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How eye movements affect unpleasant memories: Support for a working-memory account

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ABSTRACT

Eye movement desensitization and reprocessing can reduce ratings of the vividness and emotionality of unpleasant memories—hence it is commonly used to treat posttraumatic stress disorder. The present experiments compared three accounts of how eye movements produce these benefits. Participants rated unpleasant autobiographical memories before and after eye movements or an eyes stationary control condition. In Experiment 1, eye movements produced benefits only when memories were held in mind during the movements, and eye movements increased arousal, contrary to an investigatory-reflex account. In Experiment 2, horizontal and vertical eye movements produced equivalent benefits, contrary to an interhemispheric-communication account. In Experiment 3, two other distractor tasks (auditory shadowing, drawing) produced benefits that were negatively correlated with working-memory capacity. These findings support a working-memory account of the eye movement benefits in which the central executive is taxed when a person performs a distractor task while attempting to hold a memory in mind.

Introduction

Eye movement desensitization and reprocessing (EMDR) is a psychological treatment for posttraumatic stress disorder (PTSD), an anxiety disorder that can develop after exposure to events that evoke intense fear, horror, or helplessness (American Psychiatric Association, 2000). Since 1990, thousands of clinicians have been trained in the use of EMDR procedures (Cahill, Carrigan, & Frueh, 1999), and EMDR has become a more complex and integrative form of therapy (Shapiro, 2001, 2002). The present work examined how one component of EMDR—eye movements—affects participants' reactions to their memories of unpleasant events.

The current treatment manual for EMDR is Shapiro (2001). During EMDR, the therapist asks the client to hold a distressing memory in mind along with accompanying emotions and a negative cognition associated with the memory. The therapist concurrently provides some form of bilateral stimulation. Most commonly, horizontal eye movements are elicited by having the client follow a repetitive side-to-side motion of the therapist's index finger. A set of 20 or more eye movements is performed while the memory is held in mind. The client then reports current sensations, cognitions, and emotions. Sets are repeated until the client reports minimal distress associated with the memory. The therapist then guides the client to replace the negative cognition with a client-generated positive one. Alternate forms of bilateral stimulation such as vertical or diagonal eye movements (Shapiro, 2001), lightly tapping the client's hands (Shapiro, 2001), or auditory

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tones (EMDRIA, 2000; Servan-Schreiber, Schooler, Dew, Carter, & Bartone, 2006) can be used if horizontal eye movements are not effective.

The EMDR debate and how to address it

Seldom has a psychological treatment received such a widely divergent reaction from the scientific and professional community (Perkins & Rouanzoin, 2002). Strong claims about EMDR's clinical efficacy emerged relatively quickly and were challenged with similar verve (see Lohr, Lilienfeld, Tolin, & Herbert, 1999; Shapiro, 1996). On the one hand, EMDR is one of the most extensively researched psychological interventions for PTSD (Maxfield & Hyer, 2002; Shapiro, 2002). Meta-analyses of outcome studies suggest that EMDR is an efficacious PTSD treatment (Bisson et al., 2007; Davidson & Parker, 2001; Van Etten & Taylor, 1998), perhaps as effective as cognitive–behavioral/exposure therapies (e.g., Ironson, Freund, Strauss, & Williams, 2002; Lee, Gavriel, Drummond, Richards, & Greenwald, 2002; Rothbaum, Astin, & Marsteller, 2005; Taylor et al., 2003). The American Psychological Association recognizes EMDR as a ''probably efficacious'' treatment for civilian PTSD (Chambless & Ollendick, 2001), and the American Psychiatric Association (2004) has given EMDR its ''highest level of recommendation'' for the treatment of trauma.

On the other hand, McNally (1999) has dismissed EMDR as ineffective, citing non-supportive studies (e.g., Devilly & Spence, 1999) and suggesting that further efficacy research is unnecessary. Other critics have argued that EMDR may simply be a well-packaged psychological placebo (Lohr et al., 1999) or a variant of cognitive–behavioral/exposure therapy (Herbert et al., 2000). Some have even accused EMDR practitioners of promoting a dubious practice (see Perkins & Rouanzoin, 2002).

An understanding of how eye movements contribute to the effectiveness of EMDR is currently lacking (e.g., Barrowcliff, Gray, MacCulloch, Freeman, & MacCulloch, 2003; Kuiken, Bears, Miall, & Smith, 2002; Muris & Merckelbach, 1999). The claim that eye movements provide a key curative factor lacks face validity, and our limited understanding of *how* EMDR works has injured its credibility. Providing empirical support for one or more accounts of the role of eye movements in EMDR's treatment mechanism will help clarify the procedure, and might ultimately help resolve the EMDR debate (McNally, 2001). In addition, understanding the treatment mechanism will allow EMDR to be further refined (Shapiro, 2001).

Accounts of eye movement benefits in EMDR

Several experiments with non-clinical populations have found that voluntary eye movements can make unpleasant images less vivid and emotional (e.g., Andrade & Baddeley, 1993; Merckelbach, Hogervorst, Kampman, & de Jongh, 1994; Muris & Merckelbach, 1999). Eye movements can also reduce the vividness and emotionality of unpleasant autobiographical memories, relative to both focusing on the memory alone and focusing on the memory while holding the eyes stationary (e.g., Andrade, Kavanagh, & Baddeley, 1997; Barrowcliff, Gray, MacCulloch, Freeman, & MacCulloch, 2004). Shapiro and others have suggested possible neuropsychological mechanisms (e.g., ''alignment'' of perceptual and meaning details in the traumatic memory; Marquis, 1991; Shapiro, 1989) but most of these early proposals have proven difficult to test (see Armstrong & Vaughan, 1996). We next describe three major accounts of how eye movements ameliorate negative reactions to unpleasant autobiographical memories reviewed by Shapiro (2001).

The working-memory account

Working memory is a multicomponent system (e.g., Baddeley, 1986; Baddeley & Hitch, 1974; Conway, Kane, & Engle, 2003). At the center of the system is the *central executive*, a general processor that carries out higher-order cognitive functions (e.g., planning, problem solving; Engle, 2002). Working memory also includes two subsystem ''buffers'' where the central executive can allocate information to be held online for later use. The *phonological loop* stores verbal and auditory information and the *visuospatial sketchpad* (*VSSP*) stores visuospatial information. It has been suggested that the VSSP is where memories are held in mind during EMDR sessions (Andrade et al., 1997; Kavanagh, Freese, Andrade, & May, 2001).

The working-memory account of the eye movement benefits (Andrade et al., 1997; Kavanagh et al., 2001) posits that images of unpleasant memories are held in the VSSP and that these images become less vivid when eye movements concurrently use up processing resources in the VSSP. This reduced vividness then cascades into reduced emotionality. Performing eye movements while holding a memory in mind therefore constitutes a dual task or divided attention manipulation.

Andrade et al. (1997) compared the effects of 8 s of horizontal eye movements, finger tapping, or a no-movement (exposure alone) control condition on the vividness and emotionality of autobiographical memories. Participants remembered positive and negative autobiographical events in turn, and rated their vividness and emotionality before and after holding a given memory in mind during the 8 s manipulation. Eye movements and tapping each reduced vividness and emotionality relative to the control condition, and eye movements produced larger reductions than tapping. Andrade et al. (1997) argued that eye movements and tapping each taxed the VSSP, but that eye movements were more effective because they feature a visual component in addition to a motor/spatial component and are therefore more taxing (see also Baddeley & Andrade, 2000).

Van Den Hout, Muris, Salemink, and Kindt (2001) used the same design and conditions as Andrade et al. (1997) but their manipulation lasted substantially longer (90 s). Eye movements reduced the vividness/emotionality of memories relative to tapping, but here tapping did not differ from the control condition. Given that tapping should tax the VSSP (e.g., Andrade et al., 1997), its ineffectiveness is problematic for the working-memory account. However, Van den Hout et al.'s tapping task was considerably less taxing than the one used by Andrade et al. (1997).

In a similar study, Kavanagh et al. (2001) compared horizontal eye movements, passive visual interference (watching a shifting display of black and white squares), and a no-task control condition. Eye movements reduced the vividness and emotionality of distressing memories relative to the no-task control, and passive visual interference provided an intermediate benefit. At a 1-week follow-up, Kavanagh et al. (2001) found that re-ratings were still significantly reduced from baseline and, surprisingly, these reductions were now comparable for all three treatments. Kavanagh et al. suggested that exposure alone (i.e., holding a memory in mind and focusing on it) and exposure in conjunction with eye movements produced similar benefits because eye movements are not directly therapeutic. Eye movements instead constitute a "cognitive performance aid", which helps clients to engage in active treatments such as exposure, perhaps by modulating arousal such that clients are better able to tolerate holding aversive memories in mind. However, it could also be argued that eye movements should produce greater long lasting gains than an equivalent amount of exposure without eye movements, if they help people better tolerate and engage in exposure. Kavanagh et al. (2001) conceded that the lack of differences at follow-up could also be due to their brief exposure durations or small sample size.

Maxfield (2004) had participants perform either slow or fast eye movements while holding unpleasant memories in mind. Consistent with a working-memory account, fast eye movements resulted in larger decreases in vividness and emotionality, and both types outperformed a control condition. Maxfield reasoned that fast eye movements are more difficult to perform and thus more taxing on the VSSP.

The investigatory-reflex account

MacCulloch and Feldman (1996) proposed that eye movements activate an innate "investigatory reflex" that inhibits fear and permits exploratory behavior (i.e., the orienting response; see Armstrong & Vaughan, 1996). This reflex consists of two stages. The first stage is a reflexive pause, which produces a strong sense of relaxation and pleasant visceral sensations that can become associated with an unpleasant memory. This stage reduces fear through conditioning (e.g., Dyck, 1993) but does so more efficiently than conventional exposure therapy (see Rogers & Silver, 2002; Vaughan, Wiese, Gold, & Tarrier, 1994). The second stage is reflexive exploration, in which attention and other cognitive processes become more flexible, focused and efficient. This second stage is thought to produce the idiosyncratic shifts in emotion and cognition that often occur during EMDR (Kuiken et al., 2002; MacCulloch & Feldman, 1996).

Support for the first stage of the investigatory reflex comes from two studies by Barrowcliff and colleagues. Barrowcliff et al. (2003) found that eye movements reduced physiological arousal induced by exposure to aversive high-pitched tones. Although this decrease in arousal is consistent with the claim that eye movements are directly relaxing, it is also consistent with the claim that eye movements simply divert attention away from aversive stimuli. Barrowcliff et al. (2004) found reduced vividness/emotionality of unpleasant autobiographical memories, as well as reduced electrodermal arousal (galvanic skin response) after eye movements compared with an eyes stationary/focusing control condition. Importantly, eye movements produced similar decreases in the vividness/emotionality of positive autobiographical memories, but without decreasing arousal. Barrowcliff et al. (2004) noted that the working-memory account cannot explain why eye movements decreased electrodermal arousal only when negative memories were held in mind, but that the investigatory reflex cannot explain why decreased ratings occurred for positive memories. Barrowcliff et al. (2004) suggested that disruption of working memory and the investigatory reflex may both contribute to EMDR's beneficial effects.

Increased hemispheric communication (IHC) account

This account proposes that horizontal eye movements increase communication between the left and right hemispheres of the brain, thus enhancing a person's ability to remember an unpleasant event while not being negatively aroused (Christman, Garvey, Propper, & Phaneuf, 2003). Horizontal eye movements appear to reduce preexisting asymmetries in hemispheric activation (e.g., Bakan & Svorad, 1969), and have also been shown to enhance episodic memory (e.g., Christman & Propper, 2001). Consistent with the IHC account, Christman et al. (2003; see also Christman, Propper, & Dion, 2004) found that horizontal eye movements improved recognition relative to a control condition whereas vertical eye movements, which do not enhance IHC, had no such effect.

Christman et al. (2003) reasoned that if that eye movements enhance recognition accuracy, they might also help clients retrieve memories of traumatic events, which could then be treated using techniques such as exposure. In addition, IHC has been hypothesized to reduce client distress (Christman et al., 2003) and to alleviate stress and negative affect (Compton & Mintzer, 2001). Heller, Etienne, and Miller (1995) proposed that language processes located in the left hemisphere might reduce anxious arousal originating in the right hemisphere. It is therefore possible that eye-movement-elicited IHC may provide a mechanism for desensitizing distressing memories.

The present experiments

The goal of the present experiments was to compare these three accounts of how eye movements produce their beneficial effects. Participants remembered unpleasant autobiographical events and provided initial ratings of their vividness, emotionality, and a novel rating—completeness (e.g., Andrade et al., 1997; Barrowcliff et al., 2003; van den Hout et al., 2001). Clinicians have observed that traumatic memories often seem less complete during eye movements, such that details are lost, or the mental images seem fragmented or smaller (Shapiro, 2001); the present experiments provided the first test of this observation. The effect of eye movements on these ratings was then examined relative to an eyes stationary control condition. Physiological arousal was also measured in Experiments 1 and 2 to evaluate the investigatory-reflex account. Experiment 1 compared the working-memory and investigatory-reflex accounts. Experiment 2 used a similar design to compare the working-memory and IHC accounts. Finally, Experiment 3 compared the magnitude of the benefits produced by horizontal eye movements relative to two others tasks that disrupt working memory. Participants in Experiment 3 also completed a reading span task designed to measure working-memory capacity (Engle, Tuholski, Laughlin, & Conway, 1999), which was correlated with the benefit participants derived from the manipulation they received.

Experiment 1

Experiment 1 compared the working-memory and investigatory-reflex accounts of the eye movement benefits. Shapiro (2001) noted that teasing these accounts apart may be challenging because they were designed to explain the same phenomena. However, the working-memory account predicts that eye movements should reduce vividness and emotionality *only when eye movements and remembering coincide* (Andrade et al., 1997; Van Den Hout et al., 2001). Only when the memory is in the VSSP should it be subject to interference by other tasks competing for limited processing resources. In contrast, the investigatory reflex is said to evoke a strong relaxation response as well as increased attentional flexibility that remain active for up to 10 min after eye movements have ceased (Kuiken et al., 2002). If so, reduced ratings should still be detected when an unpleasant memory is brought to mind very soon after completing a set of eye movements (although the reflex might well be more effective when it coincides with remembering). To test these predictions we therefore manipulated whether participants held unpleasant memories in mind during eye movements.

Experiment 1 also included a psychophysiological measure of arousal—high-frequency heart rate variability (HF-HRV)—to examine the physiological effect of eye movements as well as whether reductions in ratings correspond to reductions in arousal (cf. Barrowcliff et al., 2004). Heart rate variability refers to beat-to-beat alternations in heart rate (Offerhaus, 1980). The high-frequency (0.12–0.40 Hz) component of HRV, derived through power spectrum analysis, provides an index of parasympathetic nervous system functioning (e.g., Hughes & Stoney, 2000). Higher HF-HRV scores (hereafter, *arousal scores*) are thus indicative of *lower* levels of physiological arousal (i.e., greater relaxation). Numerous studies suggest a link between low levels of HF-HRV and the experience of emotions such as anxiety and anger, supporting use of HF-HRV as a measure of arousal (e.g., Kawachi, Sparrow, Vokonas, & Weiss, 1995).

Barrowcliff et al. (2004) found that eye movements decreased a galvanic skin response measure of arousal, but they did not examine whether this decrease correlated with the magnitude of the eye movement benefits. If reduced arousal underlies the eye movement benefits, then higher HF-HRV arousal scores should be associated with larger eye movement benefits. In contrast, the working-memory account does not make a specific prediction about the effect of eye movements on arousal. Although arousal might decrease along with participants' ratings of emotionality, mental load or performing complex cognitive tasks has been found to *increase* arousal (see Kawachi, 1997). Performing eye movements while holding a memory in mind is challenging and potentially stressful. If so, arousal might increase relative to a control condition that imposes less mental load.

Method

Participants

Thirty-six University of Calgary undergraduates participated for course credit (mean age was 21; 25 were females; 28 were Caucasian, 8 were Asian).

Design

Experiment 1 constituted a 2 (treatment: eye movement vs. eyes stationary) $\times$ 2 (group: in-mind vs. not-in-mind) mixed model factorial design. The *in-mind* group ($n = 18$) held each unpleasant memory in mind during each treatment trial, whereas the *not-in-mind* group ($n = 18$) did not. Assignment to group was random. Participants were tested in both the eye movement and the eyes stationary condition (two memories each). A program assigned each memory to treatment by attempting to balance all three baseline ratings across the two conditions. Baseline ratings of vividness, emotionality, and completeness did not differ for memories assigned to the eye movement versus eyes stationary conditions in any of the reported experiments (all Fs < 1). The order of the two eye movement trials and two eyes stationary trials was counterbalanced across participants using a Latin square, resulting in six permutations.

Materials and procedure

Participants were tested individually in front of a computer screen. A Polar S810i heart rate monitor (*Polar Electro*, Helsinki, Finland) was attached to their chest. Participants then chose four memories from their past that still made them feel fearful, distressed, or anxious according to the following protocol adapted from Van den Hout et al. (2001):

> Please recall an occasion that made you very fearful, anxious, or distressed. This occasion should still have some emotional impact. Examples of this type of occasion include going unprepared into an examination or witnessing an accident. When you have an occasion in mind, please write a few sentences describing the occasion on the sheet provided. Please do this until you have described four occasions.

The experimenter was absent during this phase (about 10 min) to provide participants with an opportunity to recall and write in privacy.

Following the initial memory collection phase, participants were instructed to remember each experience in turn:

> Form an image or memory of the event described on your sheet, and keep your eyes open. Remember where it happened, who was present, and anything else you can think of. Bring it to mind as vividly as if it were happening right now.

After participants indicated a memory was formed they verbally rated its vividness (1 = not at all clear, 10 = extremely clear), emotionality (1 = not at all distressing, 10 = extremely distressing), and completeness (1 = not at all complete, 10 = extremely complete).

On each treatment trial, the participant either fixated on a 1 cm stationary white circle (eyes stationary trial) or followed the circle blinking from one side of the screen 21.5 cm across to the other (eye movement trial) for four periods of 24 s each. Eye movements occurred at a rate of approximately 1 movement per second. There was a 10-s rest between each 24-s period. The in-mind group then re-rated each memory, whereas the not-in-mind group retrieved the indicated memory and then re-rated it. Heart rate variability was measured throughout each trial. On in-mind trials, heart rate was measured from when recall of the memory was requested until the last re-rating. On not-in-mind trials, heart rate was measured from when eye movements or fixation began until the last re-rating. Both trial periods thus included the retrieval of the memory, the treatment, and the re-rating process. Before debriefing, participants retrieved and rated a pleasant autobiographical memory to help mitigate any emotional distress.

Results

For each memory, one difference score per rating was computed by subtracting the post-rating from the pre-rating. Ratings of the two memories in each condition (eye movements, eyes stationary) were then averaged for each participant. Fig. 1 depicts the mean difference scores in each condition/group, which were analyzed; analysis of the post-ratings alone yielded the same findings. The pre- and post-ratings for each experiment are available from the first author upon request. The order of eye movement and eyes stationary trials did not significantly affect the results here or in the remaining experiments, nor did the measured demographic variables (gender, age, ethnicity), so these variables were not included in the reported analyses. The significance level for all analyses was set at $p < .05$.

Nature of the unpleasant memories

Participants were encouraged to choose memories that were as unpleasant as possible, but they were reminded that the choice of memories was theirs. Remembered incidents ranged in severity from missed examinations or arguments to serious car accidents, assaults, and even the experience of being tortured in another country. Although PTSD symptoms were not measured during the experiment, many of the memories were of experiences that could produce PTSD in vulnerable individuals.

Ratings

A 3 (rating: vividness vs. emotionality vs. completeness) × 2 (group: in-mind vs. not-in-mind) × 2 (treatment: eye movements vs. eye stationary) split-plot analysis of variance (ANOVA) was performed on the mean pre-minus-post rating changes. The main effect of rating was not significant, $F(2, 68) = 1.94$, MSE = .64, $p = .15$, $\eta^2 = .05$, nor were the interactions between rating and treatment, or rating and group, Fs < 1. Thus, eye movements had a similar effect on all three ratings (as indicated by the 95% confidence intervals in Fig. 1; see Loftus & Masson, 1994).

The main effect of group was significant, $F(2, 34) = 13.02$, MSE = 3.17, $\eta^2 = .31$, reflecting a larger decrease in ratings in the in-mind group than in the not-in-mind group (.99 vs. .07). There was also a trend toward a main effect of treatment, $F(2, 34) = 2.96$, MSE = 4.06, $p = .09$, $\eta^2 = .09$, such that eye movements produced larger rating changes than the control (.78 vs. .28). However, these effects were qualified by an important interaction between treatment and group,

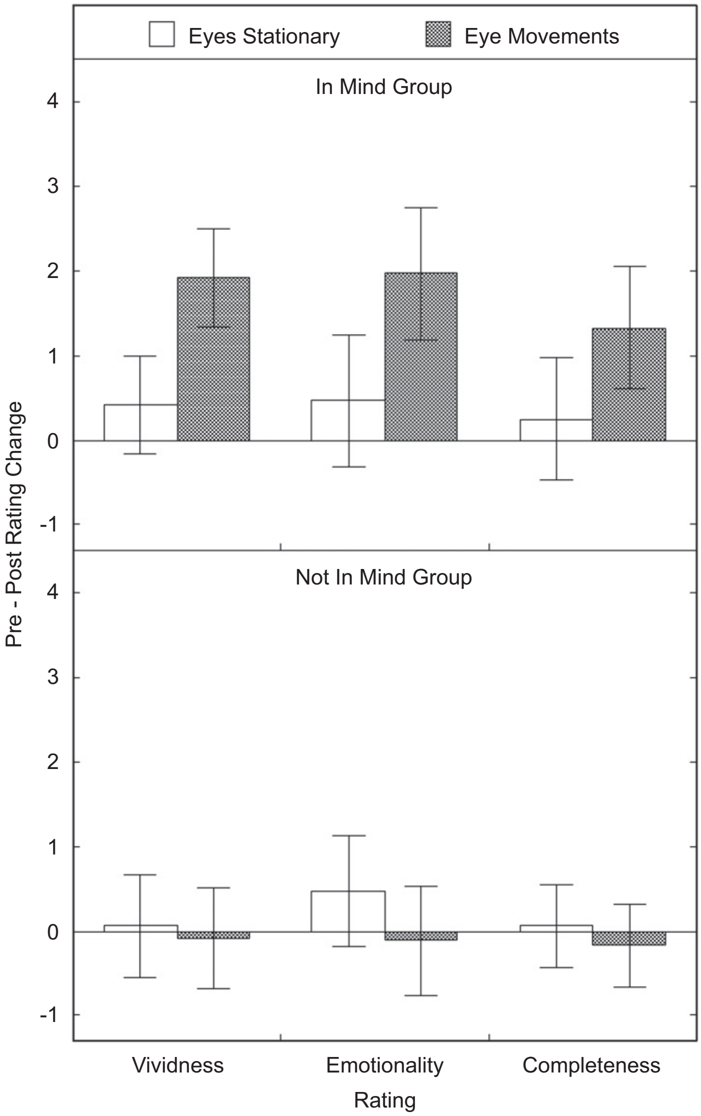

Fig. 1. Mean pre-minus-post changes in ratings of vividness, emotionality, and completeness for each treatment in each group in Experiment 1. The 95% within-subjects confidence intervals indicate, for each pair of bars, the extent to which the eyes stationary and eye movement means differed.

$F(2, 34) = 9.06$, MSE = 4.06, $\eta^2 = .23$. Follow-up ANOVAs indicated that eye movements reduced ratings of unpleasant memories in the in-mind group relative to control (1.68 vs. .30), $F(1, 17) = 8.82$, MSE = 5.15, $\eta^2 = .37$, but they had a non-significant effect in the not-in-mind group relative to control (−.12 vs. .25), $F(1, 17) = 1.14$, MSE = 2.96, $p = .30$., $\eta^2 = .07$. The absence of significant rating changes in the not-in-mind group is problematic for the investigatory-reflex account, because the benefits of this reflex should still have been operative (e.g., Kuiken et al., 2002). A working-memory account readily accommodates these results, however, because the VSSP would not have been taxed in the not-in-mind group. The three-way interaction between rating, treatment, and group was not significant, $F < 1$.

Arousal scores

Arousal scores were calculated as the natural log of the HF-HRV scores (the relevant area under the power spectrum in m s^2; Hughes & Stoney, 2000). The two arousal scores in each condition were averaged to produce two mean arousal scores per participant. These scores appear in Fig. 2 and were analyzed using a 2 (treatment: eye movements vs. eye stationary) × 2 (group: in-mind vs. not-in-mind) split-plot ANOVA.

There was a significant main effect of treatment, $F(1, 34) = 29.64$, MSE = .05, $\eta^2 = .47$, such that eye movements were associated with *more* arousal (i.e., *less* parasympathetic nervous system activation) than holding the eyes still (6.20 m s^2 vs. 6.48 m s^2). This result contradicts Barrowcliff et al.'s (2004) finding that eye movements *reduced* electrodermal arousal, and it is problematic for the investigatory-reflex account which claims that eye movements are de-arousing. The main effect of

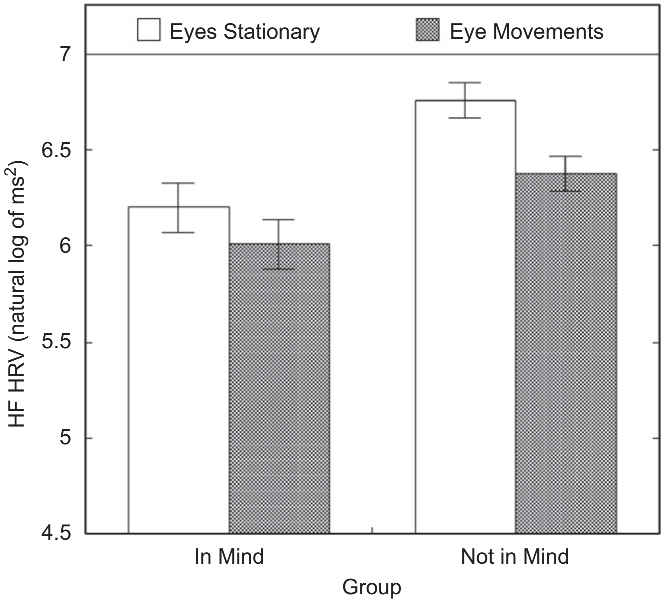

Fig. 2. Mean high-frequency heart rate variability scores in Experiment 1. The 95% within-subjects confidence intervals indicate, for each pair of bars, the extent to which the eyes stationary and eye movement means differed.

group was not significant, $F(1, 34) = 1.47$, MSE = 3.31, $p = .28$, $\eta^2 = .03$, but there was a trend toward an interaction between group and treatment, $F(1, 34) = 3.15$, MSE = .05, $p = .08$, $\eta^2 = .08$. The latter trend reflected a somewhat larger arousing effect of eye movements in the not-in-mind group (6.38 m s^2 vs. 6.76 m s^2) compared with the in-mind group (6.01 m s^2 vs. 6.20 m s^2).

Finally, the mean arousal scores during eye movement trials did not correlate significantly with reductions in ratings of vividness, $r = .16$, emotionality, $r = .21$, or completeness, $r = .20$, F's < 1.

Discussion

Consistent with a working-memory account, eye movement benefits occurred in the in-mind group (who held the memories in mind during eye movements), but not in the not-in-mind group (who brought the memories to mind and re-rated them immediately after eye movements ceased). Eye movements were also associated with more arousal (i.e., less parasympathetic nervous system activity) than the eyes stationary control condition. These two findings cast doubt on the proposal that the eye movement benefits are due to the deep sense of relaxation said to constitute the first stage of the investigatory reflex (MacCulloch & Feldman, 1996). If eye movements induced deep relaxation, and if this relaxation were the source of the eye movement benefits, then the not-in-mind group should have reported benefits as well.

Experiment 1 also renders another explanation of the eye movement benefits less plausible. Eye movement benefits could be due, at least in part, to participants' expectancies. For example, participants might infer that the researcher expects decreases in their ratings following eye movements, and may thus provide them despite not experiencing true phenomenological changes. This *demand-characteristics account* resembles the argument that EMDR produces its benefits via a placebo effect or by otherwise altering client expectancies as opposed to changing their "true" experiences of their memories (e.g., Lohr et al., 1999). The absence of eye movement benefits in the not-in-mind group challenges this account. The not-in-mind group would have generated the same expectancy yet they did not provide lowered ratings.

The increased arousal following eye movements may itself be a therapeutic mechanism. Armstrong and Vaughan (1996) argued that eye movements might intensify a client's focus on a traumatic memory and thereby make exposure more effective by extinguishing negative emotional responses more rapidly. However, higher arousal scores were not associated with larger decreases in ratings from pre- to post-intervention. Although our small sample size must be acknowledged, we did not find evidence that increased arousal is a major contributor to the eye movement benefits. Additionally, increased arousal also occurred in the not-in-mind group, yet significant eye movement benefits were not found. Increased arousal thus may be an epiphenomenon of eye movements that does not relate to their capacity to alter people's reactions to their unpleasant memories.

Experiment 2

The working-memory and IHC accounts make different predictions about the effect of vertical eye movements on unpleasant memories. The IHC account proposes that IHC is the mechanism underlying the eye movement benefits.

Vertical eye movements, which do not increase IHC, should thus be ineffective (e.g., Christman et al., 2003). In contrast, the working-memory account predicts that both horizontal and vertical eye movements should be effective because both should fill the VSSP. Although the latter account does not predict a difference in their effectiveness, if vertical eye movements are less practiced, they might be more cognitively demanding and hence more effective. Clinical experience suggests that both types of eye movements are effective (Shapiro, 2001), but Experiment 2 provides the first empirical comparison.

Participants performed horizontal or vertical eye movements while holding unpleasant memories in mind. They also re-rated their memories one week later to examine whether eye movement benefits are lasting. If eye movements directly contribute to EMDR's efficacy, their effects should be observable at follow-up. As described earlier, Kavanagh et al. (2001) found that eye movements and exposure alone were equivalently effective at a 1-week follow-up. Experiment 2 featured a longer exposure duration per memory than Kavanagh et al.'s (96 s vs. 64 s), to test their suggestion that the equivalence they obtained at follow-up may have been due to the brevity of their exposure duration.

Method

Participants

Thirty-six University of Calgary undergraduates (mean age of 22; 23 females; 22 were Caucasian, 14 were Asian) were randomly assigned to the *horizontal* or *vertical* group ($n = 18$ each).

Materials, design, and procedure

The Experiment 1 method and design were used, except here the between-subjects manipulation was eye movement type (horizontal vs. vertical); both groups kept a memory in mind during each trial. Participants returned to the lab exactly 1 week after the initial testing session to retrieve and re-rate each of the memories in the same order. They were instructed to rate their memories as they seemed at present, as opposed to how they seemed the previous week. Three participants did not return for this follow-up (one from the horizontal group, two from the vertical group).

Results

Pre-minus-post rating change scores (Fig. 3) were computed and analyzed as in Experiment 1; the follow-up scores (Fig. 4) were computed as the pre-rating minus the follow-up rating. Analysis of the post-ratings alone yielded the same pattern of findings.

Ratings immediately post-intervention

A 3 (rating: vividness vs. emotionality vs. completeness) $\times$ 2 (treatment: eye movements vs. eye stationary) $\times$ 2 (group: horizontal vs. vertical) split-plot ANOVA was performed on the mean rating changes. The main effect of rating type was not significant, $F < 1$, nor was the interaction of rating type with either group or treatment, F's < 1. There was a robust main effect of treatment, $F(1, 34) = 28.16$, MSE $= 5.21$, $\eta^2 = .45$, reflecting a greater reduction in ratings following eye movements than following the control condition (1.76 vs. .11). The main effect of group was not significant, $F(1, 34) = 1.24$, MSE $= 9.30$, $p = .27$, $\eta^2 = .04$, and the key interaction between treatment and group was not significant, $F < 1$. Horizontal and vertical eye movements were equally effective at reducing memory ratings relative to the control condition, and this benefit was roughly the same on all three ratings (see the 95% confidence intervals in Fig. 3). Given that both types of movement should tax the VSSP, the working-memory account can explain why both types of movement produce benefits. In contrast, the effectiveness of vertical eye movements, which do not increase IHC, is problematic for the IHC account. The three-way interaction between treatment, rating, and group was not significant, $F < 1$.

Ratings at 1-week follow-up

Parallel analyses were conducted to ascertain whether the eye movement benefits found immediately post-intervention persisted after 1 week. At follow-up there was a significant main effect of rating type, $F(2, 31) = 5.19$, MSE $= .94.$, $\eta^2 = .13$. The reduction was largest on the emotionality rating (emotionality $= 1.22$, vividness $= .70$, completeness $= .85$), but rating type did not feature in any significant interactions, F's < 1. The eye movement benefits persisted at follow-up, in that there was a significant main effect of treatment (1.31 vs. .54), $F(1, 31) = 5.96$, MSE $= 4.92$, $\eta^2 = .16$ (cf. Kavanagh et al., 2001). The size of the benefits did not differ between the horizontal and vertical groups, in that the interaction between treatment and group was not significant, $F < 1$. Once again, the three-way interaction was not significant, $F < 1$.

Although the eye movement benefits persisted at follow-up, the benefits appeared to be smaller than those observed immediately post-intervention. A 2 (time: immediate vs. follow-up) $\times$ 2 (group: horizontal vs. vertical) $\times$ 3 (rating type: vividness vs. emotionality vs. completeness) ANOVA tested this possibility. The main effect of group was non-significant, $F < 1$, as were the interactions between group and rating type, $F < 1$, and group and time, $F = 1.29$, MSE $= 8.93$, $p = .58$, $\eta^2 = .04$. Eye movement type thus did not appreciably affect the size of the benefits on either immediate or follow-up scores. The main effect of rating type was also non-significant, $F < 1$. However, the main effect of time was marginal,

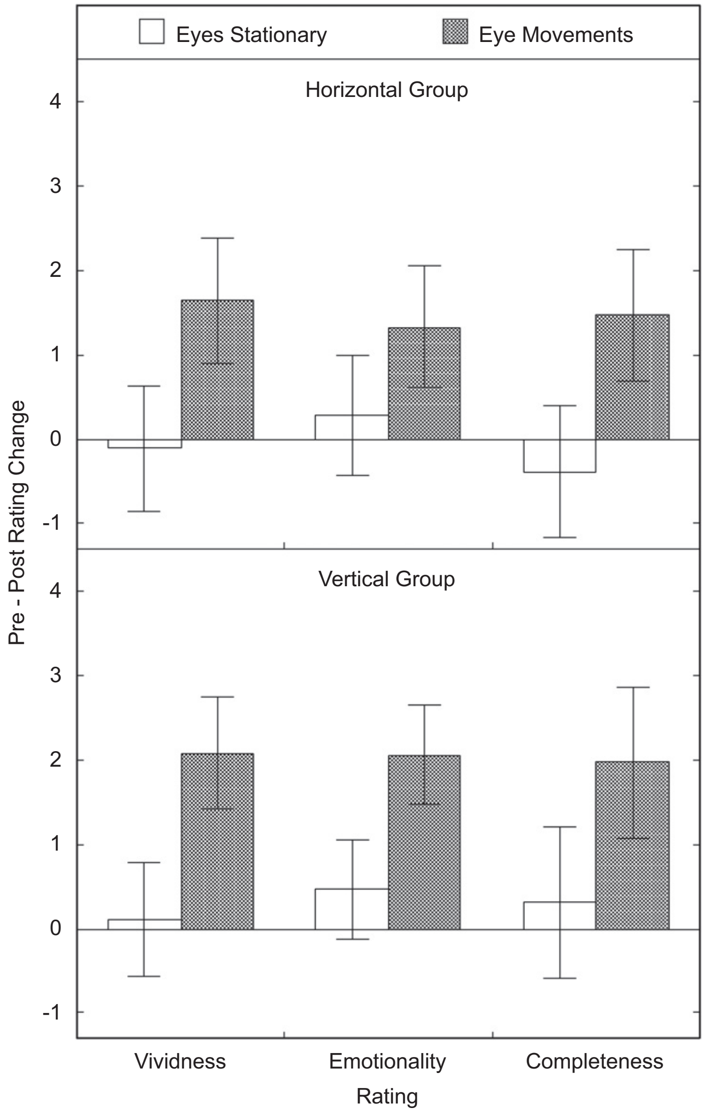

Fig. 3. Mean pre-minus-post changes in ratings of vividness, emotionality, and completeness for each treatment in each group in Experiment 2, immediately post-intervention. The 95% within-subjects confidence intervals indicate, for each pair of bars, the extent to which the eyes stationary and eye movement means differed.

$F(1,\ 31) = 2.31$, MSE = 7.16, $\eta^2 = .07$, and was qualified by a significant interaction with rating type, $F(2,\ 62) = 8.45$, MSE = .39, $\eta^2 = .21$. Follow-up ANOVAs revealed that immediate scores were larger than follow-up scores for the vividness rating (1.94 vs. 1.05), $F(1,\ 32) = 5.40$, MSE = 2.44, $\eta^2 = .14$, and the completeness rating (1.83 vs. 1.09), $F(1,\ 32) = 3.15$, MSE = 2.89, $p = .08$, $\eta^2 = .09$. For the emotionality rating, immediate and follow-up scores did not significantly differ (1.67 vs. 1.61), $F < 1$. The three-way interaction was not significant, $F < 1$.

Arousal scores

These scores were computed as in Experiment 1 and were analyzed with a 2 (treatment: eye movements vs. eye stationary) × 2 (group: horizontal vs. vertical) split-plot ANOVA. Replicating Experiment 1, eye movements were associated with significantly more arousal than keeping the eyes still (5.79 m s^2 vs. 6.15 m s^2), $F(1,\ 34) = 9.16$, MSE = .26, $\eta^2 = .21$ (Fig. 5). The main effect of group was not significant, $F < 1$, as was the interaction between treatment and group, $F(1,\ 34) = 1.86$, MSE = .26, $p = .18$, $\eta^2 = .05$, thus horizontal and vertical eye movements produced roughly equivalent levels of arousal. Arousal scores during eye movements did not significantly correlate with reductions in vividness, $r = .15$, emotionality, $r = .17$, or completeness, $r = .08$, F's < 1.

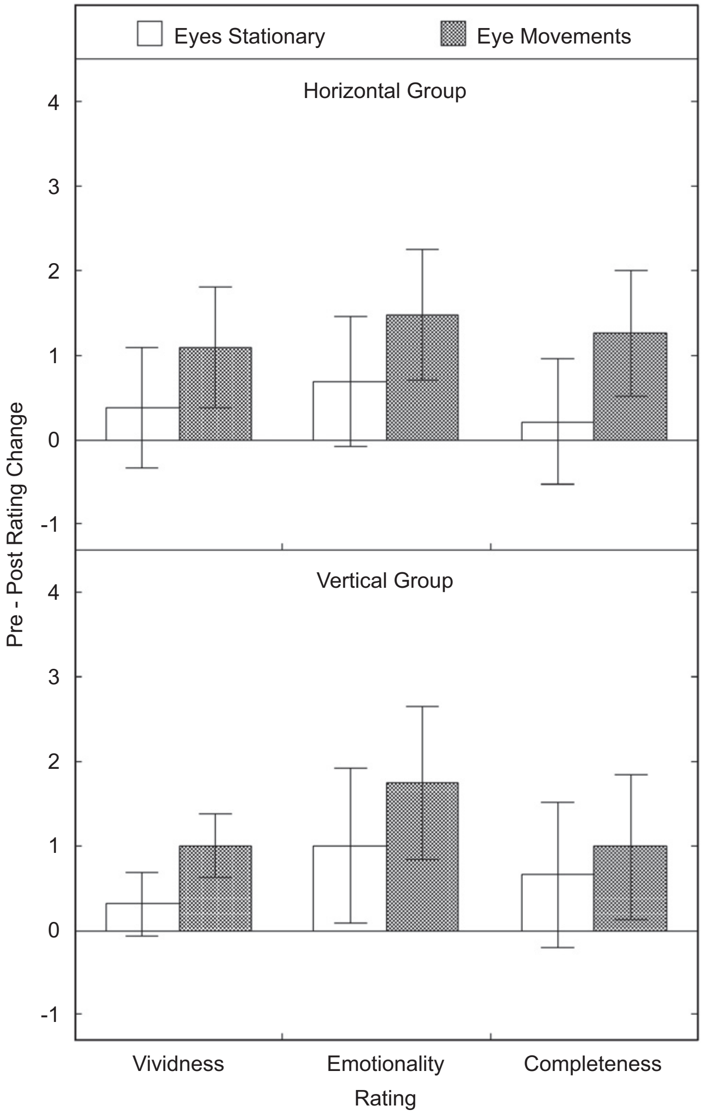

Fig. 4. Mean pre-minus-post changes in ratings of vividness, emotionality, and completeness for each treatment in each group in Experiment 2, at 1-week follow-up. The 95% within-subjects confidence intervals indicate, for each pair of bars, the extent to which the eyes stationary and eye movement means differed.

Discussion

Experiment 2 provided the first test of the IHC account using autobiographical memories. Contrary to Christman et al.'s (2003) suggestion that IHC might be the mechanism behind the eye movement benefits, horizontal and vertical eye movements produced robust and similar effects on participants' unpleasant memories. If IHC was responsible for the benefits, vertical eye movements, which do not enhance IHC, should not have been effective. Our results suggest that EMDR clinicians can use either type of eye movement based on client preference (see Shapiro, 2001), although horizontal movements are the more validated option. The working-memory account nicely accommodates the Experiment 2 findings, and the equivalence between the two types of eye movements suggests both tax the VSSP to a similar degree.

Experiment 2 also revealed that the horizontal and vertical eye movement benefits were equally persistent at a 1-week follow-up. This result is consistent with Kavanagh et al.'s (2001) speculation that they found equivalent benefits from eye movements and exposure alone at a 1-week follow-up due to their short exposure duration. Future studies could further test this possibility through systematic manipulation of exposure duration.

Both Experiment 2 and Kavanagh et al. (2001) found smaller eye movement benefits at follow-up compared with immediately post-intervention. If eye movements contribute to EMDR's long-term efficacy, it may seem odd that their benefits dissipate over time. However, note that the benefit on emotionality ratings remained at follow-up in Experiment 2.

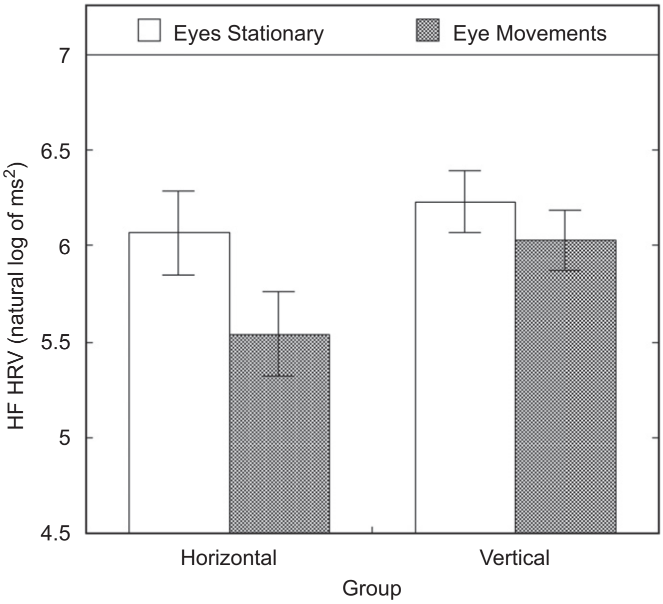

Fig. 5. Mean high-frequency heart rate variability scores in Experiment 2. The 95% within-subjects confidence intervals indicate, for each pair of bars, the extent to which the eyes stationary and eye movement means differed.

Perhaps eye movements do not permanently alter a memory's vividness and completeness (e.g., Andrade et al., 1997; Kavanagh et al., 2001), but rather, they may foster long-term changes occur in how that memory is evaluated. Although EMDR can work quickly (e.g., Shapiro, 1994), 96 s of eye movements may not be sufficient to produce long-term effects. Especially upsetting or traumatic memories may require multiple EMDR sessions to resolve successfully (Parnell, 2007).

Experiment 3

Experiment 3 attempted to identify the locus of the eye movement benefits in the working-memory system. The *VSSP account* posits that disruption of memories occurs in the VSSP (Andrade et al., 1997; Kavanagh et al., 2001). This account accommodates earlier findings, including those of Experiments 1 and 2, because visuospatial tasks were always used in previous experiments (i.e., eye movements, tapping, passive visual interference). Participants can often perform simple visuospatial and verbal tasks concurrently with minimal impairment on either task (e.g., Baddeley, Grant, Wight, & Thomson, 1973; Baddeley & Lieberman, 1980; Brooks, 1967; Quinn & McConnell, 1996). According to Baddeley and Hitch (1974), the central executive uses the VSSP to do the visuospatial task and the phonological loop to do the verbal task, thus minimizing dual-task interference.

According to the *central-executive account*, the eye movement benefits occur at the level of the central executive. This alternative is plausible given that most disrupting tasks appear to have an executive component (see Logie, 1995). The central executive is typically involved whenever attention is divided, unless one of the tasks is very easy/automated (Quinn & McConnell, 1996). More specifically, the central executive deploys "an attentional capability whereby memory representations are maintained in a highly active state in the face of interference" (Kane & Engle, 2002, p. 637), which aptly describes the task of holding a memory in mind while making eye movements. This account proposes that eye movement benefits should occur whenever a distractor task and sustaining a memory in mind both draw upon the central executive.

Experiment 3 tested the VSSP account against the central-executive account by examining whether an auditory shadowing task (having participants allocate attention to a simple speech recording; Quinn & McConnell, 1996) reduces ratings of distressing memories. This task was compared with the usual horizontal eye movement manipulation. According to the VSSP account, an auditory distractor task should not produce benefits. Rather, the memory should remain intact in the VSSP because the central executive will allocate the auditory task to the phonological loop. On the other hand, the central-executive account predicts benefits from auditory distraction. Holding a memory in mind while focusing on another task (be it visuospatial or auditory/verbal) should tax the central executive's finite capacity. If so, the memory should become less vivid, emotional, and complete.

A third group in Experiment 3 performed a particularly demanding visuospatial task while holding distressing memories in mind, namely copying the Rey complex figure (an array of geometric shapes; e.g., Meyers & Meyers, 1996). Ability to copy this figure is commonly used as both a measure of visuoconstructive abilities and as a more general measure of executive functioning (e.g., Visser, 1992). This group was included to test whether non-eye movement tasks that tax working-memory resources can also produce robust benefits, as the working-memory account predicts.

Finally, participants in Experiment 3 were also administered a reading span task (Daneman & Carpenter, 1980; Engle et al., 1999), a measure of central-executive functioning (see Conway et al., 2005). This task predominately measures domain-general aspects of executive attention, as opposed to the domain-specific storage that occurs in the VSSP and phonological loop (Engle et al., 1999). If the benefits of eye movements (and other distraction tasks) occur because executive attention is being divided, then *high-span* participants should show *smaller* benefits than *low-span* participants, because they have better central-executive functioning and hence a greater capacity to keep an upsetting memory in mind in the face of distraction. Thus, the central-executive account predicts that reading span scores should be negatively correlated with the magnitude of the observed benefits.

Method

Participants

Seventy-two University of Calgary undergraduates (mean age of 21; 47 were females; 57 were Caucasian, 13 were Asian, 2 were African) were randomly assigned to the *eye movements, auditory shadowing,* and *drawing* groups ($n = 24$ each).

Materials, design, and procedure

Experiment 3 constituted a 2 (treatment: distractor task vs. eyes stationary) $\times$ 3 (group: eye movements vs. auditory shadowing vs. drawing) mixed model factorial design. The eyes stationary condition was again used as the control. The eye movement group did horizontal movements as in Experiments 1 and 2, with the memories held in mind. Arousal was not measured in Experiment 3, and a 1-week follow-up was not included. Experiment 3 was otherwise procedurally similar to the other experiments, with the following differences. The auditory shadowing group held memories in mind while listening to an audio recording of a male voice saying "ta" at a rate of 1/s for four periods of 24 s, between each of which was a 10 s rest period without sound. This group was instructed to focus on both the audio clip and their memory. The drawing group held memories in mind while copying the Rey complex figure stimulus for four periods of 24 s, between each of which were 10 s rest periods without drawing.

After the four exposure trials participants completed the reading span task (Engle et al., 1999). They were presented with a booklet containing 12 sets of sentences (three sets of two, three, four, and five sentences). Each sentence was followed by a single upper-case letter. Participants read each sentence for a given set aloud along with the letter and said "yes" if the sentence was semantically correct (e.g., "No matter how much we talk to him, he is never going to change") and "no" if it was not (e.g., "During the week of final spaghetti, I felt like I was losing my mind"). They were instructed to remember the letters while working through the sentences, and their recall of the letters was tested after each set.

Results

Pre-minus-post rating difference scores were computed and analyzed as in Experiments 1 and 2 (Fig. 6). Analysis of the post-ratings yielded the same pattern of findings. A trial on the reading span task was scored as correct if the participant successfully remembered all the letters for that set (Engle et al., 1999). Individual reading span scores thus ranged from 0 to 12 (mean = 8.72, SE = .32). Participants were divided into high and low-span groups using a median split performed on reading span scores. Pre-ratings did not differ significantly between the high- and low-span groups, F's < 1.

Ratings

Mean pre-minus-post rating changes were analyzed with a 2 (treatment: distractor task vs. eye stationary) $\times$ 3 (rating type: vividness vs. emotionality vs. completeness) $\times$ 3 (group: eye movements vs. auditory shadowing vs. drawing) split-plot ANOVA. The main effect of rating type was not significant, $F(2, 138) = 1.42$, MSE = 1.13, $p = .19$, $\eta^2 = .02$, nor did rating type significantly interact with group, $F < 1$, or treatment, $F(2, 69) = 1.34$, MSE = 5.42, $p = .26$, $\eta^2 = .02$. There was a significant main effect of treatment, $F(1, 69) = 61.89$, MSE = 5.42, $\eta^2 = .47$; the three distractor tasks reduced memory ratings relative to holding the eyes still (1.69 vs. .05). Follow-up ANOVAs indicated that each distractor task produced benefits relative to eyes stationary: for the eye movement group (1.32 vs. .10), $F(1, 23) = 12.01$, MSE = 4.48, $\eta^2 = .34$, for the auditory shadowing group (1.45 vs. .15), $F(1, 23) = 11.34$, MSE = 5.24, $\eta^2 = .33$, and for the drawing group (2.75 vs. −.19), $F(1, 23) = 42.55$, MSE = 6.53, $\eta^2 = .65$. Given the assumption that auditory shadowing does not tax VSSP resources (e.g., Quinn & McConnell, 1996), the equivalent benefits from auditory shadowing and eye movements supports the central-executive account over the VSSP account. There was also a significant interaction between treatment and group, $F(2, 69) = 5.16$, MSE = 5.42, $\eta^2 = .12$. Follow-up tests indicated that the drawing benefits were significantly larger than both the eye movement benefits (2.75 vs. 1.77), $F(1, 46) = 6.16$, MSE = 9.54, $\eta^2 = .12$, and the auditory shadowing benefits, $F(1, 46) = 7.02$, MSE = 10.70, $\eta^2 = .13$. The eye movement and auditory shadowing benefits did not differ significantly, $F < 1$.

Correlations between benefits and reading span scores

The respective correlations between reading span scores and rating decreases for the eye movement, auditory shadowing, and drawing groups were as follows: r's = −.44, −.69, and −.58 for vividness ratings; r's = −.43, −.59, and −.49 for emotionality ratings; and r's = −.61, −.63, and −.57 for completeness ratings. All but the first of these correlations

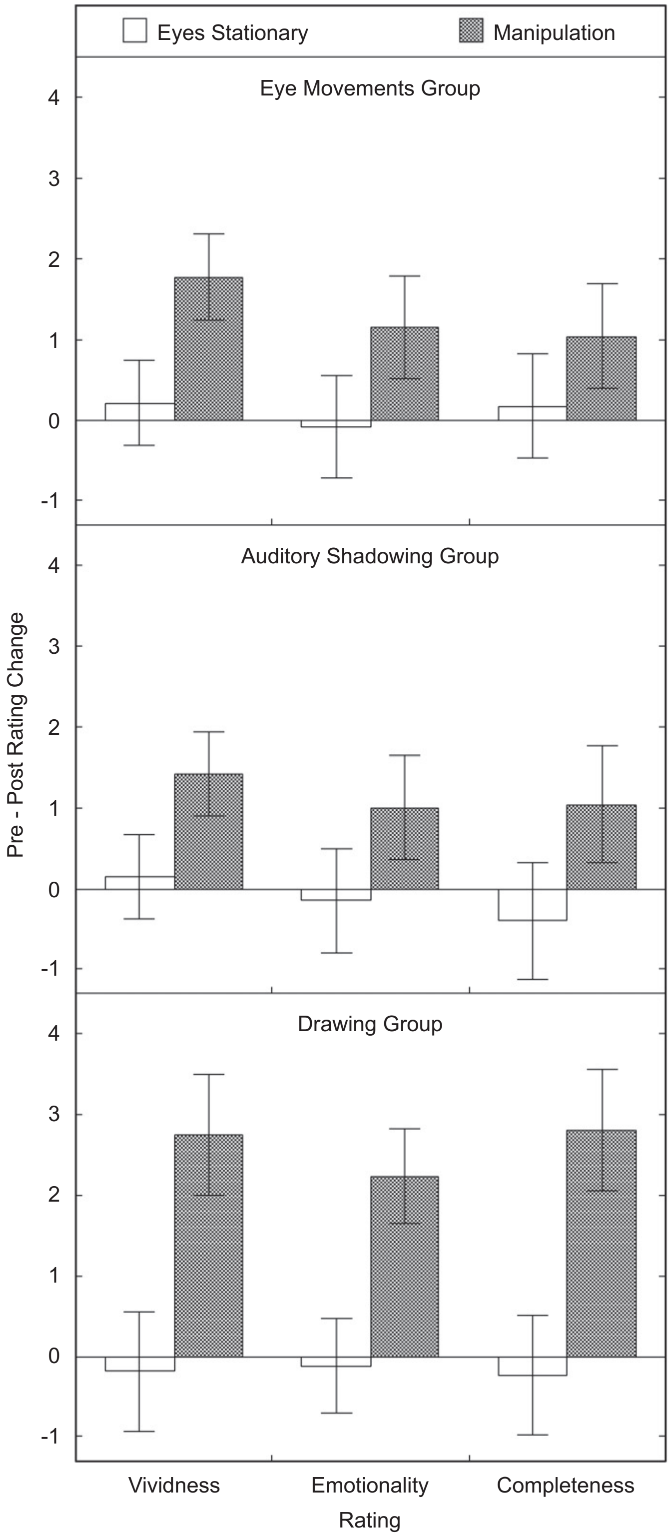

Fig. 6. Mean pre-minus-post changes in ratings of vividness, emotionality, and completeness for each treatment in each group in Experiment 3. The 95% within-subjects confidence intervals indicate, for each pair of bars, the extent to which the eyes stationary and eye movement means differed.

($p = .14$) was significant. Consistent with the central-executive account, high-span persons benefited *less* than low-span persons from all three conditions.

Discussion

Contrary to the VSSP account, auditory shadowing produced rating benefits comparable to those produced by eye movements (see also Servan-Schreiber et al., 2006), indicating that benefits occur even when the VSSP is not taxed. Assuming that auditory shadowing does not require VSSP resources (e.g., Quinn & McConnell, 1996), participants should have been able to focus on the audio clip while holding a memory in the VSSP. That participants had difficulty with this multitasking suggests that benefits occur when the central executive, rather than the VSSP alone, is taxed.

The robust negative correlations between reading span and the rating benefits for each of the three distractor tasks used in Experiment 3 provide further support for the central-executive account, assuming the reading span task is a relatively "pure" measure of central-executive functioning (e.g., Engle et al., 1999). Nevertheless, Experiment 3 does not completely rule out the possibility that some of the benefit is due to taxing the VSSP. Measures of VSSP capacity were not administered in Experiment 3 (e.g., the forward span-dissimilar, forward span-similar, and backward span tasks; Engle et al., 1999). A larger VSSP would likely help the central executive sustain a memory under distracting conditions. Baddeley (2000) has also proposed a third subsystem of working memory, dubbed the *episodic buffer*. This subsystem is thought to be responsible for forming integrated units of visuospatial and verbal information that follow a chronological sequence. The episodic buffer should therefore be involved in the recapitulation of complex autobiographical memories, and the possible role of this subsystem in the rating benefits merits further investigation.

Copying the Rey complex figure produced larger decreases in memory ratings than either eye movements or auditory shadowing, suggesting that this task was more taxing of the central executive. Although tasks that are more taxing of the central executive may produce larger benefits, this relationship may not be linear. A task that is *overly* taxing might preclude holding a memory in mind, thereby precluding benefits.

General discussion

Consistent with a working-memory account, performing horizontal or vertical eye movements, an auditory shadowing task, or a drawing task while holding an unpleasant autobiographical memory in mind decreased ratings of the vividness, emotionality, and completeness of those memories relative to an eyes stationary control. More specifically, according to a central-executive working-memory account, the central-executive component of working memory was taxed by the competing demands of holding a memory in mind while performing another task requiring executive control. Before this account is discussed in more detail, the implications of the present findings for two alternative accounts of the rating benefits are considered.

Implications for the investigatory-reflex account

The investigatory-reflex account claims that eye movements produce a deep sense of relaxation, increased attentional flexibility, or both. In EMDR, a memory or other target (e.g., cognition, image) is always held in mind during the eye movements. However, if the investigatory reflex is responsible for the rating benefits, those benefits should occur even when the target memory is brought to mind right after eye movements have ceased. The absence of rating benefits in the not-in-mind group in Experiment 1 is therefore problematic for this account. It could be argued that the reflex occurs only during eye movements, and that it only works on whatever is held in mind during the movements. However, a deep relaxation state (e.g., MacCulloch & Feldman, 1996) or a state of increased attentional flexibility (Kuiken et al., 2002) should not dissipate immediately after the movements cease.

A remaining issue, then, is whether eye movements elicit the investigatory reflex at all. Kuiken et al.'s (2002) finding that eye movements increase attentional flexibility suggests that they may elicit something like the investigatory reflex. However, this reflex is likely *not* responsible for participants' reports of reduced vividness, emotionality, and completeness. Although the investigatory reflex and interference in working memory may both occur during an EMDR trial, as suggested by Barrowcliff et al. (2004), the former does not appear to produce the decreases in vividness and emotionality that are the hallmark of the treatment.

Our findings also suggest that the investigatory reflex, if it exists, is not a state of relaxation at all. In Experiments 1 and 2, eye movements were associated with *more* physiological arousal than an eyes stationary control condition, whereas the reverse was reported by Barrowcliff et al. (2004); this discrepancy may be due to use of different measures of arousal (HF-HRV vs. electrodermal arousal) or task duration (96 s vs. 25 s). Regarding the latter, eye movements may have initially relaxed participants, consistent with the first stage of the investigatory reflex, but may have become more arousing as sets continued, thus moving the investigatory reflex into the reflexive exploration stage (MacCulloch & Feldman, 1996). Barrowcliff et al.'s (2004) shorter task duration may thus have captured the initially low levels of arousal associated with the first stage of the reflex, whereas the longer duration used here might have captured the higher levels of arousal associated with the second stage. Future research should examine how people interpret eye-movement-induced arousal, and how they avoid attributing it to the upsetting nature of the memory itself.

Implications for the interhemispheric-communication account

Experiment 2 tested Christman et al's (2003) proposal that IHC might be the mechanism behind the rating benefits. Some research implicates IHC in the amelioration of distress (e.g., Compton & Mintzer, 2001; Heller et al., 1995), and given that horizontal eye movements enhance IHC (e.g., Bakan & Svorad, 1969), this proposal is not unreasonable. Nevertheless, the finding that vertical eye movements produced roughly the same benefits as horizontal ones in Experiment 2 effectively rules out the proposal that IHC is the primary mechanism underlying the benefits, assuming that vertical eye movements do not enhance IHC.

Experiment 2 does not undermine the conclusion that horizontal eye movements performed after study can enhance recall and recognition (e.g., Christman & Propper, 2001; Christman et al., 2003). For example, considerable evidence supports the view that episodic memories are encoded using the left hemisphere but retrieved using the right hemisphere (e.g., Tulving, Kapur, Craik, Moscovitch, & Houle, 1994). Other lines of research also suggest an interhemispheric basis for episodic memory (e.g., Opitz, Mecklinger, & Friederici, 2000). IHC may facilitate initial recall of memories, but it does not appear to be responsible for the phenomenological changes that occur to memories after participants hold them in mind during EMDR.

Implications for a working-memory account

The present findings bolster support for a working-memory account of the rating benefits (e.g., Andrade et al., 1997; Kavanagh et al., 2001; Maxfield, 2004; Van den Hout et al., 2001). The previous iteration of this account posited that eye movement benefits occur when VSSP resources are taxed, but a central-executive account better accommodates the finding that a sufficiently distracting auditory task produced similar benefits in Experiment 3. The central-executive account affords no special primacy to eye movements, or any other visuospatial or bilateral task. Moreover, copying the Rey complex figure makes considerable demands upon executive functioning, and in Experiment 3 this task produced larger benefits than eye movements. Highly demanding auditory tasks (e.g., recalling a series of three auditory consonant trigrams following distraction; Mitrushina, Boone, & D'Elia, 1999) might produce similarly robust benefits. For example, Isaacs (2004) described successful use of *numerical distraction therapy*, which resembles EMDR except that clients hold digits in mind rather than making eye movements. Isaacs posited that numerical distraction therapy and EMDR might share a common underlying mechanism of divided attention, a suggestion that is completely consistent with the central-executive account.

The findings from Experiment 3 may have important clinical implications. First, if the magnitude of the eye movement benefits were related to treatment gains in EMDR, then tasks that produce larger benefits would be preferable to tasks that provide less distraction (see Shapiro, 2001). New versions of EMDR could substitute more taxing tasks for eye movements, thereby improving an already efficacious treatment. Second, if taxing the central executive is the therapeutic mechanism underlying EMDR, then measures of central executive span could be used to match clients to treatments. For example, high-span persons with PTSD, being less likely to experience eye movement benefits, might benefit more from cognitive–behavioral treatment, whereas children with PTSD (who typically have lower central executive spans than adults) may benefit more from EDMR treatment.

Despite its usefulness, the central-executive account nevertheless requires further specification. Just as working memory is not a unitary entity, the central executive itself may be composed of a number of interrelated but separable executive functions (e.g., Caplan & Waters, 1996; Cowan et al., 1998; Lehto, 1996). As with the construct of intelligence, variance in central-executive measures can be explained by both a broad "executive attentional control" factor (measured by tasks like the reading span; Kane & Engle, 2002) and by more specific subordinate factors that correspond to individual executive functions. For example, Whitney, Arnett, Driver, and Budd (2001) found that reading span is influenced by individual differences in distinct executive functions, including the ability to perform a cognitive task under divided attention. Whitney et al. (2001) differentiated this ability from the basic capacity of the central executive. Future research should aim to identify the specific executive functions that underlie the rating benefits.

Another important issue concerns the central-executive account's focus on description versus explanation. The account posits a clear, theory-grounded mechanism of rating benefits. However, it says little about how individuals perform the complex task of holding a memory in mind while performing a concurrent task. Towse and Hitch (1995) suggest that maintaining an active memory trace in mind during a reading span task requires attentional focusing. When attention is switched away from the memory trace it begins to decay. Attention must be shifted between the memory trace and the concurrent task to maintain the memory in mind (see also Barrouillet & Camos, 2001; Lepine, Bernardin, & Barrouillet, 2005).

This *rapid-attentional-switching account* of how people perform a reading span task (e.g., Barrouillet & Camos, 2001) might also apply to an EMDR trial. For example, Lepine et al. (2005) found that increasing the pace of the reading span task reduces span. They argued that faster reading reduces time for attentional switching. This finding is analogous to Maxfield's

(2004) finding that faster eye movements produced larger benefits, suggesting that an EMDR trial may also require considerable attentional switching. The negative correlations between reading span and rating benefits in Experiment 3 support this analogy. Further studies should examine whether rapid attentional switching provides a good account of the mental processing that occurs during an EMDR trial.

Implications for clinical practice

How degrading peoples' memories by taxing the central executive translates into recovery from PTSD remains to be explained. In particular, it is unclear whether rating benefits are associated with long-term changes in people's memories of an unpleasant event. The follow-up data in Experiment 2 suggest that eye movements may produce short-lived reductions in the vividness and completeness of a memory, but more persistent changes in one's emotional reaction to it. This finding supports Kavanagh et al.'s (2001) proposal that eye movements do not directly alter memories but instead help people to better focus on them. This focus (i.e., exposure) may thus be the therapeutic mechanism, with eye movements playing a key role as facilitator. Although Foa and Kozak (1986) argued that distraction can interfere with effective exposure therapy, some studies have found that it can actually facilitate habituation to feared stimuli (e.g., Oliver & Page, 2003; Johnstone & Page, 2004). It may therefore be useful to distinguish distraction from a stimulus (i.e., a manipulation that prevents any appreciable engagement with a stimulus) from reduced attention to a stimulus (see Foa, Huppert, & Cahill, 2006). EMDR may be an example of an exposure therapy that reaps the benefits of reduced attention to a feared stimulus.

Taxing the central executive might thus leave the original memory relatively intact while altering a person's emotional and cognitive reactions to it. PTSD is typically characterized by avoidance of one's own memories (e.g., Keane & Barlow, 2002). Many PTSD sufferers fear their memories and believe that they cannot cope with experiencing them (e.g., Foy, 1992; Resick & Calhoun, 2001; Shilperd, Street, & Resick, 2006). The rating benefits potentially provide a powerful opportunity for experiential learning and belief change to take place. By experiencing the memory in a weakened form (while being distracted), people may change some of their beliefs about how dangerous their memories are, as well as their beliefs about their ability to cope with remembering them (e.g., ''I can focus on this memory without becoming upset''). EMDR might therefore be analogous to the behavioral experiments cognitive–behavioral therapists often use to shift client beliefs.

Traditional exposure therapy may take longer than EMDR to change beliefs because exposure without distraction is often highly aversive. Exposure treatment does not give clients the empowering experience of holding a diluted traumatic in mind; rather, they are asked to focus on the undiluted traumatic memory. Although traditional exposure works well, it likely takes clients longer to shift their beliefs about how dangerous their memories are when they have to endure sessions of difficult exposure exercises that can potentially backfire and reinforce the belief that their memories are intolerable.

The experience of holding a traumatic memory in mind, made more palatable by the central executive's attentional resources being taxed, may ultimately work to foster acceptance of those memories. Hayes (2004) has suggested that cognitive–behavioral practice is entering a ''third wave'' characterized by treatments that seek to teach clients ways of observing their own cognitive and emotional reactions in a focused yet detached (i.e., *mindful*), non-evaluative manner (Hayes, Follette, & Linehan, 2004). Preliminary evidence suggests that teaching mindfulness skills and fostering acceptance may work at least as well as traditional cognitive–behavioral methods that teach clients to actively dispute or ''battle'' their negative reactions (Hayes, 2004).

The mechanism underlying mindfulness-based therapies, like the mechanism underlying EMDR, remains poorly understood. Segal, Teasdale, and Williams (2004) proposed that mindfulness requires attentional resources. The act of focusing on a negative cognition in a mindful fashion leaves fewer resources available for emotional reactions to it. A related parallel with EMDR may be the occurrence of a state of engaged and focused attention (Armstrong & Vaughan, 1996). Taxing the central executive might thus contribute to treatment gains in mindfulness/acceptance-based forms of CBT and EMDR alike. If their mechanisms of action are indeed similar, it would make sense to view EMDR as an example of a successful third-wave cognitive–behavioral treatment rather than a power therapy or other ''form of magic'' (see Shapiro, 2001 for a discussion of parallels between EMDR and mindfulness).

It is of course too soon to conclude that EMDR and mindfulness-based therapies share a common treatment mechanism. Most obviously, the present findings require replication with a clinical PTSD sample. In addition, a clear link between rating benefits and treatment gains in EMDR needs to be established. Surprisingly, researchers have not yet examined whether the magnitude of the eye movement benefits obtained in treatment sessions relate to long-term treatment outcomes. This examination is essential now that an understanding of the benefits of eye movements and other distractor tasks is emerging.

Kazdin (2003) has outlined a treatment-mediator strategy that researchers can use to establish a link between a benefit and an outcome. Applied to the case of EMDR, this strategy would entail measuring the eye movement benefits during EMDR sessions and then assessing whether they predicts treatment outcome as well as shifts in clients' negative beliefs about their ability to cope with traumatic memories. If the central-executive account is correct, the eye movement benefits should predict changes in negative beliefs about memories, which in turn should predict treatment outcomes.

Lee, Taylor, and Drummond (2006) provided some support for the idea that EMDR helps clients to process their traumatic memories in an emotionally detached fashion. Subjective reports during EMDR sessions were coded for whether they indicated reliving of a traumatic experience versus gaining distance from the experience. Greatest improvement on

PTSD symptoms occurred for clients who reported processing the trauma in a more detached manner. Although Lee et al. (2006) did not measure eye movement benefits via ratings, a testable prediction is that larger rating benefits should lead to more distancing, and should therefore predict treatment outcome.

Finally, an important caveat regarding the treatment mechanism behind EMDR and other psychotherapies should be noted. Taxing the central executive is only one component of EMDR. It is highly unlikely that the beneficial effects of any form of psychotherapy are due solely to one factor (Lambert & Ogles, 2004; Luborsky, Singer, & Luborsky, 1975). Factors common across all psychotherapies certainly contribute to their efficacy (e.g., Grencavage & Norcross, 1990; Ilardi & Craighead, 1994). EMDR likely works for many of the same reasons other psychotherapies work. Establishing that eye movements play a discernable role in the treatment's efficacy is important, but it should not be anticipated that eye movements will explain all or even most of the outcome variance in EDMR studies (Shapiro & Maxfield, 2002).

Conclusion

EMDR remains a controversial treatment. The present experiments allay some of this controversy by highlighting a theory-grounded explanation of eye movement benefits, namely, a working-memory account with a central-executive locus. That EMDR works does not mean that researchers and clinicians should not attempt to discover *how* it works. The present findings provide an impetus to further test the role that taxing the central executive plays in EMDR and other forms of psychotherapy.

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