On EMDR: Measuring the working memory taxation of various types of eye (non-)movement conditions

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ABSTRACT

Background and objective: A recent, large randomized controlled trial employing different forms of eye (non-) movements in eye movement desensitization and reprocessing (EMDR) showed that fixating the eyes either on a therapist's moving or non-moving hand led to equal reductions in symptoms of post-traumatic stress disorder (PTSD). However, numerous EMDR lab analogue studies found that eye movements produce larger memory effects than eyes stationary. These beneficial effects are typically explained by differences in working memory (WM) taxation. We tested the degree of WM taxation of several eye (non-)movement conditions used in the clinical trial.
Methods: All participants ($N = 40$) performed: (1) eyes moving by following the experimenter's moving finger, (2) eyes fixed on the experimenter's stationary finger, (3) eyes closed, or (4) looking unfocused into the room. Simultaneously they performed a simple reaction time task. Reaction times are an objective index of the extent to which different dual attention tasks tax WM.
Results: Eyes moving is more taxing than eyes fixed, while eyes fixed did not differ from eyes unfocused. All conditions were more taxing than eyes closed.
Limitations: We studied WM taxation in a laboratory setting; no clinical interventions were applied.
Conclusions: In line with previous lab studies, making eye movements was more taxing than eyes fixed. We discuss why this effect was not observed for reductions in PTSD symptoms in the clinical trial (e.g., differences in dependent variables, sample population, and intervention duration). For more comprehensive future insights, we recommend integration of mechanistically focused lab analogue studies and patient-oriented clinical studies.

1. Introduction

Eye movement desensitization and reprocessing (EMDR) is currently an evidence-based and first-choice treatment for post-traumatic stress disorder (PTSD; e.g., World Health Organization, 2013). In EMDR patients are instructed to make horizontal eye movements (EM) by following a therapist's finger while simultaneously recalling their traumatic memory (Shapiro, 2017). Since its inception, the necessity of the EM has been heavily debated and the intervention's general effectiveness was then frequently attributed to mere exposure (e.g., Herbert et al., 2000; McNally, 1999). Initial reviews and meta-analyses supported this idea (Cahill, Carrigan, & Frueh, 1999; Davidson & Parker, 2001), but a later more encompassing meta-analysis of lab analogue and full protocol studies showed that EM are essential and that EMDR is different from exposure-based therapies (Lee & Cuijpers, 2013).

The beneficial effects of EM have been explained by differences in working memory (WM) taxation. It has been argued that division of attention over EM and memory recall taxes the limited capacity of WM (Baddeley, 2007). The simultaneous execution of these dual attention tasks is thought to impede recall of the emotional memory and result in lowered vividness and emotionality of the memory after the intervention (van den Hout & Engelhard, 2012). These changes are hypothesized to set off a cascade of events that eventually result in PTSD symptom reduction (Gunter & Bodner, 2009). Experimental evidence supports this dual attention explanation for changes in memory vividness and emotionality and shows that larger effects are related to tasks that load more on WM compared low loading tasks (Maxfield, Melnyk, & Hayman, 2008; van Schie, van Veen, Klugkist, Engelhard, & van den Hout, 2016; van den Hout et al., 2011). Moreover, not only EM, but other types of tasks that tax WM also result in decreases in memory

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vividness and emotionality, for instance, mental arithmetic (Engelhard, van den Hout, & Smeets, 2011), playing the computer game Tetris (Engelhard, van Uijen, & van den Hout, 2010), or drawing a complex figure (Gunter & Bodner, 2008).

Although there is a consensus in the lab analogue studies that dual tasks produce better results than the frequently used recall only control condition, only a limited number of clinical studies studied these effects. Closer inspection of the meta-analysis of Lee and Cuijpers (2013) showed that only four studies with PTSD patients (out of 14 full protocol studies) were included. These four studies suffered from major methodological problems, such as small sample size (i.e., largest sample was only $N = 25$; Devilly, Spence, & Rapee, 1998), no randomization (Devilly et al.), or use of untrained therapists (Renfrey & Spates, 1994). To fulfill the need for a large randomized controlled trial, Sack et al. (2016) compared three variations of eye (non-)movements in EMDR treatment in 139 patients with PTSD: recalling the traumatic memory with (1) eyes fixed on the therapist's *moving* hand, (2) eyes fixed on the therapist's *non-moving* hand, or (3) no distraction (i.e., eyes closed *or* eyes open and looking unfocused into the room; whatever the patient preferred). All three conditions led to a comparable remission of PTSD diagnosis, but surprisingly, the eyes moving and eyes fixed condition did not differ from each other. Both conditions outperformed the no distraction condition in PTSD symptom reduction.

Sack et al. (2016) argued that these results are not necessarily in conflict with WM theory. They suggest that eyes moving and keeping the eyes fixed are equally taxing, but more taxing than no distraction. Therefore these two conditions performed comparably well in terms of symptom reduction. However, this argument is contradictory to the results from a large body of EMDR lab analogue studies in which a fixation point *or* blank screen have both been used as control conditions; though both control conditions have never been used in the same study (e.g., Barrowcliff, Gray, Freeman, & MacCulloch, 2004; Gunter & Bodner, 2008; Smeets, Dijs, Pervan, Engelhard, & Van den Hout, 2012; van den Hout, Muris, Salemink, & Kindt, 2001; van Schie, van Veen, Engelhard, Klugkist, & van den Hout, 2016; van Veen et al., 2015). In these studies, making EM repeatedly and consistently outperforms either of these control conditions in terms of memory change, which suggests that making EM is more taxing than merely recalling the memory. Thus, Sack et al.'s assumption about differences in WM taxation awaits further empirical testing.

A reliable test to assess the extent to which different tasks tax working memory is a Random Interval Repetition (RIR) task (van den Hout et al., 2011; Vandierendonck, De Vooght, & Van der Goten, 1998). In a RIR task, participants are instructed to respond as quickly as possible to randomly administered stimuli (e.g., bleeps), while simultaneously performing a dual attention task (e.g., making EM). The slowing down of reaction times in a dual attention task condition (compared to control; responding to bleeps only) provides a valid and highly sensitive measure of WM taxation. Indeed, several EMDR lab analogue studies have shown that fixating eyes on a moving object (e.g., a hand or dot on screen) is *more* taxing than a non-moving object (Engelhard et al., 2010; van den Hout et al., 2011; van Veen et al., 2015; van Veen, Engelhard, & van den Hout, 2016). However, based on the study by Sack et al. (2016) one could also hypothesize that fixating eyes on a moving hand or on a non-moving hand would be *equally* taxing. In a within-subjects design ($N = 40$), we tested the WM taxation of all conditions from the Sack et al. paper: (1) eyes moving by following the experimenter's moving finger, (2) eyes fixed on the experimenter's stationary finger, (3) eyes closed, or (4) looking unfocused into the room. While performing these conditions, participants simultaneously responded as fast as possible to bleeps by pressing a button. We compared two competing hypotheses: eyes moving is *more* taxing than eyes focus or both conditions are *equally* taxing. Furthermore, we expect that these two conditions are more taxing than keeping eyes closed or unfocused. Based on previous WM literature closing one's eyes seems to reduce visual input and thus should be the least taxing (Vredeveldt,

Hitch, & Baddeley, 2011).

2. Materials & methods

2.1. Participants

Forty students from Utrecht University participated in this study ($M_{age} = 22.35$ years, $SD = 2.65$, range = 19-30; 9 men, 31 women). They participated in exchange for 4 euros or course credits. Participants were all right-handed (due to convenience of responding, because the response box was situated on right side of participant's body), did not report problems with sight or hearing, did not use medicine for emotional problems, and did not report using excessive recreational drugs or tobacco. All students gave informed consent before participation.

2.2. Procedure

Participants sat on a chair diagonally across the experimenter such that the right front leg of both the chairs touched. This setup mimicked a clinical EMDR setting and ensured that participants properly engaged in the eye movement conditions. It allowed the experimenter to check that the participant acted in accordance with the eye (non-)movement instructions.

Participants were first familiarized with the RIR task (Vandierendonck et al., 1998) that was adapted from van den Hout et al. (2011). During the RIR, participants were instructed to respond to a 200Hz bleep that was played through headphones to both ears simultaneously at a moderate volume. Participants responded by pressing the button of a response box with the index finger of their right hand following the bleep as fast as possible. The inter-stimulus interval (1500 ms or 900 ms) alternated quasi-randomly to reduce predictability of the subsequent bleep with a maximum of four consecutive identical intervals. Participants started with a short practice in which they responded to 8 bleeps. Following the practice phase there were four blocks of 80 bleeps, which were separated by 30-s breaks. During these four blocks participants engaged in four types of eye movements; (1) eyes moving by following the experimenter's finger that moved horizontally in front of them with a speed of approximately one left-right-left movement per second, (2) eyes fixed on the experimenter's stationary finger, (3) eyes closed, or (4) eyes unfocused while looking into the room without focusing on anything specifically. Latin square counterbalancing was used to negate sequence effects. The experiment was presented using E-Prime 2.0 software (Psychology Software Tools, 2012. Pittsburgh, PA).

2.3. Data analysis

JASP was used for data analysis (version 0.9.1, JASP team, 2018). JASP is a free, open-source software package that can be used for Bayesian Hypothesis Testing (BHT) and for Null Hypothesis Significance Testing (NHST). We report BHT because equivalence could be expected between some conditions; only BHT is able to qualify evidence in *favour* of the null hypothesis (Dienes, 2016). We simultaneously report NHST to facilitate comparisons with previous literature.

Regarding BHT, JASP produces a Bayes Factor (BF) for each requested test. A BF expresses the *relative* likelihood of the data under H_1 compared to H_0 (or vice versa). In JASP, H_0 states that an effect is absent. Thus, $BF_{10} = 8$ means that the data are eight times more probable under H_1 than under H_0, thus showing evidence is in favour of the H_1. $BF_{01} = 8$ means the opposite and shows that the data are eight times more probable under H_0 than H_1. Because a BF is always *relative*, the BF for the other hypothesis is easily determined by dividing 1 by a given BF (e.g., if $BF_{10} = 8$, then $BF_{01} = 0.125$).

The BF is a continuous scale, but qualitatively categories of evidence can be used to facilitate scientific communication (Jeffreys, 1961; Wetzels & Wagenmakers, 2012). The categories are defined by arbitrary
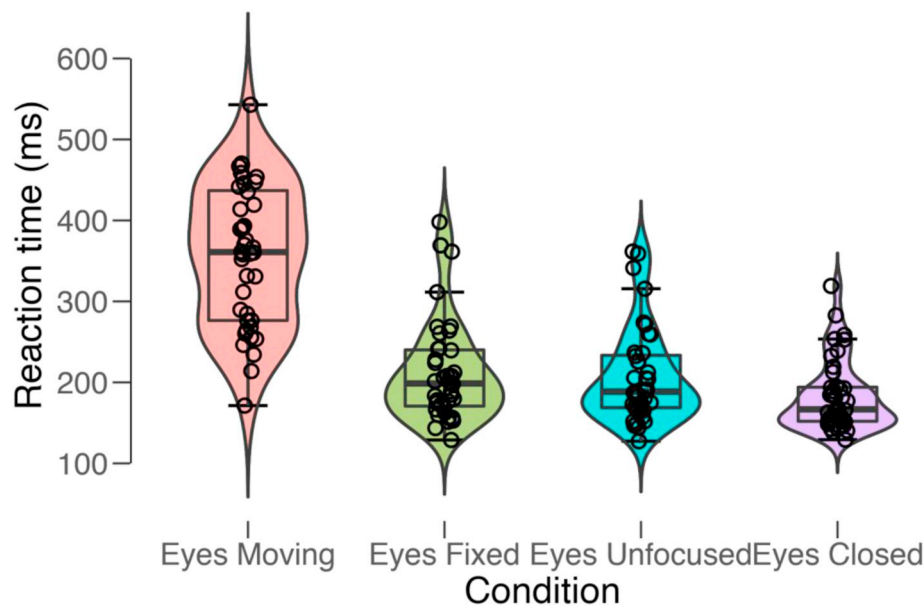
Fig. 1. Violin plots for averaged reaction time in millisecond (ms) with individual data points (circles) and boxplots superimposed for each experimental condition.

cut-offs and should therefore not be viewed as absolute (e.g., a BF of 9.9 is equally valuable as a BF of 10.0). BFs around 1 represent evidence that is not in favour of H_1 or H_0. BFs between 1 and 3 ($1-\frac{1}{3}$) represent anecdotal, 3-10 ($\frac{1}{3} - \frac{1}{10}$) substantial, 10-30 ($\frac{1}{10} - \frac{1}{30}$) strong, or 30-100 ($\frac{1}{30} - \frac{1}{100}$) very strong, and above 100 (below $\frac{1}{100}$) decisive evidence for a given hypothesis.

In all BHT analyses, we used JASP's standard prior: a Cauchy distribution with scale $r = 0.707$ for t-tests (i.e., medium prior) and the default prior model probabilities of 0.5 for repeated measures ANOVA. In follow-up testing we used JASP's standard correction for multiple testing for BHT. For NHST we used Bonferroni correction for multiple testing.

3. Results

Fig. 1 shows all conditions from the most taxing to the least taxing: eyes moving ($M = 356.56$, $SD = 87.24$), eyes fixed ($M = 212.15$, $SD = 62.20$), eyes unfocused ($M = 207.42$, $SD = 58.78$), and eyes closed ($M = 183.13$, $SD = 43.84$). There is a clear difference between the four conditions, $BF_{10} = 1.62 \times 10^{32}$, Greenhouse-Geisser corrected F (1.83, 71.54) = 114.9, $p < .001$, $\eta_p^2 = .747$. Follow-up tests show that the eyes moving condition differed from all other conditions, $BFs_{10} > 6.99 \times 10^9$, $ts(39) > 10.60$, $ps < .001$, $ds > 1.68$. Note specifically that, the eyes moving condition was more taxing than the eyes fixed condition. Moreover, eyes fixed did not differ from the eyes unfocused condition, $BF_{01} = 11.19$, $t(39) = 0.71$, $p = 1.00$, $d = 0.11$, but did differ from eyes closed, $BF_{10} = 62.07$, $t(39) = 4.16$, $p = .001$, $d = 0.66$. Eyes unfocused and eyes closed also differed, $BF_{10} = 8.08$, t (39) = 3.38, $p = .01$, $d = 0.54$, showing that eyes closed was the least taxing of all conditions. Ergo, eyes moving is *more* taxing than eyes fixed (and not *equally* taxing). Eyes fixed did not differ from eyes unfocused and – in line with our expectations – all conditions were more taxing than eyes closed.

4. Discussion

In the last thirty years, the use of EM in EMDR has been heavily disputed (e.g., Herbert et al., 2000; McNally, 1999). The largest randomized clinical trial thus far showed that there is no evidence for a difference between eyes moving and eyes fixated in the reduction of PTSD symptoms (Sack et al., 2016), while both conditions

outperformed a control condition (i.e., eyes unfocused/closed). Sack et al. concluded that this finding could be explained by comparable WM taxation of the eyes moving and eyes fixed conditions. Although theoretically plausible, another body of evidence suggests that eyes moving is more taxing than eyes fixed (e.g., Barrowcliff et al., 2004; Gunter & Bodner, 2008; Engelhard et al., 2010; van den Hout et al., 2011; van Veen et al., 2015; 2016). Given the relevance for clinical practice, we tested the WM taxation of four different eye (non-)movement conditions used in Sack et al.'s study. We found clear evidence that eyes moving is more taxing than eyes fixed; eyes fixed did not differ from eyes unfocused, but all conditions were more taxing than eyes closed. Thus, these results are in line with previous EMDR lab analogue studies, but do not support the WM explanation proposed by Sack et al.

A body of literature shows that participants are slower in reaction times when they have been instructed to simultaneously make EM compared to making no EM (Engelhard et al., 2010; Mertens et al., 2018; van den Hout et al., 2011; van Veen et al., 2015). The current study is in line with these previous studies and also shows that making EM is more taxing than control conditions, irrespective of whether participants focused on a fixation point or looked unfocused into the room in those conditions. A previous study by Onderdonk and van den Hout (2016) found that the slowing down of reaction times during EM could be explained by two essential components: changing visual input and the effort of continuous motor movement. Since all other non-eye movement conditions in our study lack these two components, they are logically less taxing compared to the eyes moving condition.

How can we explain that the eyes moving and eyes fixed conditions differ in WM taxation, but produce similar clinical outcomes? One explanation is that in the long run larger WM taxation (i.e., memory recall + EM) does not produce additional effects compared to mere exposure. This explanation would even be in line with the meta-analysis of Lee and Cuijpers (2013), in which the beneficial effect of EM was found, because it comprised mostly laboratory studies with short intervention durations and mainly process measurements (e.g., vividness/emotionality). How these measures are affected when intervention durations are lengthened is currently unclear, but it is possible that the effect of exposure in the long term may outweigh the effect of divided attention (e.g., van Veen, van Schie, van der Schoot, van den Hout, & Engelhard, 2019). The study of Sack et al. (2016) indeed suggests that exposure is an important factor, because all groups contain a strong element of exposure and all show improvement. However, without a

waitlist control group (controlling for passage of time and general treatment effects) other explanations - besides exposure - cannot be excluded as viable alternative explanations.

Alternatively, the discrepancy between which conditions are taxing on WM and which conditions result in symptom reduction may actually be related to the type of dependent measures used in these studies. Lab analogue studies frequently employ variables that are a reflection of the process of change (e.g., vividness and emotionality), while clinical studies use measures that reflect clinically relevant outcomes (e.g., PTSD diagnosis, symptom reduction; see Lee & Cuijpers, 2013). It is possible that changes in process variables are not directly or causally linked to changes in clinical outcome measures or clinical analogue measures (e.g., van Schie, van Veen, & Hagenaars, 2019), or that there are multiple mechanisms of action in EMDR (e.g., Gunter & Bodner, 2009; Maxfield, 2008). Thus, higher WM taxation and linked changes in vividness and/or emotionality may not result in symptom change per se. Perhaps the path leading to changes in clinical outcomes is mediated by other variables than changes in vividness and/or emotionality. For instance, (re)appraisal of the traumatic experience made possible by dividing attention may be the driving force behind PTSD symptom reduction (e.g., Cheung & Bryant, 2017).

Because this analogue study was specifically focused on addressing whether different clinically deployed eye (non-)movement conditions differed in divided attention, we tested healthy participants on a reaction time task. It is possible that patients (compared to healthy individuals) differ in their reaction times as a result of their PTSD. There are indeed some indications that working memory capacity in PTSD patients is impaired (e.g., Schweizer & Dalgleish, 2011) and as a result eyes fixed or eyes unfocused may have become divided attention tasks given the limits of working memory capacity. For example, there is anecdotal evidence that (some) patients display intense hyper focus when focusing on a non-moving hand, which has been argued to be sufficiently taxing on WM (Matthijssen, Verhoeven, van den Hout, & Heitland, 2017). However, there is also experimental work that shows that more taxing interventions (e.g., faster EM compared to slower EM) produce greater memory change irrespective of WM capacity (van Schie et al., 2016), suggesting that an individual's capacity may play a lesser role in EMDR's overall effectiveness.

Concluding, the current study addressed a critical question in uncovering the working mechanisms of EMDR: do different eye (non-) movement conditions differ in WM taxation? Though contradictory with the results of a large sample clinical study (see Sack et al., 2016), we show that they do and crucially that eyes moving is more taxing than any other eye (non-)movement conditions, specifically eyes fixed. This finding necessitates further investigation into how EMDR works, particularly into if and how certain parts of the EMDR procedure (e.g., EM) affect clinical symptomatology. A long overdue integration of mechanistically focused EMDR lab analogue studies and patient-oriented clinical studies will hopefully provide sensible and insightful answers to this key question.

Conflict of interest and funding

Author contributions

SCvV and KvS developed the study concept. SK was responsible for data collection and was supervised by SvV. KvS analysed the data. KvS and SCvV interpreted the data. KvS, SCvV and SK drafted the manuscript. SCvV and KvS provided critical revisions to the manuscript. All authors approved the final version of the paper for submission.

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