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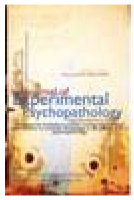

Eye Movements Enhance Recollection of Re-Imagined Negative Words: A Link Between EMDR And Sire?

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Abstract

Do eye movements primarily affect emotion, as in Eye-Movement Desensitization and Reprocessing therapy (EMDR), or memory retrieval, as in Saccade-Induced Retrieval Enhancement (SIRE)? Despite growing confidence in the effectiveness of the former, the latter memory effect is sometimes not replicated. I argue here that the memory enhancement due to eye movements can be obtained, when conditions are made more similar to EMDR: a) participants are explicitly instructed to retrieve and re-imagine the memories during the eye movements, and b) emotionally negative material is involved. An exploratory memory experiment is presented that compares horizontal eye-movement and eye-fixation conditions. Mixed lists of positive, neutral, and negative words were studied and explicitly recollected during the eye manipulation. Results showed evidence for enhanced recollection due to eye movements, with a large effect size specifically for negative words. The crosstalk between these different domains may not only be helpful for gaining a better understanding of SIRE but also for improving the effectiveness of EMDR.

Keywords: Eye Movements, EMDR, SIRE, Memory vs. Emotion, Re-imagining during Eye Manipulation

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Introduction

Eye-Movement Desensitization and Reprocessing therapy (EMDR, Shapiro, 1989), and laboratory research into the effects of eye movements (Saccade-Induced Retrieval Enhancement, SIRE) contrast sharply because the former deals with emotional processing (e.g., of anxious memories; Armstrong & Vaughan, 1996; Lee & Cuijpers, 2013) and the latter mainly with memory retrieval of emotionally neutral material (e.g., Christman, Garvey, Propper, & Phaneuf, 2003; Lyle, Logan, & Roediger, 2008; Matzke, Nieuwenhuis, van Rijn, Slagter, van der Molen, & Wagenmakers, 2015). An adversarial-collaboration replication study joining proponents and skeptics of the SIRE phenomenon (Matzke et al. 2015) however could not reproduce the SIRE effect obtained by Lyle et al. (2008). Although the manipulation in this paradigm, involving a 30 s period of eye movements at a 1 s pace, was very similar to the eye movements in a therapeutic setting, Lyle and collaborators did not refer in any way to EMDR. The to-be-retrieved material, moreover, did not consist of traumatic material, but of low-to-medium frequency, presumably affectively neutral, words. In contrast to most SIRE researchers, Matzke and collaborators explicitly linked SIRE to EMDR, but did not consider EMDR accounts and procedural characteristics of this therapy (cf, Phaf, 2016). I present an experiment here that finds the memory enhancement, primarily for negative words, when the procedure is made more similar to EMDR.

After the pioneering study of Christman et al. (2003), eye-movement effects were reported not only on word recall and recognition (e.g., Lyle et al., 2008; Lyle, Hanaver-Torrez, Hackländer, & Edlin 2012; Nieuwenhuis et al., 2013), but also on critical lure recall in the Deese-Roediger-McDermott paradigm (e.g., Parker & Dagnall, 2007; Parker, Buckley, & Dagnall, 2009), recall of autobiographical events (e.g., Parker & Dagnall, 2010), object and location memory (Brunyé, Mahoney, Augustyn, & Taylor, 2009), geographical memory (Propper, Brunyé, Christman & Januszewskia, 2012), and even on such diverse fields as attentional control in a flanker task (Edlin & Lyle, 2013) and creativity (e.g., Shobe, Ross, & Fleck, 2009). The most prominent SIRE effects were found in studies that also considered participant handedness. Lyle et al. (2008), for instance, only obtained the effect in strongly right-handed participants. Handedness seemed an important moderator of SIRE in this study, because the non-strongly right-handed participants tended to show the opposite effect. More recent research by Lyle et al. (2012) revealed that SIRE could be found for all consistent handers, irrespective of direction (i.e., right or left). As noted by Lyle and Edlin (2015), moreover, eye-movement effects tend to be much more variable with inconsistent (i.e., mixed) handers than with consistent handers, which also makes comparisons between handedness groups more difficult. In general, however, the chances of finding SIRE seem much higher in consistent handers than in mixed handers.

In the original account of SIRE effects (Christman et al., 2003) eye movements were assumed to increase the interaction between left and right hemispheres, which generally seems to take place at a lower level for consistent than mixed handers. In agreement with this hemispheric activation hypothesis, baseline memory performance is often lower in consistent than in mixed handers (Lyle et al., 2008, 2012), so that there is more room for enhancement by eye movements in the former group. The hemispheric interaction hypothesis however seems contradicted by vertical eye movements not only resulting in similar SIRE effects as horizontal eye movements (Lyle et al., 2008; Lyle & Edlin, 2015; but see Brunyé et al., 2009; Parker & Dagnall, 2007), but also in an EMDR context by having similar effects on vividness and emotionality (Gunter & Bodner, 2008). Even stronger evidence against the hypothesis may be the finding that horizontal eye movements do not increase interhemispheric EEG coherence (Samara, Elzinga, Slagter, & Nieuwenhuis, 2011).

In spite of many other studies reporting SIRE effects (e.g., Brunyé et al., 2009; Christman et al., 2003; Lyle & Edlin, 2015; Nieuwenhuis et al., 2013; Samara et al., 2011), the skeptics in the adversarial collaboration (Matzke et al., 2015) could not believe that the mere execution of 30 s of eye movements could have these striking effects on memory. The preregistered collaborative study indeed could not replicate SIRE. Although the proponents had previously obtained such effects (Nieuwenhuis et al., 2013; Samara et al., 2011), similar to the skeptics they did not analyze the underlying processes, other than the hemispheric activation theory, which they had previously dismissed (Samara et al., 2011). Considering other accounts, particularly from the EMDR domain, could have yielded further clues about the differing results. The authors of the replication attempt tried to reproduce the setup of Lyle and collaborators as closely as possible, except for the added inclusion of a three-word recency buffer at the end of the study list, and a stricter selection of affectively neutral words. I will argue that the use of buffer items at the end of the study list can restrict the concurrent activation of the words during the eye movements, and consequently may be an important cause for the failure to replicate.

Two broad categories of explanations for EMDR can be distinguished, attentional engagement (i.e., regulation) and distraction accounts. The most prominent example of the former applies the orienting response (OR, Sokolov, 1990) to EMDR (Armstrong & Vaughan, 1996; Stickgold, 2002). Bilateral eye movements would trigger repeated orienting responses that engage attention to potential threats and encourage the person to deal with them. Sokolov distinguished two responses, the alerting reaction and the investigatory reaction. The alerting or surprise reaction is elicited by sudden external stimuli, and is followed by an investigatory assessment of the stimulus source and meaning. Eye movements would eventually provide relaxation, because no danger is detected while performing these assessments. Fear arousal is thus recoded to a sense of security. The regulation account explicitly requires the anxious memories to be held active during the execution of the eye movements. Regulation is accompanied by a further memory elaboration and could thus well account for SIRE. In addition, Stickgold noted the correspondence between the OR and rapid-eye-movement (REM) processing in sleep. The re-orienting generated by eye movements would lead to a transfer and successful integration of hippocampus-based episodic memories into semantic cortical networks, which should weaken the associated affect.

Distraction accounts also require the traumatic memory to be held active during eye movements. The working-memory (WM) explanation, for instance, assumes that eye movements and the simultaneous retrieval of traumatic memories lead to an overload of visuospatial WM. The taxing results in an attenuation of emotional intensity and clarity not only of painful, but also of other emotional, memories before they are reconsolidated into long-term memory (Andrade, Kavenagh, & Baddeley, 1997; van den Hout & Engelhard, 2012; van den Hout, Muris, Salemink, & Kindt, 2001). In essence, this constitutes a valence-independent, dual-attention task with increasing load reducing performance on other tasks involving WM. Retrieval during eye movements was explicitly controlled for by van den Hout, Bartelski, and Engelhard (2013). Emotional vividness and fragment recognition only decreased for the picture that was kept in mind, but not for the other studied picture that was not retrieved during eye movements. Neither Lyle et al. (2008) nor Matzke et al. (2015) explicitly instructed their participants to retrieve the studied material during eye movements. The latter authors did refer to EMDR, but missed a crucial element of the therapeutic procedure (see Lee & Cuijpers, 2013). Without instruction, re-imagining during the eye movements probably depends on the interpretation of the experimental context, and the motivation for performing well in the memory task, of the participants.

Recently, a new account in terms of top-down attentional control emerged in the SIRE literature (Edlin & Lyle, 2013; Lyle & Edlin, 2015; Lyle & Martin, 2010). According to this account, eye movements would increase top-down attentional control both during and after their execution, and thus aid memory retrieval, particularly when retrieval is difficult. If episodic memories can be retrieved relatively easily by bottom-up cues alone, there is little need for top-down attentional control, and no SIRE effect should be observed. A possible neural basis would be the activation by eye movements of frontoparietal regions, such as bilateral frontal eye fields, intraparietal sulcus, and superior parietal lobe, which can enhance attentional processing in other areas involved for instance in memory retrieval (see Lyle & Martin, 2010). An attentional modulation of tasks, not specifically involving episodic memory retrieval, that are performed immediately after the eye movements is fairly well supported by research (e.g., Edlin & Lyle, 2013; Lyle & Orsborn; 2011; Di Noto, Uta & DeSouza, 2013). For instance, Lyle and Orsborn found enhanced famous-novel face classification of bilaterally or unilaterally presented faces due to pre-test saccadic eye movements. This effect was particular to novel faces in sRH individuals. This research moreover added to the evidence weighing against the hemispheric interaction hypothesis. The classification advantage of bilaterally presented famous faces above unilaterally presented faces (i.e., bilateral gain) is generally thought to depend on such hemispheric interaction. The bilateral gain effect was indeed obtained here, but it was not modulated by either handedness or eye movements.

At first sight, the top-down attentional control account seems to agree well with a regulation account in EMDR, such as the OR hypothesis (cf, Edlin & Lyle, 2013), but it also allows for a combination of attentional control and distraction accounts. The enhanced attentional control by eye movements primarily works on stimuli that are difficult to retrieve without such top-down control. These memory traces may be intrinsically weak, or weakened before (e.g., see Lyle & Edlin, 2015), or during the eye movements. In the latter case, the over-loading of WM by eye movements and the enhanced attentional control afterwards could be complementary mechanisms that cooperate to produce SIRE. The retrieval and re-imagining during the eye movements is, however, less essential here than in the other two accounts, because enhanced attentional control can work also on memories not retrieved during the eye movements, provided they require such top-down control for subsequent retrieval due to their difficulty. Separated from the WM hypothesis, the top-down attentional control hypothesis seems less well suited to also explain EMDR effects. Not only are the patients frequently plagued by intrusive hyper-retrieval of their traumatic memories, but the purported therapeutic effects on traumatic memories also seem to extend over longer time periods than the enhanced attentional control that applies moreover much more generally than only on these anxious memories.

The present experiment sought to contrast regulation and distraction accounts in a SIRE context, particularly with respect to emotional stimuli. EMDR accounts focus on emotional memories, whereas laboratory eye-movement research mostly employs neutral material (but see Samara et al., 2011). To further narrow the gap between these fields of research, both emotional (i.e., negative and positive) and neutral words had to be studied in this experiment. According to the OR hypothesis, recall enhancement after the eye movements would be expected primarily for negative words, provided the words are kept active during the eye manipulation. A similar provision is also essential to the WM hypothesis, but here a memory weakening, irrespective of affective valence, is expected. The top-down attentional control hypothesis entails no special position for valence, and would expect a SIRE effect for all word types, with the extent of the effect being similar for positive, neutral, and negative words, provided they are equally difficult to retrieve afterwards.

The experiment focused on SIRE but also investigated a subsidiary dopamine hypothesis supplementing regulation accounts, such as the OR hypothesis. It was tentatively assumed that eye movements would increase phasic dopamine production, through evolutionary old networks in the brain. A direct tectonigral connection from superior colliculus to substantia nigra pars compacta appears to be responsible for the short-latency elevation in dopamine due to unexpected visual events (Redgrave & Gurney, 2006). It may well correspond to an alerting signal that enables the investigatory reaction from the orienting response (see Bromberg-Martin, Matsumoto, & Hikosaka, 2010), as well as the enhanced top-down attentional control attributed to the eye movements. The duration of enhanced attentional control could, for instance, be conjectured to correspond to the decay times of elevated dopamine levels. In the absence of other, more physiological, markers to determine dopamine level, spontaneous Eye blink Rate (EBR) was assessed here, which may be a reliable measure of, at least tonic, dopamine production (e.g., Karson, 1983). Under the OR hypothesis, it could be provisionally expected that higher recall due to the eye movements would be accompanied by higher blink rates. For transparency reasons, all dependent variables measured in the experiment are reported here.

In the binary distinction between preregistered confirmatory research and exploratory research of Wagenmakers Wetzels, Borsboom, van der Maas, and Kievit (2012) the present experiment qualifies as exploratory in its entirety, because the statistical tests have not been preregistered. Wagenmakers et al. (p.635) say that “Also, we wish to emphasize that we have nothing against exploratory work per se. Exploration is an essential component of science and is key to new discoveries and scientific progress; without exploratory studies, the scientific landscape is sterile and uninspiring.“ They however also argue that this type of research invalidates the p-values. For this reason, the test statistics are omitted here and the advice of Cumming (2014) to report effect sizes (ES) and confidence intervals (CI) is followed. The CIs should however not be used as a kind of disguised significance test, whether they include zero or not, but serve estimation purposes (see also Gardner & Altman, 1986). The CIs indicate plausible lower and upper values for the point estimate and thus provide a measure of uncertainty (i.e., measurement accuracy). Estimation may be a more important research goal than hypothesis testing, certainly when the latter decisions prove to be highly fallible (Hartgerink, Wicherts, & van Assen, 2017; Ioannidis, 2005; see also Phaf, 2016). According to Cumming (p.26): “I strongly suggest that the best plan is simply to go cold turkey, omit any mention of NHST, and focus on finding words to give a meaningful interpretation of the ES estimates and CIs that give the best answers to your research questions.”

Method

Participants

Forty psychology students (18-27 yr., 27 female) from the University of Amsterdam with Dutch as first language and normal or corrected-to-normal vision participated for either course credit or a financial compensation. The study was approved by the Ethical Review Board of the Faculty of Social and Behavioral Sciences at the University of Amsterdam. All participants gave written informed consent in accordance with the Declaration of Helsinki. Persons who had undergone EMDR therapy could not participate. Handedness groups were distinguished with the Dutch handedness inventory (van Strien, 1992), ranging from -10 (extremely left-handed) to +10 (extremely right-handed). Although it was argued by Edlin et al. (2015) that it shares only 60% of the items with the Edinburgh Handedness Inventory (Oldfield, 1971), and differs in response format, it may be better suited to the Dutch context. Because in the Netherlands left-handers were often forced to write with their right hand, this item was replaced by van Strien by other items (e.g., in which hand do you hold a (tennis) racket?). Because the experiment primarily focused on consistent handers, a very strict criterion was applied for this group. It was determined that twenty-nine participants had a consistent hand preference (right score 10, N = 27; left score -10, N = 2; mean age 21.4 yr., 21 female), and eleven a mixed hand preference (score between 9 and -9; mean age 21.5 yr., 6 female). They were randomly divided over the eye-manipulation groups (14 consistent handers, 6 mixed handers performed eye-movements; 15 consistent handers, 5 mixed handers performed fixation).

Design

The memory task had a 2 x 3 mixed factorial design. Bilateral eye movement vs. fixation served as between-participants manipulation. The second independent variable concerned the within-participants manipulation of word valence, positive, neutral, or negative. Research focused mainly on the consistent handers, but results of the mixed handers are also reported. Dependent variables were number of correctly recalled words, subjective mood ratings in the different phases, and number of eye blinks per minute. False recall rates were low and did not allow for a meaningful analysis.

Material and Apparatus

Stimuli were presented against a white background in a dimly lit room on a 23″ Asus VG246HE monitor with a 1920 x 1080 resolution and 100 Hz refresh rate. Participants were comfortably seated in a height-adjustable chair. Distance from the screen during the eye manipulation was fixed at 30 cm with a chin rest.

The study list consisted of 24 positive, 24 neutral, and 24 negative words. Word emotionality was previously validated in a perceptual clarification task (Phaf, van der Leij, Stienen, & Bierman, 2006). Word categories were matched for word length and Dutch word frequency. Presentation order was determined randomly (without replacement) by the computer. The list started with three neutral words that were not scored to exclude primacy effects. Words were presented centrally in black letters (Arial font, size 32), and were displayed sequentially for 2 s with a 0.5 s interval.

Horizontal eye movements were induced by alternating a black fixation cross (+, font size 32) between left and right positions (distance 30 centimeter, 53° visual angle). It changed side every half second and appeared on each side 30 times. In the control condition, the fixation cross changed color, from red to green to blue, for 30 s every half second.

To enable counting EBR from the video recordings, participants looked at a white wall on a 1m distance for three minutes. Their eyes were filmed before and after the eye manipulation with a camcorder Toshiba Camileo x200. Mood was indicated on a 7-point scale. It had "negative" as the left label, "neutral" as the middle label and "positive" as the right label.

Procedure

Participants were informed that the influence of eye movements on memory for emotion words was investigated and that video recordings of their eyes would be made. They first completed the handedness inventory, indicated baseline mood level and their EBR was measured. Subsequently, the word list was studied for later memory testing, immediately followed by a rehearsal-preventing task (counting backwards with 3s from 300 for 3 minutes). Participants were either instructed to follow the cross alternating between left and right with their eyes (i.e., not with head movement), or fixate on the color-changing cross in the center of the screen. The explicit instruction was given to retrieve and imagine the studied words as much as possible, both during eye movements and during fixation. The execution of the eye movements was checked by the experimenter. Next, EBR was measured again. For free recall, participants wrote down as many studied words as possible on a lined piece of paper for 5 minutes, and subsequently indicated their mood. In the exit interview participants were asked for impressions and possible strategies used during the experiment.

Results

Recall (see Table 1) ranged from 5 to 33 out of 72 words, so all participants exceeded the minimum performance level in Matzke et al. (2015), and no participants had to be excluded from the analyses due to a lack of motivation. In the exit interview, all participants reported no knowledge about whether eye movements should increase or reduce memory. In addition, they all reported to have retrieved words from the study list during the eye manipulation, with the negative words being mentioned more frequently than the other word types.

Table 1: Average number of recalled words (SD) as a function of valence, eye condition, and hand preference.

	Consistent hand preference		**Mixed hand preference**	
	Bilateral	**Fixation**	**Bilateral**	**Fixation**
Neutral	6.07 (2.56)	4.73 (2.63)	3.00 (2.00)	4.20 (3.49)
Negative	7.14 (2.38)	4.33 (2.38)	3.17 (1.17)	3.20 (1.79)
Positive	4.93 (3.03)	4.07 (2.02)	3.33 (1.75)	3.20 (2.28)
Total	18.14 (6.78)	13.13 (4.91)	9.50 (3.62)	10.60 (7.13)

Conceptually replicating the results of Lyle et al. (2008, 2012), the consistent handedness group showed higher overall recall after eye movements (*M* = 18.14 ± 6.78) than after fixation (*M* = 13.13 ± 4.91; Cohen's *d* = 0.85, 95% CI M_{diff} [0.47, 9.55]). In absolute terms, this pattern seemed to reverse for the mixed-handedness group (EM: *M* = 9.50 ± 3.62, Fix: *M* = 10.60 ± 7.13; Cohen's *d* = -0.20, 95% CI M_{diff} [-9.05, 6.85]), but could only be measured with low accuracy, due to the low number of mixed handers. Contrary to the hemispheric interaction hypothesis, moreover, mixed handers showed lower overall recall (*M* = 10.00 ± 6.32) than consistent handers (*M* = 15.55 ± 5.22; Cohen's *d* = 0.92, 95% CI M_{diff} [1.58, 9.52]).

To enable a more detailed comparison with Matzke et al. (2015), the word categories were considered separately for consistent handers. The SIRE effect (i.e., increase in recall after eye movements relative to fixation) concentrated upon the negative words (Cohen's *d* = 1.18, 95% CI M_{diff} [0.99, 4.63]). Similar, but smaller, enhancements for the consistent handers seemed to occur with neutral (Cohen's *d* = 0.52, 95% CI M_{diff} [-0.64, 3.32]), and positive words (Cohen's *d* = 0.34, 95% CI M_{diff} [-1.08, 2.81]).

Subjective mood reports (Table 2) were not clearly influenced by eye movements or handedness consistency. The participants were overall positively biased with respect to the midline neutral report (4), both before (*M* = 5.23, 95% CI [4.97, 5.49]), and after (*M* = 5.03, 95% CI [4.69, 5.37]) the eye manipulation.

Table 2: Mood reports (SD) on a scale from 1 (Negative) to 7 (Positive) as a function of handedness, eye condition, and pre or post eye manipulation.

	Consistent hand preference		**Mixed hand preference**	
	Bilateral	**Fixation**	**Bilateral**	**Fixation**
Pre	5.36 (0.84)	5.27 (0.96)	5.17 (0.41)	4.80 (0.84)
Post	5.14 (1.17)	5.27 (1.03)	4.83 (0.75)	4.20 (1.30)

EBR (see Table 3) showed overall somewhat higher levels after the eye manipulation (M = 16.90 ± 9.41) than before (M = 14.07 ± 8.07; Cohen's d = 0.36, 95% CI M_{diff} [-1.52, 4.97]). There was also the suggestion of a larger increase in EBR due to eye movements (M = 4.76 ± 8.86) than to fixation (M = 1.84 ± 4.02), only for consistent handers (Cohen's d = 0.43, 95% CI M_{diff} [-2.26, 8.10]). The reverse effect for mixed handers, indicating larger increases due to fixation (M = 4.20 ± 4.30) than to eye movements (M = 0.33 ± 4.55), could only be measured with low accuracy in the experiment (Cohen's d = -1.02, 95% CI M_{diff} [-10.62, 1.55]), due to the low number of participants in this group.

Table 3: Average number of eye blink per minute (SD) as a function of handedness, eye condition, and pre or post eye manipulation.

	Consistent hand preference		**Mixed hand preference**	
	Bilateral	**Fixation**	**Bilateral**	**Fixation**
Pre	13.62 (8.09)	13.53 (8.05)	11.06 (6.13)	20.53 (9.03)
Post	18.38 (10.06)	15.38 (8.68)	10.72 (5.20)	24.73 (9.31)

Discussion

Consistent handers showed an enhancement of recollection due to eye movements, particularly for negative material, in an experiment in which they were explicitly instructed to retrieve memories during the eye manipulation. Lyle et al. (2008) did not instruct their participants to do so, but eye movements were performed immediately after study, so that some words may still have been active in working memory. Matzke and colleagues, however precluded this recency effect by incorporating a buffer of three words. If the enhancement in the experiment of Lyle et al. (2008) applied to the last words of the list that were still active in working memory, this may explain the contrasting findings. In the present experiment a rehearsal-preventing task was included, which similarly empties working memory of the words, but the distinct instruction was given to retrieve the words during the eye manipulation. This is more similar to EMDR where the patients are expressly asked to retrieve their painful memories. In view of the large enhancement effect for negative words in this study, it seems better to achieve control over memory retrieval during eye movements than to leave it open for interpretation by, and motivation of, the participants, as may have been the case with Lyle et al. and Matzke et al.

The top-down attentional control hypothesis stemming from SIRE research would not strictly require the words to be kept active during the eye movements for recall enhancement to occur. Two different versions of attentional control effects can actually be distinguished, one with memory retrieval and re-imagining during the eye movements (i.e., in combination with the WM hypothesis, see the introduction), and one without such re-imagining. In the latter version, the differential recall of emotion words would be explained by the negative words being intrinsically more difficult to retrieve afterwards, and needing more attentional control, than the neutral and positive words. This assumption however was not borne out by the current results. Recall performance after fixation for consistent handers did not reveal this difference in retrieval difficulty between the different types of words. If anything, in absolute terms recall was higher for negative than for positive words in this condition. Also the spontaneous reports in the exit interview, which indicated a preferential retrieval of negative words during the eye manipulation, did not support their absence of re-activation during the eye manipulation.

Interestingly, an alternative explanation for the contrast between the nonreplication of Matzke et al. (2015) and Lyle et al.'s (2008) Experiment 1 that words were easier to retrieve in the former and needed less top-down attentional control than in the latter, does not seem compatible with the absolute levels of recall in the no-eye movements conditions. Cross-experimental comparisons should of course be treated with caution, but the percentage recall after no-eye movements with consistent handers in Lyle et al.'s Experiment 1 (24.8 %) was higher than in Matzke et al.'s (2015) nonreplication (19.6 %), and in the present experiment (over all word types: 18.2 %). The contrast between the nonreplication and studies finding a SIRE effect can presumably better be explained by differences in re-activation during the eye manipulation. The explanation of the present enhancement effect in terms of the top-down attentional control hypothesis would moreover also seem to require a weakening of the memory representation, according to the WM-account, by the re-imagining during the eye movements.

The gap between clinical work and laboratory studies may be further narrowed by the current finding that the SIRE effect most strongly applied to negative words (for a similar finding see, Samara et al., 2011). The words in the Matzke et al. (2015) study were selected to be affectively neutral, whereas emotionality of the words was not explicitly controlled by Lyle et al. (2008). If more relatively negative words were present in the latter than in the former study, this may also partly explain the different findings. McDaniel and Bugg (2008) moreover suggested that intra-item associations are strengthened more in mixed lists (i.e., of negative, positive, and neutral words) than in pure lists (i.e., only of neutral words), leading to higher recall with the former than the latter lists. If indeed eye movements enhance intra-item elaboration, this should more readily show up in mixed than in pure lists. Another difference of the present study with the Lyle et al. and Matzke et al. studies was the much larger visual angle between the positions of the crosses in the eye-movement condition (53° vs. 27°). This experiment was, however, set up not to literally replicate the SIRE effect, but to investigate its own hypotheses concerning emotional processing, while maximizing the eye-movement effects and making the width of the eye movements more comparable to EMDR (see Shapiro, 1989). In addition to this procedural difference, the selection of negative words, and the explicit instruction to retrieve words during eye movements, seem to have strongly amplified the effect (i.e., from medium to very large) relative to the Lyle et al. study.

The enhancement for negative words may not be due specifically to their affective nature but may result from selective retrieval of notable words from the study list during the eye manipulation. The smaller, or absent, memory enhancement for positive words, even smaller than for neutral words, however, seems at odds with such selective retrieval. In agreement with a regulation account applying mainly to negative affect, these findings suggest that the eye-movement effects are specific to negative valence and not merely to all material attracting attention. Further research of course remains needed to investigate whether the selective enhancement by the eye movements is due to word conspicuousness or to negative valence, or conversely, to retrieval of negative words being more difficult, which would require enhanced top-down attentional control.

The loading of working memory by eye movements seems hard to reconcile with the present findings. Van den Hout and Engelhard (2012) noted that "But according to the WM theory, all emotional memories should lose their vividness when WM is taxed during recall. This implies that just as negative memories become less unpleasant after using 'recall + eye movements', pleasant memories should also become less pleasant." (p.729) Eye movements should, according to this distraction account, apply equally strongly to negative and positive words (cf, van den Hout et al., 2001), but this seems not the case here, at least with respect to the memory performance measured. More importantly, without assuming enhanced top-down attentional control, the taxing of working memory during retrieval should not only lead to a decrease in emotional vividness but also to a reduction in memory strength for both positive and negative words, which was again not found here. In addition, it could be argued that eye movements load visuospatial working memory, whereas words are held active in phonological (i.e., verbal) working memory. Eye movements have indeed been found to reduce memory for pictorial material (van den Hout et al., 2013), but a modality-specific working memory account probably cannot at the same time explain a memory effect on words that are held active in verbal working memory. It can also not be excluded that the distraction account applies more strongly to EMDR than to SIRE, because only with EMDR the traumatic memories may flood WM and compete with the taxing eye movements.

Recoding and regulation, and possibly enhanced attentional control, of specifically negative memories, presumably resulting from some kind of OR mechanism, seem to be the most likely candidate to account for SIRE and EMDR, as well as for the present SIRE findings. The measurements of EBR, and presumably dopamine level, did not yield clear evidence, but the similarity of the pattern of results across eye conditions and also to some degree across handedness groups is suggestive of the same processes being active. Spontaneous EBR, however, is thought to primarily reflect tonic dopamine level (e.g., see Slagter, Georgopoulou, & Frank, 2015), which only indirectly modulates the phasic dopamine level that is assumed to be enhanced by eye movements. There remains a clear need to extend the range of dependent variables in eye-movement research and to focus more directly on emotional measures. Lee and Cuypers (2013) obtained moderate to large effect sizes, primarily on emotional vividness, in their meta-analysis, but also noted that there was an over-reliance on subjective report. It would be worthwhile to pursue more implicit affective dependent variables, such as evaluation speed (see Fazio, Sanbonmatsu, Powell, & Kardes, 1986) or approach-avoidance tendencies (see Phaf, Mohr, Rotteveel, & Wicherts, 2014) in future laboratory studies on eye movements.

It remains largely unexplained why handedness should modulate the SIRE effect, if the interhemispheric activation hypothesis does not hold. Some intriguing clues were however provided by the fMRI study of Petit et al. (2015), which was suggested to me by the reviewer Keith Lyle. The study suggested that eye dominance rather than handedness, to which it is positively correlated, controls the execution of saccades. Contrary to the contralateral organization of handedness, eye dominance and saccades appear to be ipsilaterally controlled. In support of this notion, Petit and collaborators observed the strongest right-biased hemispheric asymmetry in a visually guided saccade task with strongly left-handed, but right-eye dominant, participants. Because eye dominance was not controlled for in the SIRE studies, this indeed leaves open the possibility that the number of cross-lateralized hand-eye dominant participants varied between studies leading to different SIRE effect sizes.

Even if eye dominance would matter more to SIRE than handedness, the results of Petit et al. (2015) do not clearly support the hemispheric interaction theory. The strongly right-handed participants, who had 86.6 % right eye preference and constitute the majority in most SIRE experiments, overall showed almost no hemispheric asymmetry in their study. Conversely, mixed handers, irrespective of eye dominance, revealed the same rightward asymmetry as strong left-handers. Contrary to the hemispheric interaction hypothesis, moreover, in the present experiment consistent handers had a higher overall memory performance than mixed handers, but the SIRE effect was again specific to consistent handers (cf, Lyle et al., 2008, 2012). It should be noted however that the number of mixed handers in this study was too small, and the results with this group generally too variable (see Lyle & Edlin, 2015), to draw clear conclusions about this group.

It may be speculated that eye dominance corresponds to the lateralization of the orienting response. Kinsbourne and Lempert (1979) have argued that left-brain language lateralization, which is mostly the case in right-handed persons, arises from right-biased orienting to salient percepts, suggesting that also the orienting response is lateralized. The correspondence between the ipsilateral neural centers controlling eye movements and those responsible for the orienting response may well determine the SIRE effect. If the eye movements activate the same-hemisphere orienting centers, possibly through the alerting by a direct dopaminergic tectonigral connection from superior colliculus to substantia nigra (cf, Bromberg-Martin et al., 2010), this may effectuate the emotional regulation observed in EMDR and the memory enhancement found in SIRE. Evidently, much more research needs to be done to investigate the role of eye dominance and of phasic dopamine levels in eye-movement effects. At present there do not even seem to be studies transposing the lab findings to the clinical domain, for instance by investigating whether EMDR is more effective in consistent than mixed handers. The other way round, making SIRE conditions more comparable to EMDR, for instance by re-imagining the memories during the eye movements, seems to strongly amplify the former effect. The crosstalk between different domains may thus be very fruitful, not only for gaining a better understanding of SIRE but also for improving the effectiveness of EMDR.

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