EM tasks individually. Note again that no statistical inferences regarding differences between the EM tasks can be drawn from these interactions because the overall three-way interaction between Time, Condition and EM Task was not statistically significant (Nieuwenhuis et al., 2011). Bonferroni-corrected p-values are reported. This interaction was not significant for any of the EM tasks: dot tracking: $F(1, 31) = 2.97$, $p = .285$, $\eta_p^2 = .09$; letter identification: $F(1, 31) = 1.52$, $p = .681$, $\eta_p^2 = .05$; and dot tracking + letter identification: $F(1, 31) = 0.84$, $p = 1$, $\eta_p^2 = .03$. A graphic illustration of changes in vividness for the EM tasks and the control task over time is given in Figure 4.

Bayesian analyses

In the analyses described above, we failed to observe support for differences in the effectiveness of the tasks to reduce memory emotionality and vividness. However, in the classical null hypothesis significance testing framework (NHST), no evidence can be accumulated in favour of the

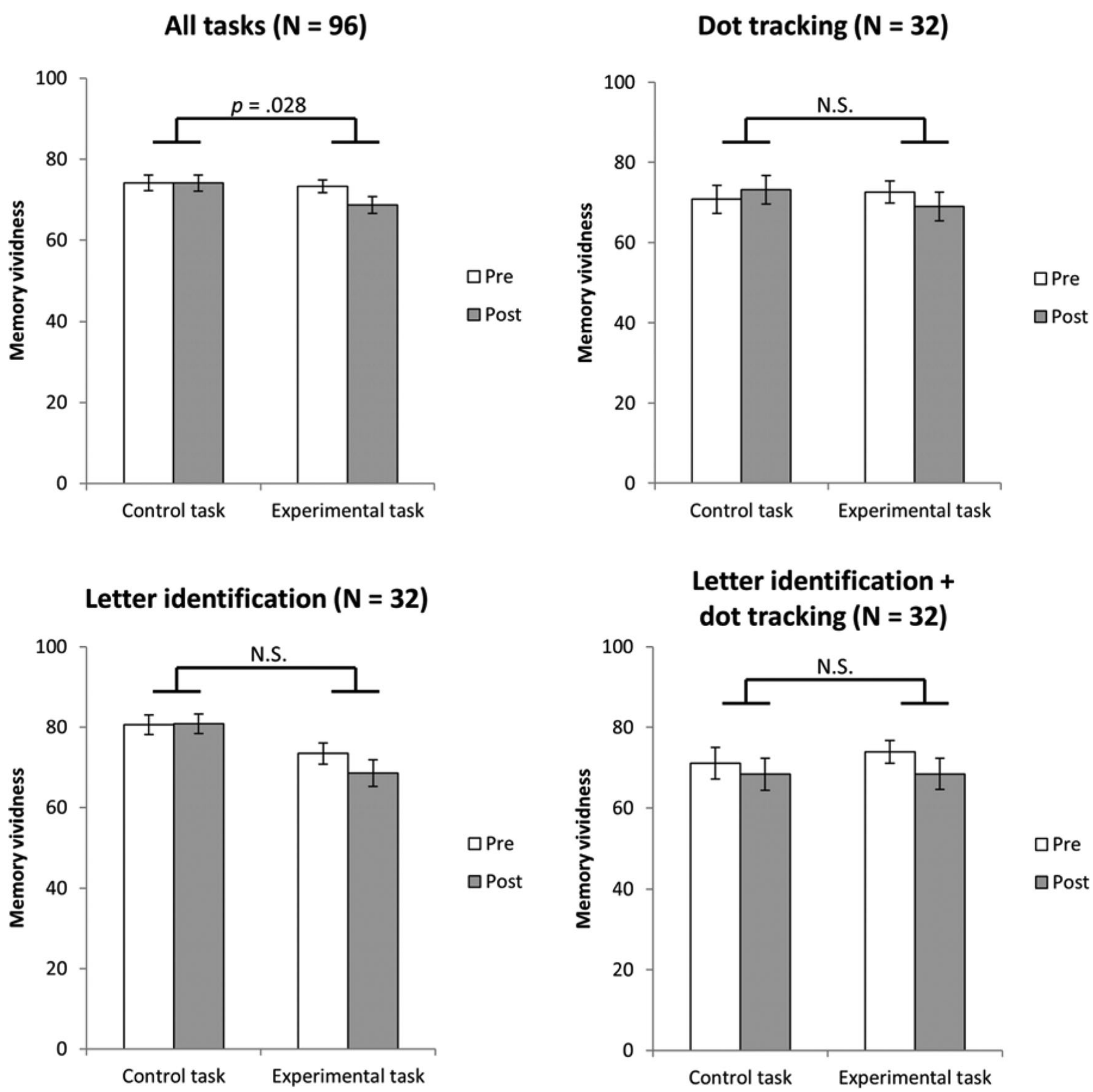

Figure 4. Pre- and post-intervention vividness scores of the negative autobiographical memories. Means (and standard errors) are presented for all different eye-movement tasks combined (top left), and the different tasks specifically.

null hypothesis (Wagenmakers, 2007). To complement these analyses, we conducted Bayesian analyses in JASP (JASP Team, 2018) to quantify the relative support of the null hypothesis (i.e., *an absence* of a difference in the effectiveness of the several EM tasks to reduce memory emotionality and vividness) compared to the alternative hypothesis (*the presence* of a difference in the effectiveness of the different EM tasks to reduce memory emotionality and vividness). This was done by computing separate Bayes factors. The Bayes factors quantify the support between two hypotheses, here the null and the alternative hypothesis. In this study, Bayes factors (BF_{01}) above 1 suggest relative more support of the data coming from the null hypothesis compared to the alternative hypothesis. These analyses indicated decisive evidence against any difference between the EM tasks regarding their effectiveness to reduce emotionality (BF_{01} three-way interaction between Time, Condition, and Task = 75.556) and very strong evidence against such a difference between the EM tasks for vividness (BF_{01} three-way interaction = 69)[3].

Correlational analyses

To explore the relationship between WM taxation and memory emotionality and vividness reductions, we calculated the correlation between the degree of slowing down during the EM task (RT index = RT EM task − RT control task; we selected the RTs for the EM task for each participant that was used during the autobiographical memory task) and the reduction of memory emotionality and vividness from pre- to post-intervention (relative to the control condition; emotionality/vividness index = [post-intervention emotionality/vividness − pre-intervention emotionality/vividness EM task] - [post-intervention emotionality/vividness − pre-intervention emotionality/vividness control task]; cf. van den Hout, Engelhard, Beetsma, et al., 2011). Prior to performing these analyses, one extreme outlier was identified based on visual inspection of the data (i.e., RT index = 504 ms, vividness index = 47, emotionality index = 31). Without this outlier, all correlations (both for all EM tasks combined and for each EM task individually, and for both emotionality and vividness ratings) were not significant, absolute r's < .13, p-values >.2. Hence, WM load of the EM tasks as measured with the RT task did not significantly predict reductions in memory vividness or emotionality in the autobiographical task.

Discussion

In the present study, we compared three different EM tasks (dot tracking, letter identification and dot tracking + letter identification) regarding their effectiveness to change negative autobiographical memories. Our results indicate that all EM tasks induced a substantial slowing down of RTs to auditory cues relative to a control task, implying that all tasks load WM. Furthermore, we found that the letter identification task developed by Andrade et al. (1997) slowed RTs most (i.e., induced the highest WM load). Despite this substantial WM load, we only observed a small (Cohen's d_z = 0.26) reduction of memory vividness after the EM task intervention (i.e., when combining the results of all different EM tasks), and did not observe significant parallel reductions of memory emotionality. Furthermore, we did not observe differences in the effectiveness of the different EM tasks to reduce memory emotionality and vividness. In fact, Bayesian analyses indicate strong relative support in our data for the absence of such differences between the EM tasks, compared to the presence of such differences. Finally, we did not observe significant correlations between WM taxation of the EM tasks and reductions of memory emotionality or vividness.

The lack of differences between different EM tasks on emotional memories, particularly given that one task (i.e., the letter identification task) was both more taxing and presumably induces more visuo-spatial interference, is inconsistent with both WM theory and prior studies showing stronger effects of tasks that tax WM more (e.g., Gunter & Bodner, 2008; Maxfield et al., 2008; van Schie et al., 2016; van Veen et al., 2015; though see van den Hout et al., 2010, and Engelhard, van Uijen, et al., 2010). Furthermore, the lack of consistent correlations between the WM taxation of the EM tasks and reductions in memory emotionality and vividness are difficult to accommodate with a WM account. Some studies also found a lack of correlations between WM taxation and reductions of memory emotionality and vividness (e.g., van den Hout, Engelhard, Beetsma, et al., 2011), or even positive correlations (i.e., less WM load was related to larger reductions in memory vividness; Engelhard, van Uijen, et al., 2010), while others found the predicted negative correlations (e.g., Engelhard, van Uijen, et al., 2010; Gunter & Bodner, 2008, for emotionality; van den Hout et al., 2010). This inconsistency between WM taxation and the effects on emotional memory might be explained by the proposed inverted U-shape relationship between WM taxation and the effectiveness of dual-tasks on memory suggested by Gunter and Bodner (2008). This proposal implies that there should be a negative correlation between WM taxation and effects on memory for relatively low taxing dual-tasks (i.e., greater reductions of memory emotionality/vividness when the WM task is more taxing), no correlation for optimally taxing dual-tasks, and a positive correlation for highly taxing dual-tasks (i.e., smaller reductions of memory emotionality/vividness when the WM task is more taxing). Though this proposal is not inconsistent with the results reported in the literature (given that positive, negative, and no correlations are reported), evidence for such an inverted U-shape relationship between the difficulty of the dual-task and the sign of the correlation coefficient remains to be demonstrated within a single set of studies. The current study did not find evidence for such a relationship between task difficulty and the sign of the correlation coefficient, possibly because all tasks were quite taxing (i.e., the parameters of the EM tasks were based on prior studies that found these parameters to be optimal, see Andrade et al., 1997; Homer et al., 2016; Maxfield et al., 2008; van Veen et al., 2015).

Another striking result is that the effects of the EM tasks were only obtained for memory vividness, but not for emotionality, and this effect was quite small. Also here the findings are somewhat inconsistent over studies. Whereas most studies have found reductions of both memory emotionality and vividness (e.g., Kavanagh, Freese, Andrade, & May, 2001; Kemps & Tiggemann, 2007; Leer, Engelhard, & Van Den Hout, 2014; van den Hout et al., 2001; van Veen et al., 2015), some studies have found reductions only for memory vividness (e.g., Andrade et al., 1997, Experiment 1–3; Maxfield et al., 2008, Experiment 1; van den Hout, Engelhard, Rijkeboer, et al., 2011, Experiment 4), or emotionality/distress (e.g., Lee & Drummond, 2008; Schubert, Lee, & Drummond, 2011). Also here, the WM account can be used to explain the differences over studies: for some participants (with high WM capacity), the EM task may not be sufficiently taxing, resulting in smaller reductions of memory emotionality and vividness. Alternatively, the task may be too difficult for some participants (with low WM capacity), likewise resulting in only small or no reductions of memory emotionality and vividness. Hence, absence of effects in some studies may be explained by the dual-tasks being unadjusted to participants' WM capacity. However, a recent study did not find evidence for the idea that effects of dual-tasking depend on an individual's WM capacity (van Schie et al., 2016).

Finally, the results from our study indicate that the effect of the EM tasks is not only one-directional. Some participants actually show increases in memory vividness and emotionality after the intervention (i.e., approximately 34% and 40% of participants indicate an increase in memory emotionality and vividness, respectively, after the EM tasks). This would not be expected on the basis of a WM account, given that this account predicts that memory can only be impaired due to competition between resources required for the EM tasks and for the recollection of the memory. Increases in memory vividness and emotionality may be explained by changes in the accessibility of the memory due to repeated recollection (e.g., Bornstein, Liebel, & Scarberry, 1998). At present, it is not clear why some participants show these increases in memory emotionality and vividness and others do not. Future studies using trajectory analyses may elucidate how common this is and might help to identify individuals who benefit insufficiently from EM task interventions. One proposal that can accommodate both increases and decreases in memory emotionality and vividness is that recollecting a distressing memory and performing a taxing task may increase self-efficacy or adjust maladaptive meta-cognitive beliefs about the negative memory for some participants (e.g., Andrade et al., 1997; Gunter & Bodner, 2008). Indeed, there is some evidence from clinical practice that changes in coping and self-efficacy beliefs may be related to the treatment effects of EMDR (e.g., Korn & Leeds, 2002; Shapiro, 2001; Sprang, 2001). Such changes in participants' appraisals regarding their coping potential to deal with the emotional memories may make the memory less distressing, vivid and emotional. In contrast, when participants do not change their appraisals regarding their coping potential, repeatedly recalling an aversive memory may make this memory even more vivid and distressing. However, this mediating role of changed self-efficacy and coping appraisals regarding the effects of EM tasks on emotional memories remains to be empirically tested.

In conclusion, we found that the dot tracking task developed by van den Hout et al. (2001), the letter identification task developed by Andrade et al. (1997), and a newly developed tasks that combined features of the two other tasks were equally effective in changing the vividness (but not emotionality) of emotional memories, despite differences in the amount of WM taxation. Furthermore, no significant correlations were observed between WM taxation and reductions of memory emotionality and vividness. Finally, some participants in our sample showed increases in memory emotionality and vividness after the EM tasks. Although the current findings do not exclude a WM explanation, alternative possibilities, for instance, related to self-efficacy or meta-cognitive beliefs, should be considered and tested to explain the variance in the effects of EM tasks on emotional memories between individuals and studies.

Notes

1. Because GPower does not handle power calculations with interactions between within-subjects variables well (https://stats.stackexchange.com/questions/59235/repeated-measures-within-factors-settings-for-gpower-power-calculation), we used the between-subjects ANOVA option. We assumed that the power calculations based on difference scores (i.e., the pre-post rating difference for the EM task relative to the control task) provide a reasonable estimate for the required sample size for our planned analyses (see our preregistration and the *Data reduction and analysis* section).
2. To investigate whether participants' RTs improved over the blocks of the RT task, we included Block (i.e., block 1 to 4) as an extra factor in our analysis of the RT task (with EM Task [control, dot tracking, letter identification, dot tracking + letter identification] being the other factor). The results of this analysis indicated that there was no main effect of Block, $F(3, 279) = 1.82$, $p = .150$, $\eta_p^2 = .02$, and no interaction between Block and EM Task, $F(9, 837) = 0.76$, $p = .656$, $\eta_p^2 = .01$. Furthermore, even when considering the last block of the RT task, the main effect of EM Task remained significant, $F(3, 282) = 90.66$, $p < .001$, $\eta_p^2 = .49$, due to shorter RTs for the control task ($M = 388.50$, $SD = 78.05$) compared to the dot tracking task ($M = 442.99$, $SD = 111.54$; $p < .001$), the letter identification task ($M = 520.98$, $SD = 116.62$; $p < .001$), and the combination task ($M = 504.62$, $SD = 105.33$; $p < .001$). Hence, this analysis suggests that there were no strong practice effects during the RT task and that the differences between the control and the EM tasks remained present after three block of practice.
3. For all our analyses we used the default options in JASP, which use a Cauchy prior distribution with the scale factor of the fixed

effects for the alternative hypothesis set to 0.5. However, to test how immune the results are to the choice of the prior distribution, we repeated all our analyses using different scale factors for the fixed effects as well (i.e., 0.707 and 1; Krypotos, Blanken, Arnaudova, Matzke, & Beckers, 2017), with the direction of the main results remaining the same. Here, we report only the results using the default settings in JASP.

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No potential conflict of interest was reported by the authors.

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Data and materials availability statement

The data and materials of the experiment reported in this article are available at https://osf.io/yanqz/. The protocol of the reported experiment can be obtained on request by contacting the last author of this article (i.m.engelhard@uu.nl).

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