Time-course of eye movement-related decrease in vividness and emotionality of unpleasant autobiographical memories

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The time-course of changes in vividness and emotionality of unpleasant autobiographical memories associated with making eye movements (eye movement desensitisation and reprocessing, EMDR) was investigated. Participants retrieved unpleasant autobiographical memories and rated their vividness and emotionality prior to and following 96 seconds of making eye movements (EM) or keeping eyes stationary (ES); at 2, 4, 6, and 10 seconds into the intervention; then followed by regular larger intervals throughout the 96-second intervention. Results revealed a significant drop compared to the ES group in emotionality after 74 seconds compared to a significant drop in vividness at only 2 seconds into the intervention. These results support that emotionality becomes reduced only after vividness has dropped. The results are discussed in light of working memory theory and visual imagery theory, following which the regular refreshment of the visual memory needed to maintain it in working memory is interfered with by eye movements that also tax working memory, which affects vividness first.

Keywords: Mental imagery; Intrusive memory; Transdiagnostic; Eye movement desensitisation and reprocessing; EMDR; Working memory; Post-traumatic stress disorder; PTSD.

Since its inception two decades ago (Shapiro, 1989, 2001), eye movement desensitisation and reprocessing (EMDR) has become an established treatment for post-traumatic stress disorder (PTSD). Memories of negative events tend to become less vivid and emotional when patients with post-traumatic stress disorder make eye movements while experiencing these memories. Meta-analyses have reported significant additive effects for eye movements in clinical trials (Lee & Cuijpers, 2012), and substantial therapeutic effects of EMDR, that are at least as large as those of other established treatments for other anxiety disorders (Bisson et al., 2007; Bradley, Greene, Russ, Dutra, & Westen, 2005; Seidler & Wagner, 2006). The main question concerns the mechanism underlying this effect: How can an activity as simple as making eye movements when memorising an event affect so profoundly how that memory is experienced? While the research conducted to date has yielded useful insights into the perceptual and memory mechanisms involved, it is still relatively unclear what the relation is between the respective memory features vividness and emotionality, and to what extent a reduction in one depends on a reduction in the other. Are emotional experiences related to memories intense only when visual representations of those memories are vivid (i.e., of high quality or high in detail)—in other words, do memories need to be vivid in order to be experienced as strongly emotional? To address
this issue the present study investigated the time-course of changes in vividness and emotionality during eye movement when retrieving a negative memory. The implication of the above reasoning is that changes in emotionality should occur after or perhaps simultaneously with, but not prior to, changes in vividness. Knowing the timeline on which reductions in vividness and emotionality occur will not only increase our understanding of how quality of memory and emotionality of aversive memories are related, but might also help to make interventions more efficient. We will start by briefly describing the research on underlying memory mechanisms to date before outlining the present study.

Substantial progress towards understanding the mechanism underlying the effects of eye movements has been made by applying working memory theory (Andrade, Kavanagh, & Baddeley, 1997; Baddeley & Hitch, 1974), following which memory retrieval calls for limited-capacity working memory (WM) resources. Assuming that eye movements also tax working memory, they would compete for resources with simultaneous ongoing memory retrieval. With memory retrieval now being somewhat compromised, vividness and emotionality of the memory may become affected. Laboratory simulations of EMDR have indeed yielded support for WM theory. For example, recall of aversive autobiographical memories combined with making eye movements in the laboratory has been found to reduce vividness and emotionality, whereas recall without making eye movements has not (Andrade et al., 1997; Gunter & Bodner, 2008; Kavanagh, Freese, Andrade, & May, 2001; Kemps & Tiggemann, 2007; Maxfield, Melnyk, & Hayman, 2008; Van den Hout, Muris, Salemink, & Kindt, 2001). Effects of eye movements extend beyond the manipulation of extending working memory: the effects of eye movements during 24-second phases were maintained over a 1-week period for memories of past events (e.g., Gunter & Bodner, 2008, Exp. 2), which suggests there may be long-term gains. In sum, laboratory data suggest that EMDR and related procedures derive their effects from WM taxing during recall of aversive memories (Engelhard, Van den Hout, & Smeets, 2011; Holmes, James, Kilford, & Deeprose, 2010; Gunter & Bodner, 2008; Maxfield et al., 2008; Van den Hout et al., 2010, 2011).

It is still unclear under WM theory how vividness and emotionality are related. More specifically, while it could be envisioned that both emotionality and vividness of a mental representation are affected equally and simultaneously by taxing working memory events, it is equally conceivable that a reduction in one quality automatically triggers a reduction in the other. It has been proposed earlier (Gunter & Bodner, 2008) that memories held in the visuospatial sketchpad (VSSP)—a WM subsystem concerned with temporarily maintaining and manipulating visuospatial information (Baddeley, 2002; Baddeley & Hitch, 1974)—become less vivid when eye movements use up processing resources, with this vividness reduction then cascading into reduced emotionality. One way to address the issue would be to inspect the time-course of changes in vividness and emotionality. If changes in emotionality are triggered by changes in vividness, changes in vividness would have to occur prior to changes in emotionality. Thus, in the present research, we focused on the time-course of eye movement effects on vividness and emotionality from unpleasant memories in order to increase our understanding of the processes causing changes in vividness and emotionality. We referred to Kosslyn's visual mental imagery theory (Kosslyn 1980, 1994) as a framework for deriving hypotheses, as this theory describes in detail the presumed processes taking place when visual memories are retrieved and recreated in the (equivalent of) the VSSP in order to derive information from these memories. Recent research demonstrated that both theories—of working memory and mental imagery—can in fact be compared as the cognitive processes underlying both mental imagery and working memory have in common that they are both depictive (i.e., like visual images) representations (Borst, Ganis, Thompson & Kosslyn, 2012).

Previous research, aimed at testing the working memory account of EMDR, showed differences in vividness and emotionality changes as a result of eye movements (e.g., Engelhard, Van Uijen, & van den Hout, 2010; Van den Hout et al., 2011). With respect to time-course, research by Andrade et al. (1997) and Kemps and Tiggemann (2007) suggests a rapid decline of vividness, and to a lesser extent emotionality, as participants reported a decrease in either feature after only 8 seconds. Kemps and Tiggemann (2007) also reported a decline in vividness and emotionality after only 8 seconds. However, in most studies vividness and emotionality were assessed only prior to and following the usual 4 × 24-second blocks (e.g., Engelhard, Van den Hout, Janssen, & Van der Beek, 2010; Engelhard, van Uijen, et al.,
imagery can be likened to the priming of the visual memory representation in long-term visual memory (Kosslyn, 1994, p. 75) so that it becomes accessible to inspection in WM. To this end the visual image is recreated in the VSSP (comparable to what is referred to as visual buffer by Kosslyn, 1994). During EMDR patients are instructed to maintain the memory while making eye movements. This requires that patients devote attention to, and thus fixate on, the image in the VSSP. As a result of continued fixation, the visual image quickly fades due to neural adaptation. To fight adaptation and keep the visual image alive it has to be constantly reactivated. This is accomplished by maintaining attention on the image so that information about the memory can be swapped between long-term memory and VSSP.

The refreshment process is known to require much working memory effort (Kosslyn, 1994, Ch. 9). It would then logically follow that adding the extra burden of eye movements on top of the already existing working memory load of refreshing and maintaining the image has immediate consequences. It may lead to an instant deterioration in the ability to refresh the image, leaving a faded, less vivid image. The image, now reduced in vividness, may be rated as less emotional, just as a picture with blurred details would be rated as less emotional. Summarising, we posit that because maintaining a visual autobiographical memory in working memory places a heavy tax on working memory, additional working memory tasks like eye movements cause immediate deterioration of the vividness of that memory and, as a results, of its emotional value.

We derived the following research questions/hypotheses from this theory: First, how quickly do ratings of vividness fall after eye movements have started? Following the reasoning outlined above, we hypothesise that this drop is nearly instantaneous (Hypothesis 1). Specifically we tested whether significant drops in vividness and emotionality occurred as soon as 2 seconds after starting eye movements in multiple 24-second eye movement blocks. We further hypothesised that the time-course in vividness is non-linear, as some ability to create at least a skeletal image in the VSSP will remain. In other words we expect changes in vividness ratings to show a non-linear time-course characterised by a sharp drop soon after starting eye movements (Hypothesis 2). Lastly, how quickly do ratings of emotionality fall in comparison to ratings of vividness? Our hypothesis would be that changes in emotionality occur after vividness has changed, or simultaneously, but not prior to drops in vividness. Reductions in emotionality may show a time-course that is similar or somewhat delayed compared to the vividness time-course (Hypothesis 3). These hypotheses were tested in a laboratory experiment in which naïve participants repeatedly retrieved negative memories, with the experimental group engaging in eye movements while the control group kept their eyes stationary. Vividness and emotionality were assessed before and after the intervention of four blocks of 24 seconds. To address the first hypothesis, i.e., that changes in vividness occur very quickly, we inserted assessments in each block as early as 2 seconds after starting the intervention. To test the second and third hypothesis, that the course of change in vividness is not linear, and that emotionality drops off at an equal or slower rate than vividness, we added assessments at 4, 6, and 10 seconds after starting the intervention. To test the prediction related to time-course were further tested not only over time-points within a single intervention block (of 24 seconds) but also over multiple blocks up to 96 seconds, and over multiple memories.

**METHOD**

**Participants**

A total of 61 participants (40 female, 21 male) were recruited from among Utrecht University students. Age varied between 18 and 26 years ($M = 21$ years, $SD = 2.3$). Prospective participants were asked to explain EMDR. Only participants who did not know the treatment or provided an incorrect explanation were included in the study. They were told the purpose of the study was to determine the role of working
memory in visualising negative memories. Participants were randomly assigned to the EM (Eye Movement) condition \((n = 32)\) or control condition ES (Eyes Stationary; \(n = 29\)). A randomisation check was performed to investigate whether there were already initial differences at baseline between participants assigned to the EM and ES groups, but this was found not to be the case. There were no significant between-group differences in baseline vividness or emotionality of the memory that was first tested \((t < 1.0\) for both vividness and emotionality). All participants received course credit or money in exchange for participation.

**Methods and procedure**

After receiving information about the study and signing informed consent, naïve participants were asked to recall three occasions that had made them feel very fearful or distressed, and still had some emotional impact (e.g., loss of a loved one, missing an exam, termination of a romantic relationship). Following Van den Hout et al. (2001), participants wrote down a label for each memory. Participants were positioned in front of a 19-inch computer screen at a distance of about 50 cm. Instructions appeared on the screen. Prior to each episode they were asked to “Form an image of [label] now. Remember where it happens, who is present, and anything else you can think of. Bring it to mind as vividly as if it were happening right now.” Each of the three memories received a label, which was a keyword by which the memory could be identified. Participants were then asked to rank the memories for emotionality, starting with the most emotional to the least emotional, and to write down corresponding labels. The experimenter then labelled the memories as 1 (most emotional), 2 (medium emotional), and 3 (least emotional). Using the emotionality labels 1–3, the experimenter assigned a memory to Episodes 1 to 3 so that intensity of emotionality associated with that memory was counterbalanced over episodes.

With the help of the keyword label, the participants retrieved one of the negative memories during an episode consisting of four blocks of 24 seconds, separated by 10-second pauses between blocks (cf. Engelhard, van den Hout, et al., 2010; Engelhard, van Uijen, et al., 2010; Gunter & Bodner, 2008; van den Hout et al., 2001, 2011). There were three episodes (of four 24-second blocks each) in total, with each episode involving one of the three labelled memories to prevent adaptation to the memory over the multiple blocks and episodes. Distribution of the three memories over episodes was counterbalanced. During memory retrieval the experimental group was required to engage in eye movements, while the control group kept their eyes stationary. For the experimental group the task involved the visual tracking of a white dot (1 cm diameter) moving from the left side of the computer screen 21.5 cm across to right side of the screen and back in 2 seconds (1 cycle per second), while in the control group participants were asked to keep their eyes focused on a stationary dot of the same size and hue. The experiment was programmed in E-prime (Version 1.2, 1996). Participants practised making eye movements in the EM condition or watching the stationary dot in the ES condition with a positive memory.

At pre-test, post-test, and at various times throughout the procedure the task was interrupted by 100-mm visual analogue scales (VAS) that ranged from 0 = not vivid at all (pleasant) to 100 = extremely vivid (unpleasant). Participants were asked to rate the vividness and emotional intensity of the image they were experiencing. After finishing the ratings the participants resumed memory recall in combination with either EM or ES.

The additional time-points at which vividness and emotionality (see Table 1 for assessment schedule) were assessed were: at 2 seconds into all four blocks of all three episodes (so twelve 2-second assessments in total). Furthermore, vividness and emotionality were assessed at 4 seconds during Block 1 of Episode 1, at 6 seconds during Block 1 of Episode 2, and at 10 seconds during Block 1 of Episode 3. The 4, 6, and 10-second assessments in Block 1 were distributed over the three episodes, because we reasoned that four assessments (at 2, 4, 6, and 10 seconds) would likely disrupt memory retrieval too much when made in a single block or memory. After each assessment within a block there was a 10-second pause for filling out the VAS. Thus, when taking into account the three pre-tests and three post-tests, twelve 2-second assessments, and the respective 4-, 6-, and 10-second assessments, vividness and emotionality were assessed 21 times in total to evaluate the time-course of changes in vividness and emotionality. To assess whether participants performed the static/dynamic EM as
At each time-point there was a 10-second pause between blocks. The bottom row indicates the time of assessment on the total timeline of a single episode regardless of block. The experimental group (EM) engaged in eye movements during four blocks of 24 s, while the control group (ES) kept their eyes stationary.

requested, the experimenter sat diagonally behind participants while testing was ongoing. At the end of the experiment participants were debriefed about EMDR and the goals of the study. They were told explicitly not to talk to their fellow students who might still participate about the purposes of the experiment because this could influence results.

### RESULTS

#### Test of replication

Gunter and Bodner (2008) reported significant decreases in both vividness and emotionality after four blocks of 24 seconds of eye movement intervention with a 10-second pause between blocks. Before addressing the hypotheses we started out by testing whether our results show a replication of this finding. A repeated-measures ANOVA on vividness and emotionality ratings with Time (Pretest vs Post-test) and Episodes (1 vs 2 vs 3) as within-participants factors and Condition (EM vs ES) as between-participants factor. For vividness, a significant interaction between Time and Condition was found, $F(1, 59) = 8.70$, $p = .005$, reflecting the observation that there was a decline in scores in the EM, but not the ES group (Figure 1a). There were no main effects of Time, Episode, and Condition or additional interaction effects ($ps > .05$). Post-hoc paired $t$-tests revealed that the change in vividness from pre- to post-test was significant only in the EM group, $t = 2.75$, $df = 31$, $p = .01$, not in the ES group, $t = -1.32$, $df = 28$, $p > .20$. The effect size $d$ (Cohen, 1992) corresponding to the between-group difference in pre-to-post change in vividness was $d = .73$ indicating the size of the effect of the EM intervention on reduction in vividness from pre- to post-intervention was medium to large (see Table 2).

For emotionality, both the interaction between Time and Condition, $F(1, 59) = 4.17$, $p = .046$, and the main effect of Time, $F(1, 59) = 4.47$, $p = .039$, were statistically significant, in the absence of any other effects ($Fs < 1.0$). Post-test scores in the EM group were significantly reduced from pre-test ($t_{EM} = 2.78$, $df = 31$, $p < .01$), but no such drop occurred in the ES group ($t < 1.0$, Figure 1b). The effect size $d$ (see Table 2) corresponding to the between-group difference in pre-to-post change in emotionality was $d = .45$ indicating the size of the effect of the EM intervention on reduction in emotionality from pre- to post-intervention was close to medium.

Thus the relative decrease in vividness and emotionality over $4 \times 24$-second blocks as a result of making eye movements during recall encountered in previous studies was replicated in the present study.

#### Hypothesis 1: Vividness drops after 2 seconds

To test whether significant drops in vividness scores occurred as soon as 2 seconds after starting the EM intervention, we ran a repeated-measures ANOVA on vividness and emotionality ratings with Time (Pretest vs 2 s in Block 1), Episodes (1 vs 2 vs 3), and Condition (EM vs ES) as factors. For vividness a significant interaction between Time and Condition was found, $F(1, 59) = 4.77,$
Time-course of vividness and emotionality as a function of eye movements, tests were conducted to investigate the time-course over a single block (Block 1) and over all four Blocks.

**Hypothesis 2: Time-course of vividness**

With respect to the second research question regarding the time-course of vividness and emotionality as a function of eye movements, tests were conducted to investigate the time-course over a single block (Block 1) and over all four Blocks.

**Table 2**

<table>
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<th>df</th>
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<th>ES</th>
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Means and standard deviations for vividness and emotionality per group per research question (RQ). EM = Eye movement group; ES = Eyes stationary group. d refers to Cohen’s d: \(d = \frac{(M_{ES1} - ME1) - (M_{ES2} - ME2)}{SDP-ES}\), here corresponding to the difference in change between the mean scores of the ES and EM groups from the first time of assessment (row 1 of specific comparison) to the last (row 2 of specific comparison) relative to the pooled ES standard deviation (SDP-ES).

*For the within Block 1 comparison, means refer to changes in ratings from 2 to 4 seconds, and from 2 to 10 seconds, respectively (see Hypotheses 2 and 3).

Time-course within Block 1. Starting with the former, we calculated difference scores from 2 s to 4 s (Timepoint 2 – Timepoint 4), from 2 s to 6 s (Timepoint 2 – Timepoint 6), and from 2 s to 10 s (Timepoint 2 – Timepoint 10) for vividness and emotionality respectively, in Block 1. A 2 (Condition) × 3 (Time) repeated-measures ANOVA was conducted on the calculated difference scores. The pattern of results for this difference score is depicted in Figure 3a; for a depiction of the mean ratings (without conversion to difference scores) the reader is referred to the portion of Figure 5 below that corresponds to Block 1.

For vividness, a significant interaction of Condition × Time emerged, \(F(2, 58) = 3.78, p < .05\) with no significant main effect of Condition or Time (ps > .05). Figure 3a shows an increase in difference scores in vividness over the three intervals from 2 to 4, 2 to 6, and 2 to 10 seconds in the EM group, implying a decrease in vividness over time. Within the EM group, post-hoc t-test pairs with Bonferroni corrections did not reveal significant differences for each of the pairs 2–4, 2–6, and 2–10 seconds (ps > .015). Thus, while vividness decreased, there was neither acceleration nor deceleration of decrease over the 10-second period. Within the ES group the depicted differences do not show a pattern of decreased vividness.

$\text{RQ1}$: Time-course of vividness

With respect to the second research question regarding the time-course of vividness and emotionality as a function of eye movements, tests were conducted to investigate the time-course over a single block (Block 1) and over all four Blocks.

$\text{RQ2}$: Time-course of vividness

$p = .033$, in the absence of other main or interaction effects. As can be seen in Figure 2a, vividness ratings drop over the 2-second interval, but only in the EM condition ($t = 2.49, df = 31, p = .02$; $t < 1.0$ in the ES condition). The corresponding effect size was $d = .33$ (relatively small effect).

**Figure 2.** Vividness and emotionality changes after 2 seconds. Ratings of vividness (a) and emotionality (b) of the memory before and at 2 seconds into the first block averaged over the three episodes of four blocks. EM = Eye movement; ES = Eyes stationary.
effect of Block, F(2,37, 139.95) = 2.57, p = .07. The effect of Condition was not significant, F(1, 59) = 1.23, p = .27. There were no significant effects involving Episode. The pattern of findings is displayed in Figure 4a. Vividness does not show a further decrease over blocks after Block 2. The corresponding effect size comparing changes in vividness from pre-test to 2-second assessment in Block 4 (so after 74 seconds) in the EM group compared to the ES group, is d = .53 (medium effect size).

**Hypothesis 3: Time-course of emotionality**

As was done for vividness to evaluate the former hypotheses, repeated-measures ANOVA were conducted using the same factors used above to test drops in emotionality from pretest to 2 seconds in Block 1; from pretest to 10 seconds in Block 1; and over blocks from pretest into Block 4. From pretest to 2 s into Block 1, the Time × Condition failed to reach significance, F(1, 59) = 2.04, p = .158. All other effects were not significant (see Figure 2b). Thus there was no decrease in emotionality over 2 seconds following eye movements. The corresponding effect size was d = .17 (small effect).

Analyses on changes in emotionality from 2 to 10 seconds into Block 1 (performed on differences scores 2–4 s, 2–8 s, and 2–10 s; see Figure 3b) failed to reach significance: Condition × Time, F(2, 58) = 1.89, p > .05. The effect size associated with the change in emotionality from 2–4 seconds compared to 2–10 seconds in the EM group relative to the ES group is d = .43. Finally, analysing ratings from pretest and at 2 s into each of the four blocks, a significant effect of Time × Condition, F(4, 56) = 2.85, p = .032, was found in the context of a significant main effect of Time, F(2,16, 127.5) = 3.28, p = .037. The effect of Condition was not significant, F(1, 59) = 1.07, p = .30. There were no significant effects involving Episode. Figure 4b shows a decrease in emotionality in the EM group over Time, which is significant within that group, F (2,11, 65.35) = 6.10, p = .003. Pairwise comparisons between the pretest and subsequent time-points show a significant difference between pretest and Timepoint 5 (Block 4, 2 s, 74 s into the four-block session) at p = .03. Within the ES

![Figure 3](image-url)

**Figure 3.** Vividness and emotionality changes within a block. Periodic changes in ratings of vividness (a) and emotionality (b) of the memory from 2 to 4 (Episode 1), 2 to 6 (Episode 2), and 2 to 10 seconds (Episode 3), respectively, into the first block of each episode of four blocks. Positive differences indicate drops with respect to the 2-second measurement. EM = Eye movement; ES = Eyes stationary.

Significant differences were found between groups for the vividness change from 2 to 10 s: t = 2.59, df = 59, p = .01, indicating that vividness differences occurring between 2-s and 10-s assessments were significantly different between groups. This is also reflected by the effect size associated with this difference, d = 1.06, implying that the drop in vividness in the EM group (relative to the ES group) at 10 seconds is much larger than the drop in vividness at 4 seconds into the intervention. Thus vividness continues to decline after 2 seconds.

**Time-course of change over all blocks.** Finally, to explore the speed with which drops in vividness and emotionality occur over the four 24-second blocks, focusing on the immediate drop at 2 s into the intervention in each block, a 3 (Episode) × 5 (Time: also including pretest) × 2 (Condition) repeated-measures ANOVA was conducted on the dependent measures. For vividness, the main effect of Block, F(2.37, 139.95) = 2.64, p = .065, and the interaction effect of Condition × Block, showed a statistical trend, F(2.37, 139.95) = 2.57, p = .07. The effect of Condition was not significant, F(1, 59) = 1.23, p = .27. There were no significant effects involving Episode. The pattern of findings is displayed in Figure 4a. Vividness does not show a further decrease over blocks after Block 2. The corresponding effect size comparing changes in vividness from pre-test to 2-second assessment in Block 4 (so after 74 seconds) in the EM group compared to the ES group, is d = .53 (medium effect size).
group the effect of Time is not significant, \( F < 1.0 \). The effect size comparing changes in emotionality from pretest to 74 seconds after pretest in the EM group compared to the ES group, was \( d = .33 \) (small to medium effect size). So, summarising, changes in emotionality from pretest and relative to the ES group did not occur over 2s, or 10 s into Block 1. Significant reductions were encountered in Block 4, after 74 s.

To allow a direct comparison between vividness and emotionality, Figure 5 shows the differences scores for both these measures over all

Figure 4. Vividness and emotionality changes over blocks. Ratings of vividness (a) and emotionality (b) of the memory at pretest, and at 2 seconds into Blocks 1–4 (indicated as B1_2 – B4_2) averaged over the three episodes. EM = Eye movement; ES = Eyes stationary.
DISCUSSION

Gunter and Bodner (2008) proposed that memories held in the visuospatial sketchpad become less vivid when eye movements use up processing resources, with this vividness reduction then cascading into reduced emotionality. The present study specifically investigated the implications of this explanation for the time-course of vividness and emotionality changes, using insights gained from Kosslyn’s visual imagery theory (1980, 1994). Specifically, we tested whether reductions in vividness of the memory, as opposed to emotionality, occur almost instantaneously after starting eye movements (Hypothesis 1; at 2 seconds). Second, the time-course of further changes in both vividness and emotionality were charted beyond 2 seconds until 74 seconds into the intervention at regular intervals, to test that the time-course of changes in vividness is non-linear but characterised by a sharp drop in the beginning (Hypothesis 2), and is either accompanied or followed, but not preceded by, reductions in emotionality (Hypothesis 3).

A laboratory test in which non-clinical participants were asked to retrieve visual memories of occasions with a negative emotional connotation was conducted to evaluate the hypotheses. The experimental group (EM) was instructed to move their eyes during memory retrieval, while the control group (ES) stared at a dot at the centre of the screen. At various times throughout three 96-second episodes both groups were asked to complete visual ratings of vividness and emotionality associated with the memory.

The results revealed that, in line with Hypothesis 1 and compared to the ES group, vividness of the memory in the EM group dropped significantly after only 2 seconds of starting the eye movement intervention. From 2 to 10 seconds into the EM condition, vividness still dropped
substantially relative to the ES condition. Rate of reduction in vividness fell after this initial 10-second reduction to non-significance over the remaining duration up to 74 seconds, supporting the hypothesis (2) of nonlinearity for vividness.

For emotionality, the time-course was clearly different from that of vividness. The results implied that decreases in emotionality happen more gradually than changes in vividness. Significant reductions were only found over a 74-second period, occurring over multiple 24-second blocks with pauses in between, rather than within blocks—and not after 2 seconds or 10 seconds into the first block of EM intervention. With respect to Hypothesis 3 we may conclude that changes in emotionality lag behind those in vividness, but do not precede these changes.

These findings are in line with the notion that eye movements tax working memory in the sense that it becomes more difficult to maintain a vivid visual image of the memory in working memory when moving the eyes. Specifically, we posit that eye movements interfere with the frequency and rate of refreshment needed to keep the visual memory image active (i.e., swapping of information between visual long-term memory and the visual short-term memory; Kosslyn, 1994, p. 324). This interference would affect the quality of the image rapidly, as image refreshment is near-continuous and requires much effort. In addition, interference with refreshment efforts would affect emotional valence only at a later time if we assume that the image needs to be assessed by the individual in order to infer emotionality (as inference of details is an important function of imagery; Kosslyn, 1994). Thus these findings suggest that emotionality depends on vividness: low-quality, less vivid images are less impactful emotionally.

Although the results from this study endorse the theory, they do not fully prove it. First, the design of our study was suboptimal with regard to the intervals between assessments of vividness and emotionality. While there were multiple assessments in Block 1, lasting 24 seconds, assessments over the remaining three out of the four 24-second blocks were sparse, with only a single assessment at 2 seconds into each block. Thus, beyond testing whether rapid changes occur soon after starting the intervention, assessments were few and far between, not allowing careful curve fitting of the time-course of vividness or emotionality. So although the results support the hypotheses, they are only a first test. Replications of this study should incorporate more assessments spread out evenly over the 96-second duration of the intervention. Furthermore, the current study did not use standardised compliance measures. Future studies might increase reliability of the data by adding, for example, a video of the eye movements and/or compliance ratings. Finally it should be noted that the dot staring in the control condition might have unintended effects, like dissociation. Future studies may also want to add a no-task control condition.

Likewise, additional evidence is needed to evaluate the theory that there is interference in the visuospatial subsystem of working memory, as we propose. Other explanations not involving the visuospatial subsystem could be envisioned that would lead to rapid reductions in vividness. Further evaluation of the theory involving cognitive neuroscience techniques may help to elucidate how activity in the early visual cortex implicated in visual mental imagery (Kosslyn & Thompson, 2003) changes during eye movements. The focus of the present study was on eye movements interfering with the ability to refresh the visual imagery while keeping it in working memory. According to Borst et al. (2012) new visual representation has to be created in the visual buffer every time the eyes move. The authors go on to state that they doubt that maintenance occurs in the visual buffer itself. Regardless of the very subsystem in which maintenance occurs, the connotation is that eye movements necessitate the recreation of the image, whether taxing working memory or taxing other cognitive or perceptual subsystems not considered part of working memory. Interestingly, in their review on the role of early visual cortex in visual mental imagery, Kosslyn and Thompson (2003) refer to Paus, Marrett, Worsley, and Evans (1995) who showed that eye movements decrease activation in early visual cortex. The implications are clear: if the retrieval of visual memories and eye movements all engage the early visual cortex, future research should place its focus there.

The finding that emotionality reductions lag behind those of vividness implies a causal relation, but an appropriate evaluation of such a causal relation would require an experimental approach. This might involve individuals rating the emotionality of either aversive pictures with varying rates of degradation or of visual memories whose vividness is experimentally manipulated. Finally, the findings from the present study cast in a new light the notion of adaptive
information processing (Shapiro, 2001), according to which the memory is encoded with the emotion at the time of the event. If that were the case, one would expect degradation of the image to be irrelevant as the image does not need to be “inspected” to infer emotionality. After all, emotionality experiences would appear automatically along with the image. In that case the time-course of vividness and emotionality ratings would be similar, which we found not to be the case. However, the present results do not preclude the possibility that changed emotionality experiences subsequently become stored in memory.

It is too early to infer clinical implications for EMDR therapy from this study. Since emotionality drops at a slower rate than vividness, with reduced emotionality being the more important goal of EMDR therapy, the present results do not support shortening EMDR intervention at this time. If future research demonstrates that emotionality reductions are caused by vividness reductions, or that dual taxing of the early visual cortex in retrieving visual memories and eye movement is causally involved in the success of EMDR, other interventions could be devised that directly target the visual cortex while not involving eye movements.

REFERENCES


